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11 November 2010

Ms. Aimee Reynolds
Project Officer
Remediation Division
Montana Department of Environmental Quality
1100 North Last Chance Gulch
Helena, Montana 59601

Subject: Revised Addendum No. 2 Final Task F Stage I – Part 2 Pilot Test Work Plan for Volatile Organic Compound-Containing Alluvial Aquifer Groundwater
Burlington Northern Livingston Shop Complex - Livingston, Montana
KJ 1096021.16

Dear Ms. Reynolds:

On behalf of BNSF Railway Company (BNSF), Kennedy/Jenks Consultants is pleased to submit the accompanying letter which presents the *Revised Addendum No. 2 Final Task F Stage I – Part 2 Pilot Test Work Plan for Volatile Organic Compound-Containing Alluvial Aquifer Groundwater* (Revised Addendum No. 2). The Addendum No. 2, dated 15 October 2010, has been revised to address the comments presented in a Montana Department of Environmental Quality (DEQ) email to Kennedy/Jenks Consultants on 26 October 2010. The following table indicates the location in the Revised Addendum No. 2 where each comment is addressed.

DEQ Comment Number	Report Section Title	Comment
1	Groundwater Monitoring	Table 4 has been added to summarize the initial sampling schedule for the Electric Shop and Locomotive Shop treatment areas. The table specifies the sampling frequency and chemical analyses for the baseline, during active treatment, during the post-application period, and following system shut-down sampling events.
2	System Operation and Monitoring	Text has been added to provide the anticipated duration of the initial groundwater recirculation system(s) operation and the potential rebounding monitoring period.
3	Groundwater Monitoring	A representative sample of the RemOx® L reagent (as supplied by Carus Corporation) will be collected and submitted for chloride chemical analyses.
4	Modeling Support	The groundwater flow domain was set with a 24 feet vertical dimension. Within this dimension, the saturated zone thickness was set between 18 and 20 feet. Future modeling will consider refinement of the saturated thickness for each respective area of interest.
5	Reporting	The report will be submitted to the DEQ within 45 days of receipt of all of the final laboratory analytical reports.

DEQ Comment Number	Report Section Title	Comment
Other	Modeling Support, Figure 2, and Table 3	For flexibility, an additional groundwater extraction well (E-5) has been included for the Electric Shop groundwater recirculation system. Note: Proposed groundwater extraction wells for the Locomotive Shop groundwater recirculation system has be re-identified as E-6, E-7, and E-8 (previously identified as E-5 through E-7). IW-08 has been re-identified as IW-8. The newly installed injection well (IW-8) will be installed with similar construction to candidate ISCO wells [i.e., 4-inch-diameter polyvinyl chloride (PVC) with dual screens]. The newly installed extraction wells (E-5 through E-8) will be constructed with 6-inch-diameter PVC to the depth of bedrock with a 5-foot screened interval placed at the base of the alluvial aquifer.

Please contact us at (253) 835-6400 if you have questions regarding this submittal.

Very truly yours,

KENNEDY/JENKS CONSULTANTS

John E. Norris, P.G.
Project Manager

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Enclosures

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Steve Caldwell, Park County Environmental Council
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Burlington Northern Livingston Shop Complex – Livingston, Montana
K/J 1096021.16

Dear Ms. Reynolds:

On behalf of BNSF Railway Company (BNSF), Kennedy/Jenks Consultants is providing this addendum (Revised Addendum No. 2) for implementation of additional *in situ* chemical oxidation (ISCO) testing at the Burlington Northern Livingston Shop Complex in Livingston, Montana (Facility). The planned additional testing to address sources of dissolved chlorinated volatile organic compounds (VOCs) in alluvial aquifer groundwater was described in the "Recommendations" section of *Task F Stage I – Part 2: Former Electric Shop Interior Follow-Up Chemical Oxidation Testing Report* (ISCO Follow-Up Testing Report) (Kennedy/Jenks Consultants 2010a). The Addendum No. 2 was submitted to address comments on the ISCO Follow-Up Testing Report provided by the Montana Department of Environmental Quality (DEQ) in its letter to BNSF dated 3 September 2010. This Revised Addendum No. 2 addresses DEQ comments provided to Kennedy/Jenks Consultants in an email dated 26 October 2010.

Introduction and Objective

Construction and sampling of candidate ISCO wells was conducted at the Facility between January and August 2010 and documented in the *Task F Stage I – Part 2: Candidate ISCO Well Construction and Sampling Report* (Kennedy/Jenks Consultants 2010b) and *Task F Stage I – Part 2: Candidate ISCO Well Sampling Report* (Kennedy/Jenks Consultants 2010c). Two rounds of candidate ISCO well groundwater sampling were completed with the highest tetrachloroethene (PCE) concentrations detected in groundwater samples collected from ISCO-2 [984 micrograms per liter (µg/L)], ISCO-13 (287 µg/L), ISCO-14 (694 µg/L), and ISCO-24 (275 µg/L). Passive diffusion bag (PDB) sampling was conducted during the second round to assess the potential vertical stratification of dissolved PCE concentrations in the alluvial aquifer near the Locomotive Shop and Transfer Pit manway areas. In general, an increase in PCE concentrations was observed with depth for PDB sampled candidate ISCO wells ISCO-2, ISCO-14, and ISCO-24. PCE concentrations in groundwater samples collected from the candidate ISCO wells for the two rounds of groundwater sampling are shown on Figure 1.

The objective of the additional ISCO testing is to apply the sodium permanganate ($NaMnO_4$) chemical oxidant over a target treatment area defined by the ISCO well sampling within which appreciable PCE source material may be present using the lessons learned from the previous ISCO testing at the Facility in order to increase the probability of effectively contacting and oxidizing such source material. Achieving a sustained reduction in the dissolved PCE concentrations within and downgradient of the target treatment zone can be used as an indication that source material has been effectively oxidized. Based on the candidate ISCO well sampling, it is proposed additional oxidant-containing groundwater recirculation testing be conducted at the two locations shown on Figure 1 (i.e., referred to as the Electric Shop Area and Locomotive Shop Area).

One working hypothesis is that VOCs are dissolved into alluvial aquifer groundwater from the alluvium/bedrock interface or lower permeability soil lenses situated near the base of the alluvial aquifer. This hypothesis is supported by the PDB sampling described above. Based upon this hypothesis and supporting data, the ISCO recirculation process described herein is designed to focus delivery of the chemical oxidant along the base of the alluvial aquifer to increase the contact time with residual source material that may be potentially present.

Technical Approach

The results of the follow-up chemical oxidation testing demonstrated that $NaMnO_4$ can be safely applied without concerns for downgradient groundwater quality degradation and that adequate chemical oxidant concentration levels can be sustained in a treatment zone through recirculation. Sustained chemical oxidant concentrations within the treatment zone resulted in complete destruction of VOCs in the dissolved phase; however, PCE concentrations appear to have rebounded following $NaMnO_4$ consumption due to the inadequate/incomplete oxidation of VOC source material.

Delivery of the $NaMnO_4$ chemical oxidant will be conducted using a larger scale version of the technical approach employed for follow-up chemical oxidant testing. The technical approach includes the following elements:

- Implement a groundwater recirculation system [i.e., extraction and injection alignment (flow paths) approximately parallel to the groundwater flow direction] to control oxidant concentration and contact time within the target treatment zone.

- Operate the groundwater recirculation system to maintain 500 milligrams per liter (mg/L) or greater $NaMnO_4$ concentration within the target treatment zone to assess the time required to achieve sufficient destruction of residual sources.

- Perform monitoring during system operation to evaluate the presence and distribution of $NaMnO_4$ and the progress of the chemical oxidation process.

- Following system shutdown, perform monitoring to assess the potential for dissolved VOC concentration rebound. If rebounding is observed, restart the oxidant-containing

groundwater recirculation system to attempt to obtain further oxidization of the source material.

Preliminary Activities

Preliminary site activities will include the following:

- Soliciting an underground injection control (UIC) permit-by-rule determination from the U.S. Environmental Protection Agency (EPA).
- Updating the task-specific health and safety plan (HASP) prepared for the initial pilot test to be used in conjunction with the *2008 Facility-Wide Health and Safety Plan (Revision No. 3)* (Facility-Wide HASP) (Kennedy/Jenks Consultants 2008).
- Obtaining well construction permits from the City of Livingston.

The *Facility-Wide Sampling and Analysis Plan* (Facility-Wide SAP) (Kennedy/Jenks Consultants 2006) includes Standard Operating Guidelines (SOGs) and the Facility-Wide Quality Assurance Project Plan (QAPP). Field activities will be performed in a manner consistent with the SOGs identified in the Facility-Wide SAP.

Groundwater Recirculation System Well Network

Modeling Support

The additional ISCO testing groundwater recirculation system will consist of a network of extraction, injection, and monitoring wells similar in design and function to those used for the former Electric Shop follow-up testing. Existing wells (i.e., extraction, injection, monitoring, and candidate ISCO) will be incorporated into the additional ISCO testing. Design of the planned oxidant-containing groundwater recirculation system included modeling to evaluate the optimal extraction/injection well network and recirculation rate that would provide coverage of the target treatment area. Independent models were completed for the Electric Shop Area and the Locomotive Shop Area. The models were developed using the U.S. Geological Survey's MODFLOW software (Harbaugh et al. 2000). The following assumptions were made in the model setup:

- Groundwater recirculation was simulated using planned well configurations.
- The base of the model (i.e., weathered bedrock) was assumed to be uniform.
- Unconfined flow was simulated.

- The groundwater flow domain was approximately 4,000 feet in the east-west direction, 1,600 feet in the north-south direction, and 24 feet in the vertical dimension. Within the vertical dimension, the saturated zone was set between 18 and 20 feet.

- Constant head boundaries were placed on the western and eastern end of the model domain and no-flow boundaries were placed on the northern and southern sides, along approximate flow lines. The boundary conditions produce simulated groundwater flow that is generally to the east.

- The hydrostratigraphy was conceptualized as a two-layer system, with a hydraulic conductivity of 800 feet per day in the lower 6 feet [approximately 30 to 36 feet below ground surface (bgs)] and a hydraulic conductivity of 380 feet per day in the overlying material. Simulated hydraulic heads in each model approximated the average condition in 2008.

- MODPATH (Pollock 1994) was used to delineate the simulated directions and travel times of groundwater in the recirculation zone.

The simulated recirculation zones for the Electric Shop and Locomotive Shop treatment areas are shown on Figures 2 through 5, respectively. Based on the model simulations, the groundwater recirculation system layout for the Electric Shop and Locomotive Shop are as follows:

- The Electric Shop groundwater recirculation system (Figure 2) will consist of existing six injection wells (i.e., ISCO-14, -16, -17, -18, -19 and IW-07) and five extraction wells [i.e., ISCO-13, -24, -25 and -35 and one newly installed well (E-4) in the vicinity of monitoring well cluster 07-2A/2B]. It is estimated groundwater recirculation would be conducted at approximately 200 gallons per minute (gpm). One additional well (E-5) will be installed in the vicinity of monitoring well 07-15 to provide flexibility in the groundwater recirculation process.

- The Locomotive Shop groundwater recirculation system (Figure 3) will consist of two upgradient injection wells [newly installed (IW-8) and existing candidate well ISCO-7] and two downgradient extraction wells (newly installed E-7 and E-8) operating at a balanced rate of approximately 80 gpm. One additional well (E-6) will be installed at the southeastern corner of the Locomotive Shop to serve as a monitoring point and potential extraction/injection point (see Figures 4 and 5) for other possible variations on system operation.

Particle tracking shown on Figures 2 through 5 illustrates the generalized flow paths 1 foot above the bottom of the model domain.

Note: Soil borings and well construction, including soil sampling and chemical analyses, will be conducted in accordance with Section 3.4.2 of *Addendum No. 1 to Final Task F Stage I – Part 2 Pilot Test Work Plan for Volatile Organic Compound-Containing Alluvial Aquifer Groundwater*

(Addendum No. 1) (Kennedy/Jenks Consultants 2009). The newly installed injection well (IW-8) will be installed with similar construction to candidate ISCO wells [i.e., 4-inch-diameter polyvinyl chloride (PVC) with dual screens]. The newly installed extraction wells (E-5 through E-8) will be constructed with 6-inch-diameter PVC to the depth of bedrock with a 5-foot screened interval placed at the base of the alluvial aquifer.

System Setup

Groundwater will be extracted from the downgradient side of the target treatment area and injected upgradient to create a subsurface recirculation cell and achieve a water balance (i.e., extraction equals injection rate). The groundwater recirculation system equipment and operation are shown schematically on Figure 3 of Addendum No. 1 and includes the following components:

- Extraction wells will house submersible pumps controlled by valves of variable frequency drives (VFDs). The groundwater extraction wells will be equipped with a pressure transducer.

- Extracted groundwater will be pumped to polyethylene mixing tank(s). Forty percent $NaMnO_4$ stock solution (RemOx-L), as supplied by Carus Chemical, will be delivered manually or by an electric metering pump to the mixing tank.

- The $NaMnO_4$ solution will be delivered to the subsurface via the injection wells under gravity and/or pumping (chemical compatible pump).

- The extraction and injection manifolds will contain individual ball valves and in-line flow meters for flow regulation to/from the wells. Pressure gauges will be made available at the injection wellheads.

- Select injection and monitoring wells will be equipped with pressure transducers and/or combination pressure transducer and oxidation-reduction potential (ORP)/electrical conductivity (EC) sensor.

- A secured containment cell will be constructed to house system equipment and $NaMnO_4$ stock solution.

Note: The 4-inch-diameter candidate ISCO wells were completed with upper and lower screened intervals. The lower portion of the well consisted of a 5-foot screened interval completed just above the top of bedrock. The upper portion of the well was screened across the water table with a bottom depth selected based upon the thickness of the alluvial aquifer to allow for at least 3 feet of blank casing between the upper and lower screens. As the desired target treatment zone is the 5-foot interval along the base of the alluvial aquifer (i.e., weathered bedrock), candidate ISCO wells selected for extraction or injection purposes will require installation of a packer system to isolate the bottom well interval.

Sodium Permanganate Mass Loading

The calculated mass and volume of $NaMnO_4$ required for the Electric Shop and Locomotive Shop groundwater recirculation systems is presented in Tables 1 and 2, respectively. The calculation was based on physical dimensions of the target treatment zones and the value of the soil oxidant demand (SOD) obtained from the bench scale study. On a strict physical dimension/SOD basis, the required masses of 40 percent $NaMnO_4$ solution for the Electric Shop and Locomotive Shop are calculated at 10,120 pounds (890 gallons) and 8,950 pounds (790 gallons), respectively. Additional $NaMnO_4$ will be required to compensate for mass loss inherent to the groundwater recirculation system operation. For example, during the follow-up pilot testing documented in the ISCO Follow-Up Testing Report, the calculated volume of 40 percent $NaMnO_4$ solution (cell dimension/SOD basis) and actual solution volume were 72 and 93 gallons, respectively (i.e., approximately 30 percent difference).

System Operation and Field Monitoring

Additional ISCO testing in the area beneath the former Electric Shop and Transfer Pit manway will be performed first followed by testing in the area beneath the Locomotive Shop and Locomotive Shop manway. This is predicated on the desired result of effecting a sustained reduction in dissolved PCE concentrations leaving the Electric Shop and Transfer Pit manway treatment area before treating the downgradient Locomotive Shop area. System operation and field monitoring will be conducted as follows:

- Prior to addition of the $NaMnO_4$ solution, hydraulic testing will be conducted to evaluate system operation, extraction/injection rates, and aquifer response (i.e., drawdown, capture zone, etc.).

- Upon completion of hydraulic testing, the extracted groundwater will be amended with the 40 percent stock solution to maintain a 500 mg/L or greater $NaMnO_4$ concentration within the target treatment zone.

- During system operation, field monitoring will be performed to evaluate the presence and distribution of $NaMnO_4$ within and downgradient of the groundwater recirculation zone (see Table 3). Field monitoring will include ORP and EC measurements using hand-held meters and/or combination pressure and ORP/EC sensor (In-Situ Level Troll 9500). ORP and EC recorded field data will be correlated to an established standard curve to determine the in-field $NaMnO_4$ concentration. Groundwater samples will also be collected from select wells for visual observation (i.e., pink/purple color indicating presence of $NaMnO_4$) and measurement of $NaMnO_4$ using a portable colorimeter.

- Real-time in-field $NaMnO_4$, ORP, and EC data will be used to adjust $NaMnO_4$ loadings. Amendment will be temporarily halted if the $NaMnO_4$ concentration in the extracted groundwater is approximately equal to the injection concentration.

- The system will be initially operated for a minimum of 4 days (based on reaction stoichiometry; consistent with specified duration for Electric Shop pilot study conducted in vicinity of monitoring well 89-3) following attainment of a nominal 500 mg/L $NaMnO_4$ concentration within the designated treatment area. During active treatment, groundwater samples will be collected from selected wells and analyzed for PCE (see Groundwater Monitoring section below). A decision to cease system operation, in consultation with the DEQ, will be based on observed reductions in PCE concentrations relative to baseline (historical) concentrations.

- Circulation of the oxidant-containing groundwater will be suspended and monitoring performed to evaluate potential dissolved PCE concentration rebound. The potential rebound monitoring period, following full consumption of $NaMnO_4$, is estimated up to two weeks (i.e., in excess of 10 pore volume exchanges assuming a groundwater seepage velocity of 140 feet/day as determined during previously completed tracer testing). If rebound is observed, additional oxidant-containing groundwater recirculation may be performed, including potential on-off cycling of system operation.

Note: Real-time chloride monitoring may be conducted in an attempt to detect the chloride ion formed by the oxidation of PCE source material. The continued formation of chloride during oxidation of PCE source material may provide a detectable indicator of this process. In theory, if an appreciable mass of PCE source material is undergoing oxidation with the recirculation cell, the increase in monitored chloride concentrations in the circulating groundwater may be adequate to identify the process and adjust the oxidant contact time to achieve total oxidation of the mass. Evaluation of chloride groundwater monitoring data will take into consideration the chloride mass associated with the injected $NaMnO_4$ solution.

Groundwater Monitoring

Groundwater monitoring of select wells will be performed in the vicinity of the target treatment areas prior to (i.e., baseline), during groundwater recirculation and rebounding period, and following system operation to assess chlorinated VOC oxidation and residual permanganate concentrations. For the follow-up pilot testing, metal oxidation and attenuation was observed suggesting site soils possess the ability to readily attenuate oxidized metals. This mainly consisted of dissolved manganese formation within and in the immediate vicinity of the target treatment zone. Therefore, the groundwater monitoring program will focus on chemical analyses for PCE using EPA Method 8260 or gas chromatography, chloride using EPA Method 300.0, and dissolved manganese using EPA Method 6020. Groundwater sample collection and chemical analyses will be performed as follows:

- PCE. Baseline and following system operation for select wells located within the target treatment area (see Table 3 and 4 for selected wells). During the active treatment and potential rebounding periods, PCE chemical analyses will be performed for select groundwater samples collected from monitoring wells with the highest baseline PCE concentrations (up to five wells per area). At discretion, groundwater samples will be periodically collected from extraction wells during groundwater recirculation.

- Chloride. Baseline, during active treatment, and following system operation for wells located in the vicinity of the Locomotive Shop and Transfer Pit manway areas (i.e., monitoring wells ISCO-2, ISCO-13, ISCO-14, and ISCO-24). During active treatment, chloride chemical analyses will be performed for select groundwater samples collected periodically from the extraction wells. A representative sample of the sodium permanganate reagant (RemOx® L as supplied by Carus Corporation) will also be submitted for chloride content analyses.

- Dissolved Manganese. Baseline and following system operation for two wells (e.g., extraction wells) located at the downgradient boundary of each of the target treatment areas.

The initial groundwater sampling schedule is presented in Table 4. The sampling schedule may be modified based on observed field conditions and monitoring results (in consultation with the DEQ).

Note: Based on a strong relationship between colorimeter measurements conducted in the field (i.e., hand-held colorimeter) and laboratory analyses (spectrophotometric method) observed during previous pilot studies, all collected permanganate samples will be analyzed using a field colorimeter.

Environmental Requirements, Criteria, and Limitations

The additional ISCO pilot testing activities identified in this Addendum No. 2 will comply with the Environmental Requirements, Criteria, and Limitations (ERCLs) identified in Addendum No. 1.

Reporting

During the groundwater recirculation process, weekly summary reports will be prepared and submitted to the DEQ summarizing field activities associated with the ISCO recirculation activities. The summary reports will include, but not be limited to, groundwater recirculation network layout, extraction and injection rates and volumes, field and groundwater monitoring results, and chemical usage (i.e., ability to sustain the $NaMnO_4$ concentration with the target treatment zone, $NaMnO_4$ stock volume used, etc.). At the conclusion of additional ISCO testing, a report will be prepared summarizing soil boring, well installation, and soil and groundwater chemical analyses results and groundwater recirculation activities. The report will also incorporate comments, as applicable, presented in the DEQ comment letter dated 3 September 2010. The report will be submitted to the DEQ within 45 days of receipt of all of the final laboratory analytical reports.

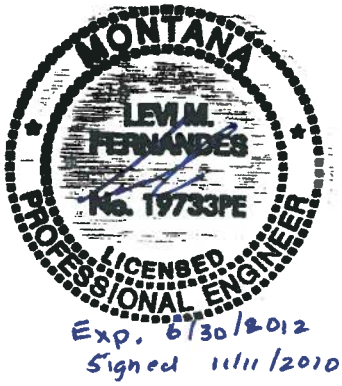
Schedule

It is anticipated that the additional ISCO testing activities will commence in January 2011, contingent upon DEQ approval of this Revised Addendum No. 2. Prior to the initiation of

Addendum No. 2 scope of work, the DEQ will be provided with a preliminary schedule of initial site activities. The schedule will be periodically updated and submitted to the DEQ as part of weekly summary reports.

Very truly yours,

KENNEDY/JENKS CONSULTANTS



Exp. 6/30/2012
Signed 11/11/2010

John E. Norris, P.G.
Project Manager

Levi Fernandes, P.E.
Project Engineer

Attachments:

Table 1: Sodium Permanganate Loading Calculations (Electric Shop Area)
Table 2: Sodium Permanganate Loading Calculations (Locomotive Shop Area)
Table 3: Field Monitoring
Table 4: Initial Groundwater Sampling Schedule

Figure 1: Planned ISCO Testing Treatment Areas
Figure 2: Recirculation – Electric Shop Area
Figure 3: Recirculation – Locomotive Shop Area
Figure 4: Recirculation – Locomotive Shop Area (Upgradient)
Figure 5: Recirculation – Locomotive Shop Area (Downgradient)

References:

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cc: Dave Smith, BNSF
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Steve Caldwell, Park County Environmental Council
Robin Billau, RTI, Inc.
Mark Hills, CDM Helena
Kent Sorenson, CDM Denver

Tables

TABLE 1

SODIUM PERMANGANATE LOADING CALCULATIONS (ELECTRIC SHOP AREA)
Burlington Northern Livingston Shop Complex

Item	Parameter	Calculated Value	Unit	Source/Equation
Dimensions				
A	Area	14,700	square feet	
B	Saturated Thickness	5	feet	Target treatment zone thickness.
C	Effective Porosity	0.25	percent	
D	Groundwater Pore Volume	137,445	gallon	A * B * C * (7.48 gallon / cubic feet)
E		520,229	Liter	D * (3.785 liter / gallon)
$NaMnO_4$ Loading Based on SOD[(a)]				
F	Mass Soil (based on 5-foot saturated thickness)	3,675,000	killogram	A * B * (110 pound / cubic feet) / (2.2 pound / kilogram)
G	$NaMnO_4$ Loading	0.5	gram $NaMnO_4$/kilogram soil	Bench-scale testing soil oxidant demand (SOD). Utilized for initial pilot test mass loading.
H	$NaMnO_4$ Required	4,047	pounds $NaMnO_4$	F * G / (454 gram / pound)
I	40% Mass $NaMnO_4$ Required	10,120	pound $NaMnO_4$	H / 0.4
J	40% Solution $NaMnO_4$ Required[(b)]	890	gallon	I / (11.43 pound / gallon)

Notes:

(a) Sodium permanganate ($NaMnO_4$) demand associated with dissolved phase chlorinated hydrocarbons were neglected in mass calculations. Mass loading calculated using bench-scale soil oxidant demand (SOD).

(b) Density of 40 percent (%) sodium permanganate stock solution is approximately 11.43 pound per gallon.

TABLE 2

SODIUM PERMANGANATE LOADING CALCULATIONS (LOCOMOTIVE SHOP AREA)
Burlington Northern Livingston Shop Complex

Item	Parameter	Calculated Value	Unit	Source/Equation
Dimensions				
A	Area	13,000	square feet	
B	Saturated Thickness	5	feet	Target treatment zone thickness.
C	Effective Porosity	0.25	percent	
D	Groundwater Pore Volume	121,550	gallon	A * B * C * (7.48 gallon / cubic feet)
E		460,067	Liter	D * (3.785 liter / gallon)
$NaMnO_4$ Loading Based on SOD[(a)]				
F	Mass Soil (based on 5-foot saturated thickness)	3,250,000	killogram	A * B * (110 pound / cubic feet) / (2.2 pound / kilogram)
G	$NaMnO_4$ Loading	0.5	gram $NaMnO_4$/kilogram soil	Bench-scale testing soil oxidant demand (SOD). Utilized for initial pilot test mass loading.
H	$NaMnO_4$ Required	3,579	pounds $NaMnO_4$	F * G / (454 gram / pound)
I	40% Mass $NaMnO_4$ Required	8,950	pound $NaMnO_4$	H / 0.4
J	40% Solution $NaMnO_4$ Required[(b)]	790	gallon	I / (11.43 pound / gallon)

Notes:

(a) Sodium permanganate ($NaMnO_4$) demand associated with dissolved phase chlorinated hydrocarbons were neglected in mass calculations. Mass loading calculated using bench-scale soil oxidant demand (SOD).

(b) Density of 40 percent (%) sodium permanganate stock solution is approximately 11.43 pound per gallon.

TABLE 3

FIELD MONITORING
Burlington Northern Livingston Shop Complex

Well	Type	Location (Relative To Treatment Area)	Screen Interval (feet below ground surface)[a]	Instrumentation[b]	Field Monitoring[c]
Electric Shop Area Wells					
07-16	Monitoring	Within	15 - 30	In Situ 9500	
07-2A	Monitoring	Within	15 - 25		X
07-2B[d]	Monitoring	Within	28.5 - 33.5		X
07-13	Monitoring	Perimeter	16.5 - 31.5		X
IW-05	Monitoring	Within	26.5 - 31.5		X
IW-06	Monitoring	Within	26.7 - 31.7		X
IW-07	Injection	Within	27 - 32	In Situ 9500	
89-3	Monitoring	Within	16.5 - 31.5		X
09-1	Monitoring	Within	18 - 33		X
09-2	Monitoring	Within	16.3 - 31.3		X
E-1	Monitoring	Within	27.5 - 32.5		X
E-2	Monitoring	Within	25.5 - 30.5	In Situ 9500	
E-3	Monitoring	Within	26.8 - 31.8		X
E-4	Extraction, Newly Installed	Within	TBD	Pressure Transducer	
E-5	Extraction, Newly Installed	Within	TBD	Pressure Transducer	
07-15	Monitoring	Within	18 - 33	In Situ 9500	
07-14	Monitoring	Downgradient	16 -31		X
08-2	Monitoring	Downgradient	14.9 - 29.9		X
08-1	Monitoring	Downgradient	16 - 31		X
89-9	Monitoring	Downgradient	14 - 34		X
L-87-5	Monitoring	Downgradient	17 - 27		X
ISCO-11	Monitoring	Downgradient	27 - 32		X
ISCO-12	Monitoring	Downgradient	27 - 32		X
ISCO-13	Extraction	Within	25.5 - 30.5	Pressure Transducer	
ISCO-14	Injection	Within	26.5 - 31.5		X
ISCO-15	Monitoring	Within	28 - 33	In Situ 9500	
ISCO-16	Injection	Within	26 - 31	Pressure Transducer	
ISCO-17	Injection	Within	28 - 33	Pressure Transducer	
ISCO-18	Injection	Within	26 - 31	Pressure Transducer	
ISCO-19	Injection	Within	31.5 - 36.5	Pressure Transducer	
ISCO-23	Monitoring	Within	25.5 - 30.5		X
ISCO-24	Extraction	Within	29 - 34	Pressure Transducer	
ISCO-25	Extraction	Within	31 - 36	Pressure Transducer	
ISCO-26	Monitoring	Downgradient	26.5 - 31.5		X
ISCO-34	Monitoring	Within	27 - 32		X
ISCO-35	Extraction	Within	31.5 - 36.5	Pressure Transducer	
Locomotive Shop Area Wells					
ISCO-1	Monitoring	Within	25 -30	In Situ 9500	
ISCO-2	Monitoring	Within	27 - 32	In Situ 9500	
ISCO-3	Injection	Within	24 - 29	In Situ 9500	
ISCO-5	Monitoring	Within	26 - 31	In Situ 9500	
ISCO-6	Monitoring	Within	27 - 32		X
ISCO-7	Injection	Within	27.5 - 32.5	Pressure Transducer	
ISCO-8	Monitoring	Upgradient	30 - 35		X
ISCO-9	Monitoring	Upgradient	30.5 - 35.5		X
IW-8	Injection, Newly Installed	Within	TBD	Pressure Transducer	
E-6	Extraction or Monitoring, Newly Installed	Within	TBD	Pressure Transducer for extraction, In Situ 9500 for monitoring	
E-7	Extraction, Newly Installed	Within	TBD	Pressure Transducer	
E-8	Extraction, Newly Installed	Within	TBD	Pressure Transducer	
92-1	Monitoring	Downgradient	23.8 - 33.8		X
L-88-12	Monitoring	Downgradient	31 - 41		X

Notes:

(a) For candidate ISCO wells, screen interval provided for lower section only. Lower screen isolated using packer system.

(b) Instrumentation includes installation of pressure transducer or combination pressure transducer with oxidation-reduction potential (ORP)/electrical conductivity(EC) sensor (In Situ 9500).

(c) Field monitoring includes periodic collection of groundwater samples for visual presence and/or measuring sodium permanganate ($NaMnO_4$) concentrations (i.e., hand-held colorimeter).

(d) **Bold** indicates wells selected for tetrachloroethene (PCE) chemical analyses using EPA Method 8260 or gas chromatography (see Table 4).

(e) Other:

ORP and EC measured for collected groundwater samples.

TBD - To be determined. Lower screen interval to be constructed at the bottom 5 feet of well.

TABLE 4

INITIAL GROUNDWATER SAMPLING SCHEDULE
Burlington Northern Livingston Shop Complex

Well	Type	Location (Relative To Treatment Area)	Screen Interval (feet below ground surface)[a]	Baseline[b]			Active Treatment[c]		Post-Application[d]	Final[e]		
				PCE[f]	Manganese[g]	Chloride[h]	PCE[f]	Chloride[h]	PCE[f]	PCE[f]	Manganese[g]	Chloride[h]
Electric Shop Area Wells												
07-16	Monitoring	Within	15 - 30									
07-2A	Monitoring	Within	15 - 25									
07-2B	Monitoring	Within	28.5 - 33.5	X						X		
07-13	Monitoring	Perimeter	16.5 - 31.5									
IW-05	Monitoring	Within	26.5 - 31.5									
IW-06	Monitoring	Within	26.7 - 31.7									
IW-07	Injection	Within	27 - 32									
89-3	Monitoring	Within	16.5 - 31.5	X			X		X	X		
09-1	Monitoring	Within	18 - 33									
09-2	Monitoring	Within	16.3 - 31.3									
E-1	Monitoring	Within	27.5 - 32.5									
E-2	Monitoring	Within	25.5 - 30.5									
E-3	Monitoring	Within	26.8 - 31.8									
E-4	Extraction, Newly Installed	Within	TBD	X			X	X	X	X		
E-5	Extraction, Newly Installed	Within	TBD	X			X	X	X	X		
07-15	Monitoring	Within	18 - 33	X						X		
07-14	Monitoring	Downgradient	16 -31									
08-2	Monitoring	Downgradient	14.9 - 29.9									
08-1	Monitoring	Downgradient	16 - 31									
89-9	Monitoring	Downgradient	14 - 34									
L-87-5	Monitoring	Downgradient	17 - 27									
ISCO-11	Monitoring	Downgradient	27 - 32									
ISCO-12	Monitoring	Downgradient	27 - 32									
ISCO-13	Extraction	Within	25.5 - 30.5	X	X	X	X	X	X	X	X	X
ISCO-14	Injection	Within	26.5 - 31.5	X		X		X		X		X
ISCO-15	Monitoring	Within	28 - 33	X						X		
ISCO-16	Injection	Within	26 - 31	X						X		
ISCO-17	Injection	Within	28 - 33	X						X		
ISCO-18	Injection	Within	26 - 31	X						X		
ISCO-19	Injection	Within	31.5 - 36.5	X			X		X	X		
ISCO-23	Monitoring	Within	25.5 - 30.5									
ISCO-24	Extraction	Within	29 - 34	X		X	X	X	X	X		X
ISCO-25	Extraction	Within	31 - 36	X	X		X	X	X	X	X	
ISCO-26	Monitoring	Downgradient	26.5 - 31.5	X						X		
ISCO-34	Monitoring	Within	27 - 32									
ISCO-35	Extraction	Within	31.5 - 36.5	X			X	X	X	X		
Locomotive Shop Area Wells												
ISCO-1	Monitoring	Within	25 -30	X						X		
ISCO-2	Monitoring	Within	27 - 32	X		X	X	X	X	X		X
ISCO-3	Injection	Within	24 - 29	X			X		X	X		
ISCO-5	Monitoring	Within	26 - 31	X						X		
ISCO-6	Monitoring	Within	27 - 32	X						X		
ISCO-7	Injection	Within	27.5 - 32.5	X						X		
ISCO-8	Monitoring	Upgradient	30 - 35									
ISCO-9	Monitoring	Upgradient	30.5 - 35.5									
IW-8	Injection, Newly Installed	Within	TBD									
E-6	Extraction or Monitoring, Newly Installed	Within	TBD	X			X	X	X	X		
E-7	Extraction, Newly Installed	Within	TBD	X	X		X	X	X	X	X	
E-8	Extraction, Newly Installed	Within	TBD	X	X		X	X	X	X	X	
92-1	Monitoring	Downgradient	23.8 - 33.8									
L-88-12	Monitoring	Downgradient	31 - 41									

Notes:
(a) For candidate ISCO wells, screen interval provided for lower section only. Lower screen isolated using packer system.
(b) Baseline - sampling event conducted prior to start-up of the groundwater recirculation system(s).
(c) Active Treatment - sampling conducted during groundwater recirculation system operation.
(d) Post-Application - sampling event conducted following oxidant recirculation.
(e) Final - sampling event conducted at the conclusion of pilot study activities.
(f) PCE - Tetrachloroethene using EPA Method 8260.
(g) Dissolved manganese using EPA Method 6020.
(h) Chloride using EPA Method 300.0.
(i) Other:
Oxidation-reduction potential (ORP) and electrical conductivity (EC) measured for collected groundwater samples.
Collected groundwater with visual presence of sodium permanganate ($NaMnO_4$) will be measured using a hand-held colorimeter.

Figures

CAR SHOP

ELECTRIC SHOP

LOCOMOTIVE SHOP

APPROXIMATE GROUNDWATER FLOW DIRECTION

ISCO-20	
DATE	PCE
MAR 2010	<0.50
JUL 2010	<0.50

ISCO-21	
DATE	PCE
MAR 2010	0.64
JUL 2010	<0.50

ISCO-22	
DATE	PCE
MAR 2010	0.62
JUL 2010	<0.50/<0.50[a]

ISCO-23	
DATE	PCE
MAR 2010	0.45J
JUL 2010	<0.50

ISCO-33	
DATE	PCE
MAR 2010	<0.50
JUL 2010	<0.50

ISCO-34	
DATE	PCE
MAR 2010	<0.50
JUL 2010	<0.50

DATE	PCE	
MAR 2010	694	
JUL 2010	DEPTH	PCE
	19.3	6.8
	22.1	10
	29.3	88

DATE	PCE	
MAR 2010	252/287[a]	
JUL 2010	DEPTH	PCE
	19.1	3.3
	26.1	2.5
	28.3	2.7

ISCO-13	
DATE	PCE
MAR 2010	54
JUL 2010	31

ISCO-19	
DATE	PCE
MAR 2010	27
JUL 2010	162

ISCO-18	
DATE	PCE
MAR 2010	<0.50
JUL 2010	<0.50

ISCO-17	
DATE	PCE
MAR 2010	7.4/6.8[a]
JUL 2010	6.7

ISCO-16	
DATE	PCE
MAR 2010	<0.50
JUL 2010	0.25J/0.24J[a]

ISCO-15	
DATE	PCE
MAR 2010	0.30J
JUL 2010	0.37J

ISCO-14	
DATE	PCE
MAR 2010	76
JUL 2010	69

ISCO-12	
DATE	PCE
MAR 2010	3.5
JUL 2010	1.1

ISCO-11	
DATE	PCE
MAR 2010	0.50
JUL 2010	0.51

ISCO-10	
DATE	PCE
MAR 2010	<0.50
JUL 2010	<0.50

ISCO-9	
DATE	PCE
MAR 2010	0.26J
JUL 2010	<0.50/<0.50[a]

ISCO-8	
DATE	PCE
MAR 2010	5.7
JUL 2010	11

ISCO-7	
DATE	PCE
MAR 2010	<0.50
JUL 2010	<0.50

ISCO-6	
DATE	PCE
MAR 2010	12
JUL 2010	5.3

ISCO-5	
DATE	PCE
MAR 2010	<0.50
JUL 2010	<0.50

ISCO-3	
DATE	PCE
MAR 2010	984
JUL 2010	DEPTH	PCE
	21.4	94
	27.6	30
	29.9	460

ISCO-2	
DATE	PCE
MAR 2010	22/21[a]
JUL 2010	22/21[a]

ISCO-1	
DATE	PCE
MAR 2010	<0.50
JUL 2010	0.19J

ISCO-35	
DATE	PCE
MAR 2010	<0.50
JUL 2010	0.28J

ISCO-36	
DATE	PCE
MAR 2010	0.38J
JUL 2010	0.34J

ISCO-37	
DATE	PCE
MAR 2010	275
JUL 2010	DEPTH	PCE
	19.3	40
	24.8	50
	32.1	154

ISCO-24	
DATE	PCE
MAR 2010	25
JUL 2010	29

ISCO-25	
DATE	PCE
MAR 2010	27
JUL 2010	25

ISCO-26	
DATE	PCE
MAR 2010	15
JUL 2010	9.2

ISCO-27	
DATE	PCE
MAR 2010	3.7
JUL 2010	4.6

ISCO-28	
DATE	PCE
MAR 2010	5.9/5.7[a]
JUL 2010	6.2

ISCO-29	
DATE	PCE
MAR 2010	<0.50
JUL 2010	<0.50

ISCO-30	
DATE	PCE
MAR 2010	<0.50
JUL 2010	<0.50

ISCO-31	
DATE	PCE
MAR 2010	<0.50
JUL 2010	<0.50

ISCO-32	
DATE	PCE
MAR 2010	<0.50
JUL 2010	<0.50

IW-8

E-4

E-5

E-6

E-7

E-8

LEGEND

- PLANNED ISCO TESTING TREATMENT AREAS
- IW-8 — PROPOSED PILOT TEST INJECTION WELL LOCATION
- E-6 — PROPOSED PILOT TEST EXTRACTION WELL LOCATION
- ISCO-9 — ISCO MONITORING WELL LOCATION
- ISCO MONITORING WELL DESIGNATION WITH TETRACHLOROETHENE (PCE) CONCENTRATION IN GROUNDWATER (ug/L)

DATE	PCE
MAR 2010	0.50
JUL 2010	0.51

- ISCO MONITORING WELL DESIGNATION WITH TETRACHLOROETHENE (PCE) CONCENTRATION IN GROUNDWATER (ug/L). JULY 2010 RESULTS ARE PASSIVE DIFFUSION BAG (PDB) SAMPLES WITH SAMPLING DEPTH (FEET BELOW TOP OF CASING)

DATE	PCE	
MAR 2010	275	
JUL 2010	DEPTH	PCE
	19.3	40
	24.8	50
	32.1	154

- ORIGINAL/REPLACED INDUSTRIAL WASTEWATER SEWER LINE
- SLEEVED INDUSTRIAL WASTEWATER SEWER LINE
- OLD INDUSTRIAL WASTEWATER SEWER LINE
- MANHOLE

NOTES:

a) SECOND NUMBER REPRESENTS ANALYTICAL RESULT FOR A FIELD DUPLICATE SAMPLE.

1) ALL LOCATIONS ARE APPROXIMATE.

0 25 50

APPROXIMATE SCALE IN FEET

N

BASEMAP SOURCE:

HORIZONS, INC. RAPID CITY, SD (1989)

Kennedy/Jenks Consultants

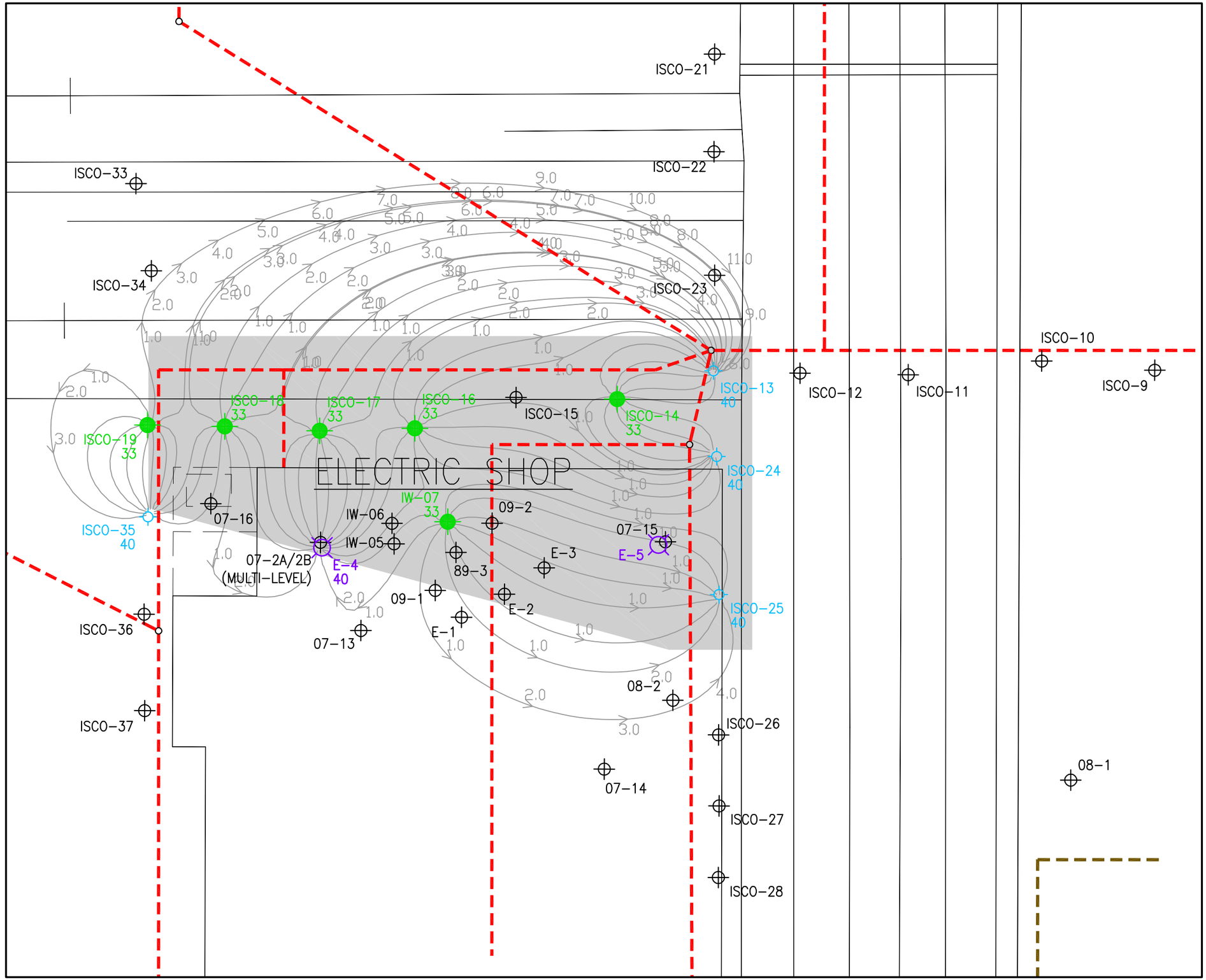
BURLINGTON NORTHERN LIVINGSTON SHOP COMPLEX – LIVINGSTON, MT

PLANNED ISCO TESTING TREATMENT AREAS

1096021.16/Task F/PT/P10SK001.rev1

11/10 (Revision 1)

FIGURE 1



LEGEND

- PLANNED ISCO TESTING TREATMENT AREA
- ISCO-14 / 33 — PILOT TEST INJECTION WELL LOCATION WITH APPROXIMATE INJECTION RATE (GPM)
- ISCO-25 / 40 — PILOT TEST EXTRACTION WELL LOCATION WITH APPROXIMATE EXTRACTION RATE (GPM)
- E-4 / 40 — PROPOSED PILOT TEST EXTRACTION WELL LOCATION WITH APPROXIMATE EXTRACTION RATE (GPM)
- ISCO-14 — EXISTING MONITORING WELL LOCATION
- MODELED GROUNDWATER FLOW PATH AND DIRECTION
- 1.0 — GROUNDWATER FLOW TIME (DAYS)
- ORIGINAL/REPLACED INDUSTRIAL WASTEWATER SEWER LINE
- SLEEVED INDUSTRIAL WASTEWATER SEWER LINE
- OLD INDUSTRIAL WASTEWATER SEWER LINE
- MANHOLE

NOTES:

1) GPM DENOTES GALLONS PER MINUTE
2) ALL LOCATIONS ARE APPROXIMATE

N

0 15 30
APPROXIMATE SCALE IN FEET

BASEMAP SOURCE:
HORIZONS, INC. RAPID CITY, SD (1989)

Kennedy/Jenks Consultants

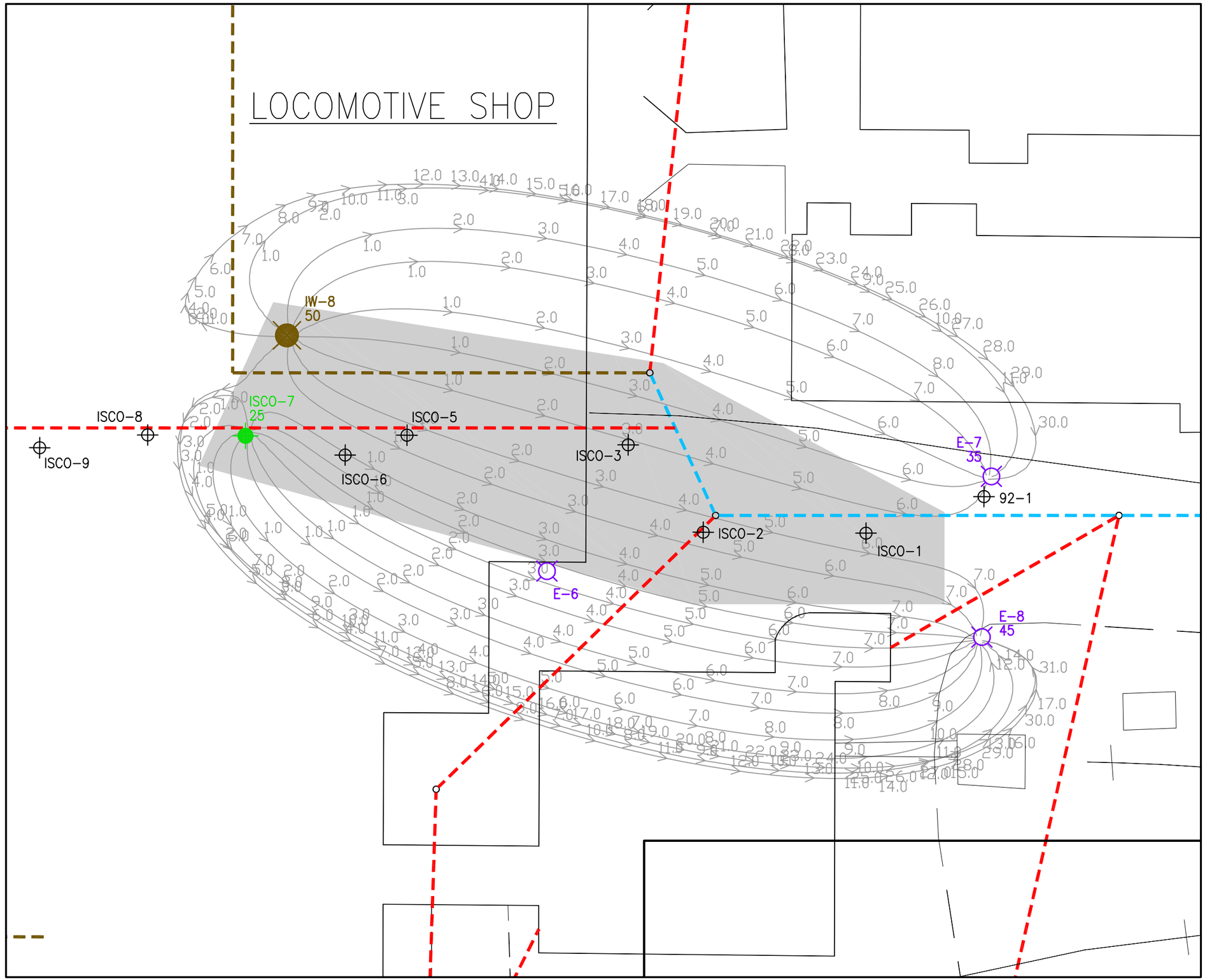
BURLINGTON NORTHERN LIVINGSTON SHOP COMPLEX – LIVINGSTON, MT

RECIRCULATION ELECTRIC SHOP AREA

1096021.16/Task F/PT/P10SK002.rev1

11/10 (Revision 1)

FIGURE 2



LEGEND

- PLANNED ISCO TESTING TREATMENT AREA
- ISCO-7 25 — PILOT TEST INJECTION WELL LOCATION WITH APPROXIMATE INJECTION RATE (GPM)
- IW-8 50 — PROPOSED PILOT TEST INJECTION WELL LOCATION WITH APPROXIMATE INJECTION RATE (GPM)
- E-8 45 — PROPOSED PILOT TEST EXTRACTION WELL LOCATION WITH APPROXIMATE EXTRACTION RATE (GPM)
- ISCO-14 — EXISTING MONITORING WELL LOCATION
- MODELED GROUNDWATER FLOW PATH AND DIRECTION
- 1.0 — GROUNDWATER FLOW TIME (DAYS)
- ORIGINAL/REPLACED INDUSTRIAL WASTEWATER SEWER LINE
- SLEEVED INDUSTRIAL WASTEWATER SEWER LINE
- OLD INDUSTRIAL WASTEWATER SEWER LINE
- MANHOLE

NOTES:

1) GPM DENOTES GALLONS PER MINUTE
2) ALL LOCATIONS ARE APPROXIMATE

N

0 15 30
APPROXIMATE SCALE IN FEET

BASEMAP SOURCE:
HORIZONS, INC. RAPID CITY, SD (1989)

Kennedy/Jenks Consultants

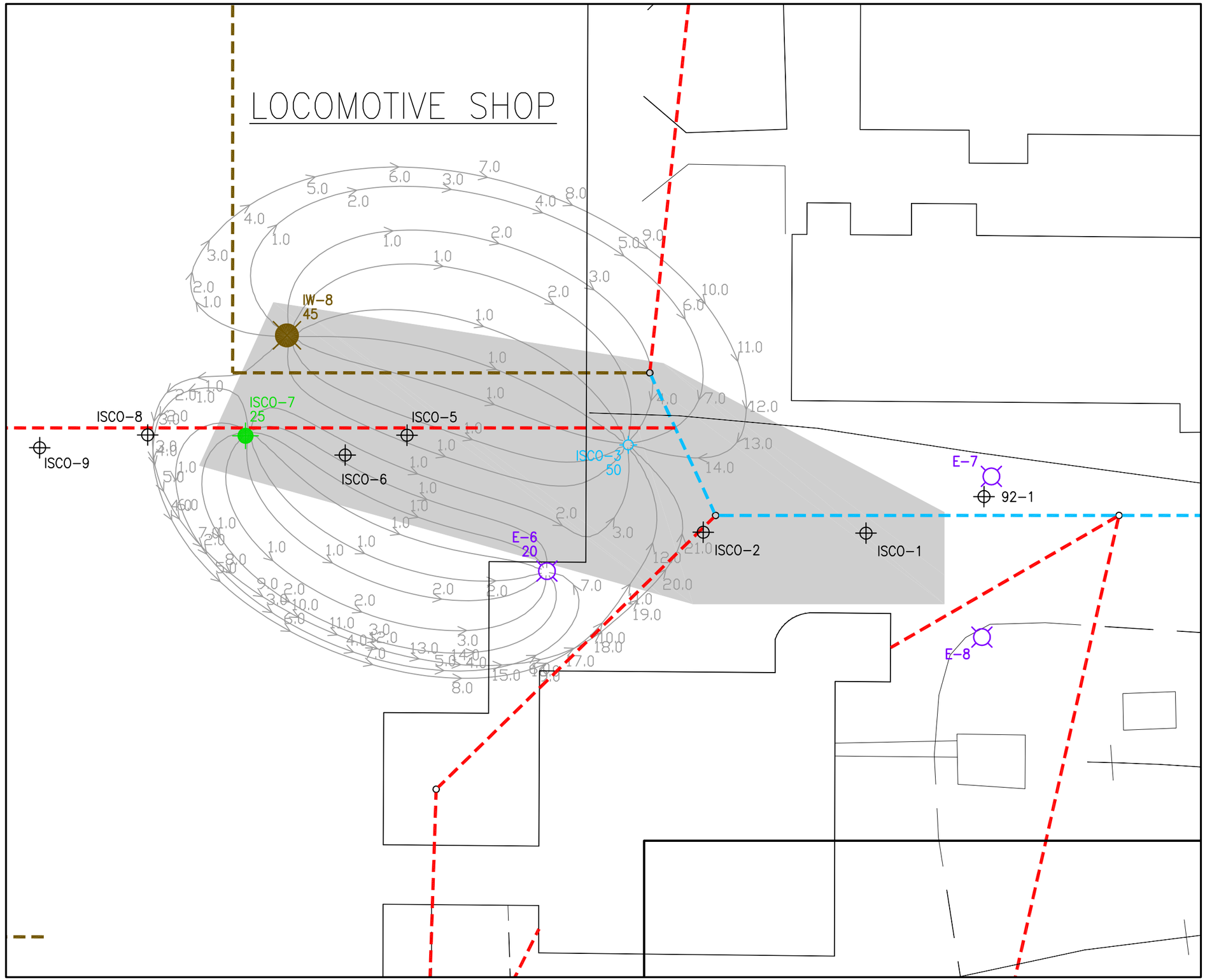
BURLINGTON NORTHERN LIVINGSTON SHOP COMPLEX – LIVINGSTON, MT

RECIRCULATION LOCOMOTIVE SHOP AREA

1096021.16/Task F/PT/P10SK003.rev1

11/10 (Revision 1)

FIGURE 3



LEGEND

- PLANNED ISCO TESTING TREATMENT AREA
- ISCO-7 25 — PILOT TEST INJECTION WELL LOCATION WITH APPROXIMATE INJECTION RATE (GPM)
- ISCO-3 50 — PILOT TEST EXTRACTION WELL LOCATION WITH APPROXIMATE EXTRACTION RATE (GPM)
- IW-8 45 — PROPOSED PILOT TEST INJECTION WELL LOCATION WITH APPROXIMATE INJECTION RATE (GPM)
- E-6 20 — PROPOSED PILOT TEST EXTRACTION WELL LOCATION WITH APPROXIMATE EXTRACTION RATE (GPM)
- ISCO-14 — EXISTING MONITORING WELL LOCATION
- MODELED GROUNDWATER FLOW PATH AND DIRECTION
- 1.0 — GROUNDWATER FLOW TIME (DAYS)
- ORIGINAL/REPLACED INDUSTRIAL WASTEWATER SEWER LINE
- SLEEVED INDUSTRIAL WASTEWATER SEWER LINE
- OLD INDUSTRIAL WASTEWATER SEWER LINE
- MANHOLE

NOTES:

1) GPM DENOTES GALLONS PER MINUTE
2) ALL LOCATIONS ARE APPROXIMATE

N

0 15 30
APPROXIMATE SCALE IN FEET

BASEMAP SOURCE:
HORIZONS, INC. RAPID CITY, SD (1989)

Kennedy/Jenks Consultants

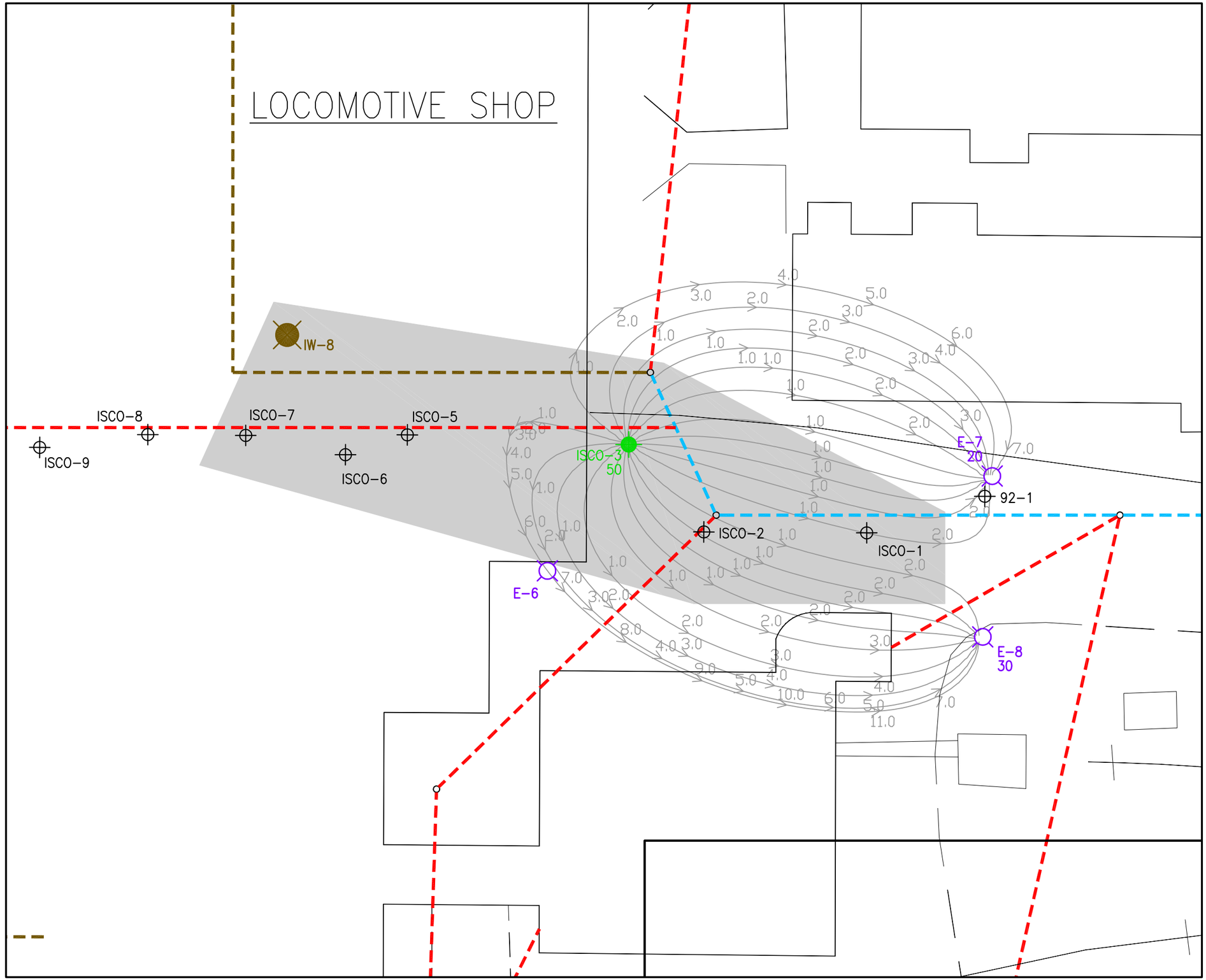
BURLINGTON NORTHERN LIVINGSTON SHOP COMPLEX – LIVINGSTON, MT

RECIRCULATION
LOCOMOTIVE SHOP AREA - UPGRADIENT

1096021.16/Task F/PT/P10SK004.rev1

11/10 (Revision 1)

FIGURE 4



LEGEND

- PLANNED ISCO TESTING TREATMENT AREA
- ISCO-3 50 — PILOT TEST INJECTION WELL LOCATION WITH APPROXIMATE INJECTION RATE (GPM)
- IW-8 — PROPOSED PILOT TEST INJECTION WELL LOCATION
- E-8 30 — PROPOSED PILOT TEST EXTRACTION WELL LOCATION WITH APPROXIMATE EXTRACTION RATE (GPM)
- ISCO-14 — EXISTING MONITORING WELL LOCATION
- MODELED GROUNDWATER FLOW PATH AND DIRECTION
- 1.0 — GROUNDWATER FLOW TIME (DAYS)
- ORIGINAL/REPLACED INDUSTRIAL WASTEWATER SEWER LINE
- SLEEVED INDUSTRIAL WASTEWATER SEWER LINE
- OLD INDUSTRIAL WASTEWATER SEWER LINE
- MANHOLE

NOTES:

1) GPM DENOTES GALLONS PER MINUTE
2) ALL LOCATIONS ARE APPROXIMATE

N

0 15 30
APPROXIMATE SCALE IN FEET

BASEMAP SOURCE:
HORIZONS, INC. RAPID CITY, SD (1989)

Kennedy/Jenks Consultants

BURLINGTON NORTHERN LIVINGSTON SHOP COMPLEX – LIVINGSTON, MT

RECIRCULATION
LOCOMOTIVE SHOP AREA - DOWNGRADIENT

1096021.16/Task F/PT/P10SK005.rev1

11/10 (Revision 1) **FIGURE 5**