Tables

in the

Engineering Evaluation/Cost Analysis

Revised and Updated 2010

for the

Twins Inn Site

Arvada, Colorado

U.S EPA, Region 8

Tables

Table 2-2. Soil Contaminant Screening Level Exceedances for the North Tank Source Area
Twins Inn Site - Engineering Evaluation/Cost Analysis

Compound	Maximum Concentration Detected and Location[1]				Screening Levels	
	Nov 2000 (µg/kg)	Soil Sample Location ID	July 2002 (µg/kg)	Soil Sample Location ID	EPA Generic SSLs[2] (µg/kg)	CDPHE Soil Evaluation Values[3] (µg/kg)
1,1,1-TCA[4]	**16,000**	DP007 at 0.5 ft	**7,300**	TS001 at 11 ft	2,000	62,000
1,1-DCE	**340**	HA002 at 12 ft	**190**	TS001 at 11 ft	60	12,000
1,2-Dichloropropane	10	DP007 at 4 ft	**63**	TS001 at 11 ft	30	8.7
Chlorobenzene	**2,200**	DP007 at 0.5 ft	69	TS001 at 11 ft	1,000	5,300
cis-1,2-DCE	88	DP007 at 0.5 ft	42	TS001 at 11 ft	400	1,300
Methylene Chloride	**3,200**	DP007 at 0.5 ft	**800**	TS001 at 11 ft	20	60
PCE	**300,000**	DP007 at 0.5 ft	**6,500**	TS001 at 11 ft	60	1,900
TCE	**19,000**	DP007 at 0.5 ft	**5,100**	TS002 at 11 ft	60	680
Toluene	19	DP007 at 6 ft	87	TS002 at 11 ft	12,000	85,000
Vinyl Chloride	**13**	DP007 at 20 ft	ND	--	10	110

Notes:

[1] No soil samples were collected in 2003 - 2009.

[2] EPA SSLs are for migration to groundwater and quoted from www.epa.gov/superfund/health/conmedia/soil/pdfs/appd_a.pdf

[3] CDPHE Table 1 Colorado Soil Evaluation Values, groundwater protection level, December 2007 from CDPHE (genericsitesro1000 mg/kgcap.xls) to URS.

[4] Concentrations exceeding screening levels for 1,1,1-TCA were also observed at HA002 (4,700 µg/kg at 12 feet bgs) and HA004 (2,100 µg/kg at 8 feet bgs).

bold and highlighted = The result exceeds one of the screening levels.
-- = No screening level
µg/kg = micrograms per kilogram
bgs = below ground surface
1,1,1-TCA = 1,1,1-trichloroethane
1,1-DCE = 1,1-dichloroethene
CDPHE = Colorado Department of Public Health and Environment
cis-1,2-DCE = *cis*-1,2-dichloroethene
DP = direct push borehole
EPA = U.S. Environmental Protection Agency
ft = foot or feet
HA = hand auger
ID = identification
ND = not detected
PCE = tetrachloroethene
SSL = Soil Screening Level
TCE = trichloroethene
TS = treatability study

Table 2-3. Soil Screening Level Exceedances for the South Pit Area
Twins Inn Site - Engineering Evaluation/Cost Analysis

Compound	Maximum Concentration Detected and Location[1]				Screening Levels	
	Nov 2000 (µg/kg)	Soil Sample Location ID	July 2002 (µg/kg)	Soil Sample Location ID	EPA Generic SSLs[2] (µg/kg)	CDPHE Soil Evaluation Values[3] (µg/kg)
1,1,1-TCA	**750,000**	HA001 at 4 ft	**85,000**	TS007 at 8 ft	2,000	62,000
1,1-DCE	ND	HA002 at 12 ft	**330,000**	TS007 at 8 ft	60	12,000
1,2-Dichloropropane	**3,400**	DP010 at 27 ft	**85,000**	TS007 at 8 ft	30	8.7
Chlorobenzene	ND	--	230	TS012 at 11.5 ft	1,000	5,300
cis-1,2-DCE	**440,000**	HA001 at 4 ft	**330,000**	TS007 at 8 ft	400	1,300
Methylene Chloride	**930,000**	HA001 at 4 ft	ND	--	20	60
PCE	**1,600,000**	HA001 at 4 ft	**9,200**	TS012 at 5 ft	60	1,900
TCE	**6,600,000**	HA001 at 4 ft	**240,000**	TS007 at 8 ft	60	680
Toluene	**59,000,000**	HA001 at 4 ft	**15,000,000**	TS007 at 8 ft	12,000	85,000
Vinyl Chloride	5	DP010 at 16 ft	**600**	TS012 at 11.5 ft	10	110

Notes:

[1] No soil samples were collected in 2003 - 2009.

[2] EPA SSLs are for migration to groundwater and quoted from www.epa.gov/superfund/health/conmedia/soil/pdfs/appd_a.pdf

[3] CDPHE Table 1 Colorado Soil Evaluation Values, groundwater protection level, December 2007 from CDPHE (genericsitesro1000 mg/kgcap.xls) to URS.

bold and highlighted = The result exceeds one of the screening levels.

-- = No screening level
µg/kg = micrograms per kilogram
1,1,1-TCA = 1,1,1-trichloroethane
1,1-DCE = 1,1-dichloroethene
CDPHE = Colorado Department of Public Health and Environm
cis-1,2-DCE = *cis*-1,2-dichloroethene
DP = direct push borehole
EPA = U.S. Environmental Protection Agency
ft = foot or feet
HA = hand auger
ID = identification
ND = not detected
PCE = tetrachloroethene
SSL = Soil Screening Level
TCE = trichloroethene
TS = treatability study

Table 2-4. Soil Screening Level Exceedances for the Plume-Transition Area
Twins Inn Site - Engineering Evaluation/Cost Analysis

Compound	Maximum Concentration Detected and Location[1]				Screening Levels	
	Nov 2000 (µg/kg)	Soil Sample Location ID	July 2002 (µg/kg)	Soil Sample Location ID	EPA Generic SSLs[2] (µg/kg)	CDPHE Soil Evaluation Values[3] (µg/kg)
1,1,1-TCA	8	DP005 at 12 ft	NS	--	2,000	62,000
1,1-DCE	ND	--	NS	--	60	12,000
1,2-Dichloropropane	**260**	DP005 at 12 ft	NS	--	30	8.7
Chlorobenzene	3	DP005 at 4 ft	NS	--	1,000	5,300
cis-1,2-DCE	330	DP005 at 12 ft	NS	--	400	1,300
Methylene Chloride	**210**	DP008 at 12 ft	NS	--	20	60
PCE	**330**	DP001 at 4 ft	NS	--	60	1,900
TCE	**390**	DP005 at 12 ft	NS	--	60	680
Toluene	360	DP008 at 12 ft	NS	--	12,000	85,000
Vinyl Chloride	**11**	DP004 at 0.5 ft	NS	--	10	110

Notes:

[1] No soil samples were collected in 2002 - 2009.

[2] EPA SSLs are for migration to groundwater and quoted from www.epa.gov/superfund/health/conmedia/soil/pdfs/appd_a.pdf

[3] CDPHE Table 1 Colorado Soil Evaluation Values, groundwater protection level, December 2007 from CDPHE (genericsitesro1000 mg/kgcap.xls) to URS.

bold and highlighted = The result exceeds one of the screening levels.

-- = No screening level

µg/kg = micrograms per kilogram

1,1,1-TCA = 1,1,1-trichloroethane

1,1-DCE = 1,1-dichloroethene

CDPHE = Colorado Department of Public Health and Environment

cis-1,2-DCE = *cis*-1,2-dichloroethene

DP = direct push borehole

EPA = U.S. Environmental Protection Agency

ft = foot or feet

HA = hand auger

ID = identification

ND = not detected

NS = Not sampled

PCE = tetrachloroethene

SSL = Soil Screening Level

TCE = trichloroethene

Table 2-5. Soil Screening Level Exceedances for the Downgradient Plume
Twins Inn Site - Engineering Evaluation/Cost Analysis

Compound	Maximum Concentration Detected and Location[1]				Screening Levels	
	Nov 2000 (µg/kg)	Soil Sample Location ID	July 2002 (µg/kg)	Soil Sample Location ID	EPA Generic SSLs[2] (µg/kg)	CDPHE Soil Evaluation Values[3] (µg/kg)
1,1,1-TCA	9	DP022 at 20 ft	NS	--	2,000	62,000
1,1-DCE	ND	--	NS	--	60	12,000
1,2-Dichloropropane	ND	--	NS	--	30	8.7
Chlorobenzene	8	DP022 at 20 ft	NS	--	1,000	5,300
cis-1,2-DCE	ND	HA001 at 4 ft	NS	--	400	1,300
Methylene Chloride	1	DP033 at 20 ft	NS	--	20	60
PCE	**130**	DP022 at 20 ft	NS	--	60	1,900
TCE	55	DP022 at 20 ft	NS	--	60	680
Toluene	2	DP006 at 8 ft	NS	--	12,000	85,000
Vinyl Chloride	ND	--	NS	--	10	110

Notes:

[1] No soil samples were collected in 2002 - 2009.

[2] EPA SSLs are for migration to groundwater and quoted from www.epa.gov/superfund/health/conmedia/soil/pdfs/appd_a.pdf

[3] CDPHE Table 1 Colorado Soil Evaluation Values, groundwater protection level, December 2007 from CDPHE (genericsitesro1000 mg/kgcap.xls) to URS.

bold and highlighted = The result exceeds one of the screening levels.

-- = No screening level

µg/kg = micrograms per kilogram

1,1,1-TCA = 1,1,1-trichloroethane

1,1-DCE = 1,1-dichloroethene

CDPHE = Colorado Department of Public Health and Environment

cis-1,2-DCE = *cis*-1,2-dichloroethene

DP = direct push borehole

EPA = U.S. Environmental Protection Agency

ft = foot or feet

HA = hand auger

ID = identification

ND = not detected

NS = Not sampled

PCE = tetrachloroethene

SSL = Soil Screening Level

TCE = trichloroethene

Table 2-6. Contaminants of Concern Summary
Twins Inn Site - Engineering Evaluation/Cost Analysis

Compound	North Tank Source Area		South Pit Area		Plume-transition Area		Downgradient Plume	
	Soil	Groundwater	Soil	Groundwater	Soil	Groundwater	Soil	Groundwater
Tetrachloroethene (PCE)	X	X	X	X	X	X	X	X
Trichloroethene (TCE)	X	X	X	X	X	X		X
1,1-Dichloroethene (1,1-DCE)	X	X	X			X		X
cis-1,2-Dichloroethene (cis-1,2-DCE)		X	X	X		X		X
Vinyl Chloride	X	X	X	X	X	X		X
1,1,1-Trichloroethane (1,1,1-TCA)	X	X	X	X		X		X
1,1-Dichloroethane (1,1-DCA)		X		X		X		X
1,2-Dichloropropane	X	X	X	X	X	X		X
Methylene Chloride	X	X	X	X	X			
Toluene			X	X				
Chlorobenzene	X							

Notes:

X = contaminant of concern identified in risk assessment (URS, 2006d)

Table 2-7. Groundwater Standard Exceedances for the North Tank Source Area
Twins Inn Site - Engineering Evaluation/Cost Analysis

Compound	Regulatory Standards		Maximum Concentration Detected and Sample Location							
			2000		2007		2008		2009	
	EPA MCL[1] (µg/L)	CBSG[2] (µg/L)	Maximum Detection (µg/L)	Sample Location	Maximum Detection (µg/L)	Sample Location	Maximum Detection (µg/L)	Sample Location	Maximum Detection (µg/L)	Sample Location
1,1,1-TCA	200	200	**140,000**	HA003 at 13.5 ft	**1,800J**	MW028	**1,300J**	MW028	**920**	MW028
1,1,2-TCA	5	5	**560**	DP007 at 17 ft	ND	MW028	ND	MW028	ND	--
1,1-DCA	---	---	**330**	HA004 at 13 ft	9.5J	MW028	8.9J	MW028	5.8	MW028
1,1-DCE	7	7	**4,000**	HA003 at 13.5 ft	**300**	MW028	**340**	MW028	**220J**	MW028
1,2-Dichloropropane	5	5	ND	--	ND	--	ND	MW028	1.8J	MW028
1,4-Dioxane	---	6.1 (3.2)[3]	ND	--	ND	--	ND	--	ND	--
Benzene	5	5	ND	--	ND	--	ND	--	ND	--
Chlorobenzene	100	100	ND	--	ND	--	ND	--	ND	--
Chloroform	80 [4]	80 [4]	ND	--	ND	--	ND	--	0.83J	MW028
cis-1,2-DCE	70	70	**1,300**	HA003 at 13.5 ft	17J	MW028	16J	MW028	13	MW028
Methylene Chloride	5	5	**3,900**	HA003 at 13.5 ft	**58J**	MW028	ND	--	ND	--
PCE	5	5	**56,000**	HA003 at 13.5 ft	**810J**	MW028	**930J**	MW028	**650J**	MW028
TCE	5	5	**220,000**	HA003 at 13.5 ft	**880**	MW028	**910J**	MW028	**690**	MW028
Toluene	1,000	1,000	ND	--	ND	--	ND	--	ND	--
Vinyl Chloride	2	2	**24**	DP007 at 17 ft	ND	--	ND	--	ND	--

Notes:

[1] U.S. Environmental Protection Agency (EPA) Drinking Water and Health Advisories, May 2009.

[2] Colorado Basic Standards for Groundwater, CDPHE Regulation No. 41. *The Basic Standards for Groundwater* , effective November 2009.

[3] Current standard for 1,4-dioxane will change to the value in parentheses on March 22, 2012.

[4] Because chloroform is a by-product/component of total trihalomethanes, the standard for chloroform is quoted as total trihalomethanes.

bold and highlighted = The result exceeds one of the screening levels.
--- = Standard does not exist
µg/L = micrograms per liter
1,1,1-TCA = 1,1,1-trichloroethane
1,1,2-TCA = 1,1,2-trichloroethane
1,1-DCA = 1,1-dichloroethane
1,1-DCE = 1,1-dichloroethene
cis -1,2-DCE = *cis* -1,2-dichloroethene
CBSG = Colorado Basic Standard for Groundwater

DP = Direct push borehole
J = the associated value is an estmated quantity
HA = hand auger
MCL = Maximum contaminant level
MW = Monitoring well
ND = Not Detected
PCE = tetrachloroethene
TCE = trichloroethene
trans- 1,2-DCE = *trans*- 1,2-dichloroethene

Table 2-8. Groundwater Standard Exceedances for the South Pit Area
Twins Inn Site - Engineering Evaluation/Cost Analysis

Compound	Regulatory Standards		Maximum Concentration Detected and Sample Location							
			2000		2007		2008		2009	
	EPA MCL[1] (µg/L)	CBSG[2] (µg/L)	Maximum Detection (µg/L)	Sample Location	Maximum Detection (µg/L)	Sample Location	Maximum Detection (µg/L)	Sample Location	Maximum Detection (µg/L)	Sample Location
1,1,1-TCA	200	200	**5,600**	DP010 at 14 ft	ND	--	6.7J	MW004	7.3J	MW005
1,1,2-TCA	5	5	ND		ND	--	ND	--	ND	--
1,1-DCA	---	5	**3,000**	DP010 at 14 ft	**55**	MW005	**69**	MW005	**90**	MW005
1,1-DCE	7	7	ND		ND	--	0.81J	MW004	3.2J	MW005
1,2-Dichloropropane	5	5	**26,000**	DP010 at 14 ft	**520**	MW005	**280**	MW005	**570**	MW005
1,4-Dioxane	---	6.1 (3.2)[3]	ND		ND	--	ND	--	ND	--
Benzene	5	5	1.6		ND	--	ND	--	1.2J	MW005
Chlorobenzene	100	100	1		0.54J	MW027	ND	--	1.3J	MW005
Chloroform	80 [4]	80 [4]	0.9		ND	--	ND	--	ND	--
cis-1,2-DCE	70	70	**170,000**	DP010 at 14 ft	**570**	MW005	**860**	MW005	**840**	MW005
Methylene Chloride	5	5	**39,000**	HA001 at 8 ft	**11J**	MW005	2.6J	MW004	1.7J	MW005
PCE	5	5	**1,900**	HA001 at 8 ft	ND	--	**190**	MW004	**48**	MW004
TCE	5	5	**26,000**	HA001 at 8 ft	**10J**	MW005	**56J**	MW004	**21J**	MW005
Toluene	1,000	1,000	**220,000**	HA001 at 8 ft	ND	MW005	ND	--	ND	--
Vinyl Chloride	2	2	**7,400**	DP010 at 14 ft	**170**	MW005	**190**	MW005	**88**	MW005

Notes:

[1] U.S. Environmental Protection Agency (EPA) Drinking Water and Health Advisories, May 2009.

[2] Colorado Basic Standards for Groundwater, CDPHE Regulation No. 41. *The Basic Standards for Groundwater* , effective November 2009.

[3] Current standard for 1,4-dioxane will change to the value in parentheses on March 22, 2012.

[4] Because chloroform is a by-product/component of total trihalomethanes, the standard for chloroform is quoted as total trihalomethanes.

bold and highlighted = The result exceeds one of the screening levels.
--- = Standard does not exist
µg/L = micrograms per liter
1,1,1-TCA = 1,1,1-trichloroethane
1,1,2-TCA = 1,1,2-trichloroethane
1,1-DCA = 1,1-dichloroethane
1,1-DCE = 1,1-dichloroethene
cis -1,2-DCE = *cis* -1,2-dichloroethene
CBSG = Colorado Basic Standard for Groundwater

DP = Direct push borehole
J = the associated value is an estimated quantity
HA = hand auger
MCL = Maximum contaminant level
MW = Monitoring well
ND = Not Detected
PCE = tetrachloroethene
TCE = trichloroethene
trans- 1,2-DCE = *trans*- 1,2-dichloroethene

Table 2-9. Groundwater Standard Exceedances for the Plume-Transition Area
Twins Inn Site - Engineering Evaluation/Cost Analysis

Compound	Regulatory Standards		Maximum Concentration Detected and Sample Location							
			2000		2007		2008		2009	
	EPA MCL[1] (µg/L)	CBSG[2] (µg/L)	Maximum Detection (µg/L)	Sample Location	Maximum Detection (µg/L)	Sample Location	Maximum Detection (µg/L)	Sample Location	Maximum Detection (µg/L)	Sample Location
1,1,1-TCA	200	200	**350**	DP018 at 23 ft	**370J**	MW030	**240J**	MW030	**150**	MW030
1,1,2-TCA	5	5	ND	--	ND	--	ND	--	ND	--
1,1-DCA	---	5	**10**	DP004 at 14 ft	**11**	MW030	**8.7J**	MW030	**7.8**	MW030
1,1-DCE	7	7	**23**	DP018 at 23 ft	**62**	MW030	**37**	MW030	**38J**	MW030
1,2-Dichloropropane	5	5	**110**	DP004 at 14 ft	1.2	MW030	**12**	MW004	**7.5**	MW004
1,4-Dioxane[3]	---	6.1 (3.2)[3]	ND	--	ND	--	ND	--	ND	--
Benzene[4]	5	5	ND	--	**660**	MW029	**850**	MW029	**800**	MW029
Chlorobenzene	100	100	ND	--	1.4	MW025	1.1	MW025	1.3	MW025
Chloroform	80 [5]	80 [5]	5.3	DP017 at 16 ft	0.35J	MW025	ND	--	0.22J	MW025
cis-1,2-DCE	70	70	**130**	DP004 at 14 ft	52	MW025	31	MW025	29	MW025
Methylene Chloride	5	5	ND	--	**11J**	MW029	2.6J	MW025	**18J**	MW029
PCE	5	5	**230**	DP001 at 16 ft	**170J**	MW030	**190**	MW004	**130J**	MW030
TCE	5	5	**280**	DP004 at 14 ft	**170J**	MW030	**160**	MW030	**130**	MW030
Toluene	1,000	1,000	53	DP008 at 24 ft	3.6J	MW029	ND	--	3.9J	MW029
Vinyl Chloride	2	2	**73**	DP009 at 15 ft	**11**	MW025	**10**	MW025	**4.4**	MW025

Notes:

[1] U.S. Environmental Protection Agency (EPA) Drinking Water and Health Advisories, May 2009.

[2] Colorado Basic Standards for Groundwater, CDPHE Regulation No. 41. *The Basic Standards for Groundwater* , effective November 2009.

[3] Current standard for 1,4-dioxane will change to the value in parentheses on March 22, 2012.

[4] Benzene is not highlighted as a contaminant of concern at this site since MW029 is downgradient of historical UST site that is not part of Twins Inn site.

[5] Because chloroform is a by-product/component of total trihalomethanes, the standard for chloroform is quoted as total trihalomethanes.

bold and highlighted = The result exceeds one of the screening levels.
--- = Standard does not exist
µg/L = micrograms per liter
1,1,1-TCA = 1,1,1-trichloroethane
1,1,2-TCA = 1,1,2-trichloroethane
1,1-DCA = 1,1-dichloroethane
1,1-DCE = 1,1-dichloroethene
cis -1,2-DCE = *cis* -1,2-dichloroethene
CBSG = Colorado Basic Standard for Groundwater

DP = Direct push borehole
J = The associated value is an estimated qantity
MCL = Maximum contaminant level
MW = Monitoring well
ND = Not Detected
PCE = tetrachloroethene
TCE = trichloroethene
trans- 1,2-DCE = *trans*- 1,2-dichloroethene
UST = underground storage tank

Table 2-10. Groundwater Standard Exceedances for the Downgradient Plume
Twins Inn Site - Engineering Evaluation/Cost Analysis

Compound	Regulatory Standards		Maximum Concentration Detected and Sample Location							
			2000		2007		2008		2009	
	EPA MCL[1] (µg/L)	CBSG[2] (µg/L)	Maximum Detection (µg/L)	Sample Location	Maximum Detection (µg/L)	Sample Location	Maximum Detection (µg/L)	Sample Location	Maximum Detection (µg/L)	Sample Location
1,1,1-TCA	200	200	**310**	DP022 at 20 ft	**670**	MW033	**870J**	MW033	**1,500**	MW033
1,1,2-TCA	5	5	ND	--	ND	;--	ND	--	0.85J	MW033
1,1-DCA	---	5	**31**	DP037 at 22 ft	**69**	MW033	**59**	MW033	**54**	MW033
1,1-DCE	7	7	**50**	DP037 at 22 ft	**110**	MW033	**180**	MW033	**180J**	MW033
1,2-Dichloropropane	5	5	**120**	DP020 at 20 ft	**7.7J**	MW033	**9.8J**	MW011D	**15**	MW011D
1,4-Dioxane	---	6.1 (3.2)[3]	33 [3]	DP035 at 22 ft	ND	--	ND	--	380J	MW033
Benzene[4]	5	5	1.7	DP020 at 20 ft	3.5	MW025	4	MW025	3.1J	MW011D
Chlorobenzene	100	100	2.4	DP020 at 20 ft	3.8J	MW033	2.1J	MW033	1.8J	MW033
Chloroform	80 [4]	80 [4]	0.9	DP027 at 14 ft	4.3	MW016	19	MW011D	12	MW011D
cis-1,2-DCE	70	70	**150**	DP020 at 20 ft	**130**	MW033	**180**	MW033	**220**	MW033
Methylene Chloride	5	5	ND	--	**6.5J**	MW033	**14J**	MW033	ND	--
PCE	5	5	**89**	DP022 at 14 ft	**360**	MW033	**240J**	MW033	**440J**	MW033
TCE	5	5	**190**	DP037 at 22 ft	**480**	MW033	**660J**	MW033	**1,100**	MW033
Toluene	1,000	1,000	1	DP020 at 15 ft	ND	--	ND	--	ND	--
Vinyl Chloride	2	2	**26**	DP028 at 14 ft	**11**	MW025	**10**	MW011D	**9.4**	MW012

Notes:

[1] U.S. Environmental Protection Agency (EPA) Drinking Water and Health Advisories, May 2009.

[2] Colorado Basic Standards for Groundwater, CDPHE Regulation No. 41. *The Basic Standards for Groundwater* , effective November 2009.

[3] Current standard for 1,4-dioxane will change to the value in parentheses on March 22, 2012.

[4] Because chloroform is a by-product/component of total trihalomethanes, the standard for chloroform is quoted as total trihalomethanes.

bold and highlighted = The result exceeds one of the screening levels.
--- = Standard does not exist
µg/L = micrograms per liter
1,1,1-TCA = 1,1,1-trichloroethane
1,1,2-TCA = 1,1,2-trichloroethane
1,1-DCA = 1,1-dichloroethane
1,1-DCE = 1,1-dichloroethene
cis -1,2-DCE = *cis* -1,2-dichloroethene
CBSG = Colorado Basic Standard for Groundwater

DP = Direct push borehole
J = the associated value is an estimated quantity
MCL = Maximum contaminant level
MW = Monitoring well
ND = Not Detected
PCE = tetrachloroethene
TCE = trichloroethene
trans- 1,2-DCE = *trans*- 1,2-dichloroethene
UST = underground storage tank

Table 2-11. Potential Federal Chemical-Specific Applicable or Relevant and Appropriate Requirements
Twins Inn Site – Engineering Evaluation/Cost Analysis

Standard Requirement, Criteria, or Limitation	Citation	Description	Applicable	Relevant and Appropriate	To Be Considered	Comments
SAFE DRINKING WATER ACT	See Below	See description below.				
National Primary Drinking Water Standards	40 CFR 141	Establishes national health-based standards (maximum contaminant levels [MCLs]) for public drinking water supply systems.		X		Shallow groundwater has been used as a source of drinking water, but the well is not part of a public drinking water supply system. Nonetheless, this regulation is potentially relevant and appropriate to activities conducted during groundwater remedial alternatives.
Maximum Contaminant Level Goals (MCLg)	40 CFR 141, Subpart F	Establishes non-enforceable drinking water quality goals set at levels of no known or anticipated adverse health effects with an adequate margin of safety.			X	The shallow groundwater has been used as a drinking water source; however, because the MCLGs are not legally binding, this regulation is to be considered. This regulation will be considered with respect to activities conducted during groundwater remedial alternatives.
Maximum Contaminant Levels (MCL)	40 CFR 141, Subpart G	Establishes drinking water quality goals set at levels of no known or anticipated adverse health effects with an adequate margin of safety.		X		Shallow groundwater has been used as a source of drinking water, but the well is not part of a public drinking water supply system. Nonetheless, this regulation is potentially relevant and appropriate to activities conducted during groundwater remedial alternatives.
National Secondary Drinking Water Standards	40 CFR 143	Establishes welfare-based standards (secondary maximum contaminant levels [SMCLs]).		X		Shallow groundwater has been used as a source of drinking water, but the well is not part of a public drinking water supply system. Nonetheless, this regulation is potentially relevant and appropriate to activities conducted during groundwater remedial alternatives.
CLEAN WATER ACT	See Below	See description below.				
Water Quality Criteria (WQC)	40 CFR 131	Sets criteria for water body and surface water quality based on toxicity to aquatic organisms and human health.			X	Human health risk assessment and ecological risk screening (UOS, 1999c) indicated that surface water does not pose an unacceptable risk to human health or aquatic organisms. This regulation will be considered with respect to activities conducted during groundwater remedial alternatives.

Table 2-11. (continued)

Standard Requirement, Criteria, or Limitation	Citation	Description	Applicable	Relevant and Appropriate	To Be Considered	Comments
RESOURCE CONSERVATION AND RECOVERY ACT (RCRA) SUBTITLE C	40 CFR 264 and 265	Defines solid wastes that are subject to regulation as hazardous wastes and sets standards for treatment, storage, and disposal of hazardous waste as administered by CDPHE.	X			The Twins Inn RA alternatives will not constitute operation or construction of a TSD facility; however, RCRA hazardous wastes will be generated during the RA, therefore this regulation is applicable. This regulation is potentially applicable to activities conducted during soil remedial alternative SO3A and groundwater remedial alternative GW5.
EPA SOIL SCREENING GUIDANCE	EPA540/R-96/018	Provides methodology for calculating risk-based, site-specific soil screening levels for contaminants in soil that may be used to identify areas needing further investigation at Superfund sites.			X	This soil screening level guidance is to be considered for the soil remedial alternatives.

Notes:

CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
CFR = *Code of Federal Regulations*
RA = Remedial Action

Table 2-12. Potential State Chemical-Specific Applicable or Relevant and Appropriate Requirements
Twins Inn Site - Engineering Evaluation/Cost Analysis

Standard Requirement, Criteria, or Limitation	Citation	Description	Applicable	Relevant and Appropriate	To Be Considered	Comments
PARTICULATES, SMOKES, CARBON MONOXIDE, AND SULFUR OXIDES	5 CCR 1001-3	Regulates the emission of particulates (including dust), carbon monoxide, and sulfur oxides from stationary sources. Establishes opacity limits.	X			Activities conducted during the soil remedial alternatives of the Twins Inn RA may generate emissions in sufficient quantities to trigger applicability; therefore this regulation is potentially applicable to those alternatives. This regulation is potentially applicable to activities conducted during groundwater remedial alternative GW5.
ODOR EMISSIONS	5 CCR 1001-4	Regulates the emission of detectable odorous air contaminants.		X		Odors were detected in and around buildings on Site, but not beyond the property boundary; therefore, this regulation is relevant and appropriate. This regulation is potentially relevant and appropriate for activities conducted during soil and groundwater remedial alternatives.
STATIONARY SOURCE PERMITTING	5 CCR 1001-5	Implements and sets rules for a regional air pollution control program, including pollutant-based permits and air emission fees. Establishes National Ambient Air Quality Standards (NAAQS).	X			Activities conducted during the soil remedial alternatives of the Twins Inn RA may generate emissions in sufficient quantities to trigger applicability; therefore this regulation is potentially applicable to those alternatives. Even if no permit is required, the substantive provisions of this regulation are potentially applicable to activities conducted during groundwater remedial alternative GW5.
STANDARDS OF PERFORMANCE FOR NEW STATIONARY SOURCES	5 CCR 1001-8	Regulates the emission of particulates and sulfur dioxides from new stationary sources. Establishes opacity limits.	X			Activities conducted during the soil remedial alternatives of the Twins Inn RA may generate emissions in sufficient quantities to trigger applicability; therefore this regulation is potentially applicable to those alternatives. This regulation is potentially applicable to activities conducted during groundwater remedial alternative GW5.
EMISSIONS OF VOLATILE ORGANIC COMPOUNDS	5 CCR 1001-9	Regulates the emission of volatile organic compounds (VOCs).	X			Activities conducted during the soil remedial alternatives of the Twins Inn RA may generate emissions in sufficient quantities to trigger applicability; therefore this regulation is potentially applicable to those alternatives. This regulation is potentially applicable to activities conducted during groundwater remedial alternative GW5.

Table 2-12. (continued)

Standard Requirement, Criteria, or Limitation	Citation	Description	Applicable	Relevant and Appropriate	To Be Considered	Comments
REGULATIONS FOR THE STATE DISCHARGE SYSTEM	5 CCR 1002-61	Regulates effluent discharges to waters of the State of Colorado from point sources and sets effluent limitations.	X			Activities conducted during the groundwater remedial alternatives of the Twins Inn RA may discharge effluent to waters of the state; therefore, this regulation is potentially applicable to those alternatives.
REGULATIONS FOR EFFLUENT LIMITATIONS	5 CCR 1002-62	Sets effluent limitations of specifically identified pollutants discharged to specific classes of State of Colorado waters.	X			Activities conducted during the groundwater remedial alternatives of the Twins Inn RA may discharge effluent to waters of the state; therefore, this regulation is potentially applicable to those alternatives.
REGULATIONS CONTROLLING DISCHARGES TO STORM SEWERS	5 CCR 1002-65	Requires a Colorado Discharge Permit System (CDPS) permit to discharge to storm sewers non-stormwater wastewater containing pollutants.	X			Activities conducted during the groundwater remedial alternatives of the Twins Inn RA may discharge effluent to waters of the state; therefore, this regulation is potentially applicable to those alternatives, even if a permit is not required.
BASIC STANDARDS AND METHODOLOGIES FOR SURFACE WATER	5 CCR 1002-31	Provides classification that establishes use categories for surface water, sets anti-degradation rules, and assigns water quality standards for surface water.	X			Applicable due to impact on surface water as a result of pollutant seepage from the Site groundwater plume. This regulation is applicable to activities conducted during groundwater remedial alternatives.
COLORADO BASIC STANDARDS FOR GROUNDWATER (CBSG)	5 CCR 1002-41	Sets non-degradation standards (Colorado Groundwater Standards) and welfare-based standards (Safe Drinking Water Standards [SDWS]) for groundwater, and establishes a "point of compliance" at impacted sites.	X			Applicable, since the shallow groundwater is contaminated. This regulation is applicable to activities conducted during groundwater remedial alternatives.

Table 2-12. (continued)

Standard Requirement, Criteria, or Limitation	Citation	Description	Applicable	Relevant and Appropriate	To Be Considered	Comments
CLASSIFICATION AND NUMERIC STANDARDS FOR THE SOUTH PLATTE RIVER BASIN, LARAMIE RIVER BASIN, REPUBLICAN RIVER BASIN, SMOKY HILL RIVER BASIN	5 CCR 1002-38 Section 38.1 to 38.6	Designates Clear Creek and its tributaries in the vicinity of the Site as use-protected and sets specific numeric standards.	X			Activities conducted during the groundwater remedial alternatives of the Twins Inn RA may discharge effluent to waters of the state; therefore, this regulation is potentially applicable to those alternatives.
PRIMARY DRINKING WATER REGULATIONS	5 CCR 1003-1	Establishes health-based standards (MCLs) for public drinking water systems.		X		Shallow groundwater has been used as a source of drinking water, but the well is not part of a public drinking water supply system. Nonetheless, this regulation is potentially relevant and appropriate to activities conducted during groundwater remedial alternatives.
HAZARDOUS WASTE ACT	6 CCR 1007-3, Subparts 260 to 265	Standards for owners and operators of hazardous waste treatment, storage and disposal facilities.	X			The Twins Inn RA alternatives will not constitute operation or construction of a TSD facility; however, RCRA hazardous wastes will be generated during the RA, therefore this regulation is applicable. This regulation is potentially applicable to activities conducted during soil and groundwater remedial alternatives.
COLORADO SOIL EVALUATION VALUES (CSEV)	CDPHE, December 2007	Soil clean-up values.			X	The soil clean-up values are to be considered for the soil remedial alternatives.

Notes:

CCR = *Code of Colorado Regulations*
RA = Remedial Action
RCRA = Resource Conservation and Recovery Act

Table 2-13. Potential Federal Location-Specific Applicable or Relevant and Appropriate Requirements
Twins Inn Site - Engineering Evaluation/Cost Analysis

Standard Requirement, Criteria, or Limitation	Citation	Description	Applicable	Relevant and Appropriate	To Be Considered	Comments
FISH AND WILDLIFE COORDINATION ACT	16 USC 661-666	Establishes provisions for protection of fish and wildlife resources and requires consultation with federal authorities if modifications of streams or other water bodies are required.		X		Although the Twins Inn RA alternatives are not expected to impact fish or wildlife resources or modify streams or other water bodies, the soil remedial alternatives require digging (SO3A), which may affect stream turbidity; therefore this regulation is relevant and appropriate. (Note: although the plume has impacted Ralston Creek, Rudden Pond and potentially Clear Creek, the ecological risk screening [UOS 1999c] indicated that surface water would not pose an unacceptable risk to aquatic organisms.)
CLEAN WATER ACT	40 CFR 230 and 231	See description below.				
EXECUTIVE ORDER ON FLOOD-PLAIN MANAGEMENT	Executive Order 11988	Requires federal agencies to evaluate the potential effect of actions taken in a floodplain and to avoid adverse impact associated with direct and indirect development of a floodplain.		X		Although the Twins Inn Site is not a federal agency, nor are the RA alternatives anticipated to affect any floodplains, the Site is located in a floodplain; therefore, this order is relevant and appropriate. This regulation is potentially relevant and appropriate for activities conducted during soil and groundwater remedial alternatives.
RESOURCE CONSERVATION AND RECOVERY ACT (RCRA) SUBTITLE C	40 CFR 264	See description below.				

Table 2-13. (continued)

Standard Requirement, Criteria, or Limitation	Citation	Description	Applicable	Relevant and Appropriate	To Be Considered	Comments
Subtitle C - Floodplain Restriction	40 CFR 264, 18 (b)	TSD facilities must be designed, constructed, operated, and maintained to avoid washouts if RCRA hazardous waste treatment, storage or disposal is planned within a 100-year floodplain.		X		The Twins Inn RA alternatives will not constitute operation or construction of a TSD facility; however, RCRA hazardous wastes will be generated during the RA and the Site is located in a floodplain; therefore, this regulation is relevant and appropriate. This regulation is potentially relevant and appropriate for activities conducted during soil and groundwater remedial alternatives.

Notes:

CFR = *Code of Federal Regulations*
RA = Remedial Action
USC = United States Code

Table 2-14. Potential State Location-Specific Applicable or Relevant and Appropriate Requirements
Twins Inn Site - Engineering Evaluation/Cost Analysis

Standard Requirement, Criteria, or Limitation	Citation	Description	Applicable	Relevant and Appropriate	To Be Considered	Comments
HAZARDOUS WASTE ACT	6 CCR 1007-3	See description below.				
Floodplain Restrictions	6 CCR 1007-3 Section 264.18 (b)	TSD facilities must be designed, constructed, operated, and maintained to avoid washouts if RCRA hazardous waste treatment, storage or disposal is planned within a 100 year floodplain.		X		The Twins Inn RA alternatives will not constitute construction or operation of a TSD facility. However, hazardous wastes will be generated in the vicinity of a floodplain; therefore, this regulation is relevant and appropriate. This regulation is potentially relevant and appropriate for activities conducted during soil and groundwater remedial alternatives.

Notes:
CCR = *Code of Colorado Regulations*
RA = Remedial Action

Table 2-15. Potential Federal Action-Specific Applicable or Relevant and Appropriate Requirements
Twins Inn Site - Engineering Evaluation/Cost Analysis

Standard Requirement, Criteria, or Limitation	Citation	Description	Applicable	Relevant and Appropriate	To Be Considered	Comments
INTERGOVERNMENTAL REVIEW OF EPA PROGRAMS AND ACTIVITIES (Executive Order 12372)	40 CFR 29	Requires state and local coordination and review of proposed EPA-assisted projects. The Administrator of the EPA is required to explain the project to the state and local officials, and consult with other affected federal agencies and provide a comment period for state review.	X			The Site is CERCLA-listed; therefore, this regulation is applicable to activities conducted during soil and groundwater remedial alternatives.
CLEAN AIR ACT (CAA)	40 CFR 50 and 52	Implements and sets rules for a regional air pollution control program. Establishes NAAQS. Administered by CDPHE.		X		Activities conducted during the soil remedial alternatives of the Twins Inn RA may generate emissions in sufficient quantities to trigger applicability; therefore this regulation is relevant and appropriate. This regulation is potentially applicable to activities conducted during groundwater remedial alternative GW5. (Note: these regulations likely do not have any affirmative action requirements.)
CLEAN WATER ACT	See Below	See description below.				
National Pollutant Discharge Elimination System (NPDES)	40 CFR 122 40 CFR 125	Requires permits for the discharge of pollutants from any point source into waters of the United States and establishes criteria and standards for technology-based treatment of discharges.	X			Activities conducted during the groundwater remedial alternatives of the Twins Inn RA may discharge effluent to waters of the state. Reevaluation of effluent allowable discharge requirements for the groundwater remedial alternatives will be required; therefore, this regulation is potentially applicable to those alternatives.

Table 2-15. (continued)

Standard Requirement, Criteria, or Limitation	Citation	Description	Applicable	Relevant and Appropriate	To Be Considered	Comments
Underground Injection Control Regulations	40 CFR 144 to 147	Establishes regulations for subsurface injections for protection of groundwater used for drinking water.	X			Applicable to groundwater remedial alternatives GW4 and GW7A because shallow groundwater has been used as a drinking water supply and these alternatives include subsurface injection.
Effluent Guidelines and Standards for Organic Chemicals	40 CFR 414	Requires specific effluent limitations for discharge under NPDES permits	X			Activities conducted during the groundwater remedial alternatives of the Twins Inn RA may discharge effluent to waters of the state. Reevaluation of effluent allowable discharge requirements for the groundwater remedial alternatives will be required; therefore, this regulation is potentially applicable to those alternatives.
RCRA SUBTITLE C	40 CFR 260-264	Regulates the generation, transport, storage, treatment and disposal of hazardous wastes generated as a result of remedial action. Also regulates construction, design, monitoring, operation and closure of hazardous waste facilities.	X			The Twins Inn RA alternatives will generate hazardous wastes that will require transportation to a permanent disposal site; therefore, this regulation is applicable. This regulation is potentially applicable to activities conducted during soil and groundwater remedial alternatives.
STANDARDS APPLICABLE TO GENERATORS OF HAZARDOUS WASTE	40 CFR 262	Establishes standards for generators of hazardous waste.	X			The Twins Inn RA alternatives will generate hazardous wastes; therefore, this regulation is applicable. This regulation is potentially applicable to activities conducted during soil and groundwater remedial alternatives.
STANDARDS APPLICABLE TO TRANSPORTERS OF HAZARDOUS WASTE	40 CFR 263	Establishes standards that apply to transporters of hazardous waste within the U.S. if the transportation requires a manifest under 40 CFR 262.		X		The Twins Inn RA alternatives will generate hazardous wastes that will require transportation to a permanent disposal site; therefore, this regulation is relevant and appropriate. This regulation is potentially relevant and appropriate for activities conducted during soil and groundwater remedial alternatives.

Table 2-15. (continued)

Standard Requirement, Criteria, or Limitation	Citation	Description	Applicable	Relevant and Appropriate	To Be Considered	Comments
LAND DISPOSAL RESTRICTIONS	40 CFR 268	Establishes restrictions for land disposal of wastes and other hazardous material.	X			The Twins Inn RA alternatives will generate hazardous wastes; therefore, this regulation is applicable. This regulation is potentially applicable to activities conducted during soil remedial alternatives.
HAZARDOUS WASTE PERMITTING PROGRAM	40 CFR 270	Establishes provisions covering basic EPA hazardous waste permitting requirements.	X			The Twins Inn RA alternatives will generate RCRA hazardous wastes; therefore, this regulation is applicable. This regulation is potentially applicable to activities conducted during soil and groundwater remedial alternatives. Even if a permit is not required, the substantive provisions are potentially applicable.
HAZARDOUS MATERIALS TRANSPORTATION REGULATIONS	49 CFR 171-177	Regulates transportation of hazardous materials.	X			The Twins Inn RA alternatives will generate hazardous wastes that will require transportation to a permanent disposal site; therefore, this regulation is potentially applicable for activities conducted during soil and groundwater remedial alternatives.
OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA)	29 USC 651-678	Regulates worker health and safety.	X			Under 40 CFR 300.38, requirements of the Act apply to response actions under the National Contingency Plan (NCP). The risk assessment (UOS 1999c) identified chemical and indoor air exposure concerns. OSHA exposure limits are developed for 8-hour worker exposures; these standards may also be considered in the protection of people in their homes. OSHA HAZWOPER requirements also apply to field crews conducting RA activities. Therefore, this regulation is applicable. This regulation is applicable to activities conducted during soil and groundwater remedial alternatives.

Notes:

CDPHE = Colorado Department of Public Health and Environment
CFR = *Code of Federal Regulations*
EPA = U.S. Environmental Protection Agency
FS = Feasibility study
HAZWOPER = Hazardous Waste Operations and Emergency Response
NAAQS = National Ambient Air Quality Standards
RA = Remedial Action
USC = United States Code

Table 2-16. Potential State Action-Specific Applicable or Relevant and Appropriate Requirements
Twins Inn Site - Engineering Evaluation/Cost Analysis

Standard Requirement, Criteria or Limitation	Citation	Description	Applicable	Relevant and Appropriate	To Be Considered	Comments
STATIONARY SOURCE PERMITTING	5 CCR 1001-5	Implements and sets rules for a regional air pollution control program, including pollutant-based permits and air emission fees. Establishes NAAQS. Administered by the CDPHE.	X			Activities conducted during the soil remediation alternatives may generate emissions in sufficient quantities to trigger applicability; therefore this regulation is potentially applicable to those alternatives. This regulation is potentially applicable to activities conducted during groundwater remedial alternative GW5.
STANDARDS OF PERFORMANCE FOR NEW STATIONARY SOURCES	5 CCR 1001-8	Regulates the emission of particulates and sulfur dioxides from new stationary sources. Establishes opacity limits.	X		.	Activities conducted during the soil remediation alternatives may generate emissions in sufficient quantities to trigger applicability; therefore this regulation is potentially applicable to those alternatives. This regulation is potentially applicable to activities conducted during groundwater remedial alternative GW5.
REGULATIONS FOR THE STATE DISCHARGE SYSTEM	5 CCR 1002-61	See description below.				
Permit Requirements for Discharge	5 CCR 1002-61 Section 61.3 to 61.11	Requires permits for the discharge of pollutants for any point source into waters of the state. These regulations also describe the requirement for submitting a permit to the state and the contents of those permits	X			Activities conducted during the groundwater remedial alternatives of the Twins Inn RA may discharge effluent to waters of the state; therefore, the substantive provisions of this regulation are potentially applicable to those alternatives, even if a permit is not required.
Definition of Effluent Limitations	5 CCR 1002-61 Section 61.8(2)	Incorporates 40 CFR 414 and requires specific effluent characteristics for discharge into waters of the state.	X			Activities conducted during the groundwater remedial alternatives of the Twins Inn RA may discharge effluent to waters of the state; therefore, this regulation is potentially applicable to those alternatives.
Stormwater Discharges	5 CCR 1002-61 Section 61.4(3)	Sets standard for stormwater discharges from specific identified sites and associated on-site activities.	X			Activities conducted during the groundwater remedial alternatives of the Twins Inn RA may discharge effluent to waters of the state; therefore, this regulation is potentially applicable to those alternatives.

Table 2-16. (continued)

Standard Requirement, Criteria or Limitation	Citation	Description	Applicable	Relevant and Appropriate	To Be Considered	Comments
HAZARDOUS WASTE ACT	6 CCR 1007-3	See description below.				
Hazardous Waste Permit Regulations	Part 100, Section 100.10 to 100.64	Establishes permit regulations for owners and operators of new and existing hazardous waste treatment, storage, and disposal (TSD) facilities. These regulations also describe the requirement for submitting a permit to the state and the contents of those permits.		X		The Twins Inn RA alternatives will not constitute operation of a TSD facility. However, hazardous wastes will be generated during the RA; therefore, this regulation is relevant and appropriate. This regulation is potentially relevant and appropriate for activities conducted during soil and groundwater remedial alternatives.
EPA Identification Numbers	Part 262, Subpart A, Section 262.12	Requires hazardous waste generators to obtain EPA identification.	X			Twins Inn PRP Group will generate waste during the Twins Inn RA and will utilize its EPA identification numbers. This regulation is applicable. This regulation is potentially applicable to activities conducted during soil and groundwater remedial alternatives.
The Manifest	Part 262, Subpart B, Section 262.20	Establishes manifest requirements prior to hazardous waste transport.	X			The Twins Inn RA alternatives will generate hazardous waste that will require off-site transportation; therefore, this regulation is applicable. This regulation is potentially applicable to activities conducted during soil and groundwater remedial alternatives.
Pre-Transport Requirements	Part 262, Subpart C	Establishes accumulation, packaging, and labeling requirements prior to hazardous waste transport.	X			The Twins Inn RA alternatives will generate hazardous waste that will require off-site transportation; therefore, this regulation is applicable. This regulation is potentially applicable to activities conducted during soil and groundwater remedial alternatives.

Table 2-16. (continued)

Standard Requirement, Criteria or Limitation	Citation	Description	Applicable	Relevant and Appropriate	To Be Considered	Comments
General Operational Standards for Hazardous Waste Treatment, Storage and Disposal Facilities	Part 264, Section 264.1 to 264.77	Establishes standards that apply to owners and operators of hazardous waste treatment, storage and disposal facilities.		X		The Twins Inn RA alternatives will not constitute operation of a hazardous waste TSD facility. However, hazardous wastes will be generated during the RA; therefore, this regulation is relevant and appropriate. This regulation is potentially relevant and appropriate for activities conducted during soil and groundwater remedial alternatives.
Standards for Groundwater Protection and Closure and Post-Closure at Hazardous Waste Treatment, Storage and Disposal Facilities	Part 264, Section 264.90 to 264.120	Establishes groundwater protection standards, closure, and post-closure standards that apply to owners and operators of hazardous waste TSD facilities.		X		The Twins Inn RA alternatives will not constitute operation of a TSD facility. However, impact to the groundwater at the Site is occurring and hazardous wastes will be generated during the RA; therefore, this regulation is relevant and appropriate. This regulation is potentially relevant and appropriate for activities conducted during soil and groundwater remedial alternatives.
WATER WELL CONSTRUCTION RULES	2 CCR 402-2	See description below.				
Well Permit Requirements	2 CCR 402-2, Rules 6, 10, 11, 13, 15 and 16	Establishes rules applicable to the construction and abandonment of recovery, monitoring and observation wells.	X			The Twins Inn RA alternatives will include construction of recovery and monitoring and observation wells; therefore, this regulation is applicable. This regulation is potentially applicable to activities conducted during groundwater remedial alternatives GW4 and GW7A.
Remediation Project Recovery Wells	Colorado State Engineer's Office Policy Memorandum 94-5	Establishes standards for recovery wells that consume greater than 10,862 gallons per year of groundwater.	X			The Twins Inn RA alternatives may include construction of recovery wells as part of the groundwater remedial alternatives. This standard will be applicable if it is determined that the evaporative and leakage losses from the recovery wells will consume greater than 10,862 gallons of groundwater per year. This regulation is potentially applicable to activities conducted during groundwater remedial alternative GW4.

Notes:

CCR = *Code of Colorado Regulations*
CFR = *Code of Federal Regulations*
EPA = U.S. Environmental Protection Agency
NAAQS = National Ambient Air Quality Standards
CDPHE = Colorado Department of Public Health and Environment
CRS = *Colorado Revised Statutes*
FS = Feasibility study
RA = Remedial Action

Table 3-1. General Response Actions, Remedial Technology Type, and Process Options for Soil
Twins Inn Site – Engineering Evaluation/Cost Analysis

General Response Action	Remedial Technology	Process Option
No Action	No Action	No Action
Institutional Controls	Institutional Controls	Institutional Controls
Removal	*In situ* Soil Vapor Recovery	Soil Vapor Extraction
	Excavation	Excavation
		Excavation by Auger Drilling
	In situ Release and Recovery	Surfactant Injection and Recovery
		Solvent Injection and Recovery
Treatment	*Ex situ* Biological	Landfarming
		Bioventing Cell
	In situ Biological	Bioventing
	Thermal	On-site Thermal Desorption
Containment	Physical Containment	Slurry Wall/Sheet Pile
Stabilization	Vitrification	*In situ* Soil Vitrification
Disposal	Off-site Disposal	Off-site Treatment and Disposal

Table 3-2. General Response Actions, Remedial Technology Type, and Process Options for Groundwater
Twins Inn Site – Engineering Evaluation/Cost Analysis

General Response Action	Remedial Technology Type	Process Option
No Action	No Action	No Action
Institutional Controls	Institutional Controls	Institutional Controls
In Situ Treatment	Biological/Physical	Monitored Natural Attenuation
	Biological	Anaerobic Biostimulation using Electron Donors
		Anaerobic Biostimulation using HRC®
		Aerobic Biostimulation using ORC®
		Aerobic Biostimulation using iSOC/iMOX™
		Aerobic Biostimulation using Bioventing
		Anaerobic Bioaugmentation
		Anaerobic Biorecirculation
		Phytoremediation
	Chemical	*In Situ* Chemical Oxidation using Potassium Permanganate
		In Situ Chemical Oxidation using Fenton's Reagent
		In Situ Chemical Oxidation using Ozone Sparging
Containment	Biological	Electron Donor Biowall PRB
		Bark Mulch Biowall PRB
	Chemical	Zero-Valent Iron PRB by Directional Injection
		Zero-Valent Iron PRB by Trenching
		Electrical PRB (E-Barrier)
Removal	Physical	Air Sparging with SVE
		Groundwater Recirculation Wells with Vapor Extraction
		Pumping
		Dual-Phase Extraction
		Two-Phase Extraction
	Biological/Physical	Groundwater Recirculation Wells with Biostimulation
	Thermal/Physical	Electrical Resistance Heating with SVE
		Steam Injection with SVE
Ex Situ Treatment	Biological	Liquid/Vapor-Phase Bioreactor
	Chemical	Carbon Adsorption
		UV Oxidation
	Physical	Air Stripping
Disposal	Discharge (after treatment)	Discharge to POTW
		Discharge to Surface Water
		Discharge by Reinjection
Alternate Water Supply	Physical	Alternate water supply for properties using shallow groundwater.

Notes:

HRC® = Hydrogen Release Compound
iSOC/iMOX™ = In Situ Submerged Oxygen Curtain/In Situ Cometabolic Oxidation
ORC® = Oxygen Release Compound
POTW = Publicly Owned Treatment Works
PRB = Permeable Reactive Barrier
SVE = Soil Vapor Extraction
UV = Ultraviolet

Table 3-3. Remedial Technology and Process Option Screening for Soil
Twins Inn Site – Engineering Evaluation/Cost Analysis

Process Option	Technology Description	Effectiveness	Implementability		Cost		Retain or Reject
			Technical	Administrative	Capital Cost	O&M Cost	
No Action	No further action to be taken.	Not effective.	No technical requirements.	Acceptance is difficult to achieve.	No cost.	No cost.	**RETAIN**
Institutional Controls	Use restrictions and signage established.	Effectively restricts soil disturbance and exposure.	Simple installation of signs.	Environmental covenant or restriction with Thoro property owner is required.	Minimal cost of signage. Legal cost for restrictions could be significant.	Minimal cost from maintaining signs.	**RETAIN**
Soil Vapor Extraction	*In situ* vapor extraction by vacuum applied to well casing.	Effectively removes VOCs from shallow- and intermediate-depth soil, eliminating the need for soil removal and disposal. Not effective in fine-grained soils or low-permeability clays. Can be limited by shallow groundwater depths such as those found in the South Pit area.	Requires *ex situ* vapor treatment. Requires an on-site area for the vapor treatment system and piping.	Requires access to the Thoro property. Accepted technology. May require an emissions permit.	Vapor extraction and treatment equipment required.	Requires frequent O&M.	Reject
Excavation	Large-scale soil removal for *ex situ* treatment or off-site disposal.	Efficient, rapid removal of contaminated soil. Excavation depth is limited to the depth reached by equipment, therefore can only be used for shallow soil treatment. Non-specific treatment that removes soil volumes, not particular contaminants.	Process is construction intensive. Requires a large, on-site construction staging area for excavation support and soil stockpiling. May require containment or vapor suppression.	Requires access to the Thoro property. Accepted technology. May require a soil storage permit, depending upon amount of excavated soil and concentrations of contaminants.	Can be cost intensive due to heavy equipment. May require off-site transport and treatment of excavated soil.	No cost expected.	**RETAIN**
Excavation by Auger Drilling	Small-scale soil removal for *ex situ* treatment or off-site disposal.	Effective removal of contaminated soil. May be used near, or even beneath, structures, unlike conventional excavation. Not limited by depth since larger rigs can reach greater depths. Less efficient removal of contaminated soils than conventional excavation. Non-specific treatment that removes soil volumes, not particular contaminants.	Requires a large, on-site construction staging area for excavation support and soil stockpiling.	Requires access to the Thoro property. Technology not as common as conventional excavation and may not be accepted. May require a soil storage permit, depending upon amount of excavated soil and concentrations of contaminants.	Can be cost intensive due to drill rig and excavation support equipment. May require off-site transport and treatment of excavated soil.	No cost expected.	**RETAIN**
Surfactant Injection and Recovery	Injection of complexing agent to increase suspension of contaminants sorbed to soil particles and surfactant/contaminant recovery.	Able to remove sorbed-phase VOCs. Provides groundwater treatment through surfactant and VOC extraction in addition to soil treatment. Surfactants must be removed from soil through extraction, treated, and possibly reused for maximum effectiveness. Mobilized contaminants must be captured to avoid further discharge to the plume or unaffected groundwater.	Easily implemented with direct push technology. Requires an on-site area for an extraction and separation system. Requires complete capture of released contaminants.	Requires access to the Thoro property. Technology may not be accepted for use in populated, urban areas.	Surfactant extraction and separation system is required.	O&M, including periodic surfactant addition, may be required.	Reject
Solvent Injection and Recovery	Injection of releasing agent to dissolve contaminants sorbed to soil particles and solvent/contaminant recovery.	Able to remove sorbed-phase VOCs. Provides groundwater treatment through solvent and VOC extraction in addition to soil treatment. Injected solvents must be removed from soil through extraction, treated, and possibly reused for maximum effectiveness. Mobilized contaminants must be captured to avoid further discharge to the plume or unaffected groundwater.	Easily implemented with direct push technology. Requires an on-site area for an extraction and separation system. Requires complete capture of released contaminants.	Requires access to the Thoro property. Technology may not be accepted for use in populated, urban areas.	Solvent extraction and separation system is required.	O&M, including periodic solvent addition, may be required.	Reject

Table 3-3. Remedial Technology and Process Option Screening for Soil
Twins Inn Site – Engineering Evaluation/Cost Analysis

Process Option	Technology Description	Effectiveness	Implementability		Cost		Retain or Reject
			Technical	Administrative	Capital Cost	O&M Cost	
Landfarming	On-site plowing and mixing of excavated, stockpiled soil with addition of moisture and nutrients.	Commonly used soil treatment technology for VOCs. More effective for treatment of SVOCs.	*Ex situ* process requiring excavation and stockpiling of soil. Requires a large, on-site area for spreading, plowing, and mixing.	Requires access to the Thoro property. May require an emissions permit. Technology may not be accepted for use in populated, urban areas. May require a soil storage permit, depending upon amount of excavated soil and concentrations of contaminants.	May need to purchase equipment and materials such as liners and dust cover.	Requires frequent O&M.	Reject
Bioventing Cell	Induction of microbial activity into excavated, stockpiled soil by addition of air, moisture, and nutrients; also called "biopile."	Commonly used soil treatment technology for VOCs. Reworking soil aerates soil to induce rapid growth of indigenous aerobic microbes that can degrade VOCs. Aerobic degradation is more effective than anaerobic degradation for some VOCs such as DCE, DCA, and vinyl chloride. Aerobic degradation is less effective than anaerobic degradation for some VOCs such as PCE, TCE, and TCA.	*Ex situ* process requiring excavation and stockpiling of soil. Requires an on-site area for construction of the treatment cell. May require a vapor treatment system. Requires protection from freezing.	Requires access to the Thoro property. May require an emissions permit. Technology may not be accepted for use in populated, urban areas. May require a soil storage permit, depending upon amount of excavated soil and concentrations of contaminants.	Construction materials are required for the treatment cell.	Requires frequent O&M.	Reject
Bioventing	Low flow introduction of air (oxygen) into undisturbed soil to stimulate indigenous aerobic microbes *in situ*.	Commonly used soil treatment technology for fuel compounds and VOCs. Aerated soil to induces rapid growth of indigenous aerobic microbes that can degrade fuel compounds and VOCs *in situ*. Aerobic degradation is more effective than anaerobic degradation for some constituents such as toluene, DCE, DCA, and vinyl chloride. Aerobic degradation is less effective than anaerobic degradation for some VOCs such as PCE, TCE, and TCA. May be ineffective in low permeability material.	*In situ* process requiring aeration wells and a light duty air pump. Treatment process may be slow.	Requires access to the Thoro property. Accepted technology.	Materials required for well installation and air pumping system.	Limited O&M to maintain pump.	Reject
On-site Thermal Desorption	Removal of VOCs from excavated soil through heating, volatilization of contaminants, and vapor extraction and treatment.	Able to remove sorbed-phase VOCs. Effective with any soil type, including fine-grained, low-permeability soils. Very rapid treatment relative to other technologies. Requires on-site area dedicated to treatment system.	*Ex situ* process requiring excavation and stockpiling of soil. Requires an emissions treatment system. Requires installation and staging of equipment on site.	Requires access to the Thoro property. Accepted technology. May require an emissions permit. May require a soil storage permit, depending upon amount of excavated soil and concentrations of contaminants.	Treatment system equipment is required.	Power requirements are high and can be very costly for large treatment areas.	**RETAIN**

Table 3-3. Remedial Technology and Process Option Screening for Soil
Twins Inn Site – Engineering Evaluation/Cost Analysis

Process Option	Technology Description	Effectiveness	Implementability		Cost		Retain or Reject
			Technical	Administrative	Capital Cost	O&M Cost	
Slurry Wall/Sheet Pile	Impermeable cement/grout or metal wall to isolate contaminated soil from clean soil and groundwater.	Prevents contamination from migrating to areas beyond the containment. Isolates the contamination rather than removal.	Construction intensive. Requires a large construction staging area. May require horizontal injection to contain the bottom of the contaminated area.	Requires access to the Thoro property. Permission from private property owners may be required. Utilities may need to be relocated.	Cost intensive due to construction materials and heavy equipment.	Dewatering of the contained area may be required.	Reject
In Situ Soil Vitrification	Solidification method that uses heat to melt and convert waste material into glass.	Long term effectiveness is not known. More often used for inorganic contaminants. Heat required typically destroys organic contaminants rather than stabilization.	Requires application of heat up to 1200 ˚C. High electrical power requirements. Requires well installation and staging of heating equipment.	Requires access to the Thoro property. Technology may not be accepted for use in populated, urban areas.	Cost mostly derived from power requirements.	Performance monitoring costs.	Reject
Off-site Treatment and Disposal	Contaminated soil disposal at a licensed waste facility.	Effective disposal of contaminated soil. May be used for any Site contaminant. Requires off-site treatment of hazardous material before disposal.	Transportation from Site may overwhelm and damage local roads.	Requires access to the Thoro property. Accepted technology. May require a soil disposal permit, depending upon amount of excavated soil and concentrations of contaminants.	More costly than on-site use or disposal due to transportation and disposal fees. Hazardous waste disposal can be costly due to required off-site treatment by the waste disposal subcontractor.	No cost expected.	**RETAIN**

Notes:

DCA = Dichloroethane
DCE = Dichloroethene
O&M = Operation and Maintenance
PCE = Tetracholorethene
SVOC = Semivolatile Organic Compound
TCA = Trichloroethane
TCE = Trichloroethene
VOC = Volatile Organic Compound

Table 3-4. Remedial Technology and Process Option Screening for Groundwater
Twins Inn Site – Engineering Evaluation/Cost Analysis

Process Option	Technology Description	Effectiveness	Implementability		Cost		Retained or Rejected
			Technical	Administrative	Capital	O&M	
No Action	No further action to be taken.	Not effective.	No technical requirements.	Acceptance is difficult to achieve.	No cost.	No cost.	**RETAIN**
Institutional Controls	Use restrictions and signage.	Effectively restricts groundwater use and exposure to groundwater.	Simple installation of signs.	Environmental covenant or restriction with Thoro property owner is required. Water rights and classification must be established.	Minimal cost of signage. Legal cost for restrictions could be significant.	Minimal cost from maintaining signs.	**RETAIN**
Monitored Natural Attenuation	Natural physical, chemical, or biological processes that act without human intervention to reduce the risks, toxicity, mobility, volume, or concentrations of contamination.	Reduces the potential for cross contamination of uncontaminated groundwater since pumping or injection is not required. Source area or DNAPL removal may be necessary for technology to be effective. Complete dechlorination of contaminants may occur at a very slow rate, resulting in an excess of intermediate breakdown products. Contaminants could migrate to a point of exposure before they are degraded. Suspected to be currently occurring in some capacity at the site.	Passive, *in situ* approach avoiding substantial design, capital, and O&M costs. Minimal site disturbance with additional wells as the only potential intrusive activity. Can be combined with active remedial measures or used for a portion of the site.	Accepted technology. Technology should be used only in low-risk situations.	Limited to well installation, if necessary.	Requires long-term monitoring.	**RETAIN**
Anaerobic Biostimulation using Electron Donors	Indigenous anaerobic microbes are stimulated to degrade contaminants by addition of a food grade additive such as lactate, molasses, propylene glycol or edible oil, which acts as a slow release electron donor.	Enhances natural processes without adding strong or harmful chemicals. Anaerobic degradation is more effective than aerobic degradation for some VOCs such as PCE, TCE, and TCA. Anaerobic degradation is less effective than aerobic degradation for some VOCs such as DCE, DCA, and vinyl chloride. Rapid consumption may require multiple applications. Complete dechlorination of contaminants may occur at a slow rate, resulting in an excess of intermediate breakdown products. Electron donors are not microorganism-specific and may result in the stimulation of unwanted bacterial communities such as methanogens and sulfate reducing bacteria.	Passive, *in situ* approach avoiding substantial design, capital, and O&M costs, unless long-term, multiple applications are required. Minimal site disturbance. Using direct push injection as the preferred method of delivery, it can be applied very quickly and unobtrusively. Generally not added to existing monitoring wells due to residuals that are not easily removed. Can be delivered through a long-term gravity feed injection system. Depending on site groundwater geochemistry, non-precipitating phosphorus may be needed in addition to electron donors.	Accepted technology; however, effectiveness may vary from site to site. Access agreements with property owners are required and may be difficult to establish, limiting implementability.	Material costs are low. Possible long-term gravity feed injection system.	Requires some groundwater monitoring.	**RETAIN**
Anaerobic Biostimulation using slow release electron donor, HRC®	Indigenous anaerobic microbes are stimulated to degrade contaminants by addition of a proprietary, food grade, polylactate ester, which acts as a slow release electron donor.	Enhances natural processes without adding strong or harmful chemicals. Anaerobic degradation is more effective than aerobic degradation for some VOCs such as PCE, TCE, and TCA. Anaerobic degradation is less effective than aerobic degradation for some VOCs such as DCE, DCA, and vinyl chloride. Material is not microorganism-specific and may result in the stimulation of unwanted bacterial communities such as methanogens. Complete dechlorination of contaminants may occur at a very slow rate, resulting in an excess of intermediate breakdown products.	Passive, *in situ* approach avoiding substantial design, capital, and O&M costs. Minimal site disturbance. Using direct push injection as the preferred method of delivery, it can be applied very quickly and unobtrusively. Material is long-lasting and should not require multiple, long-term applications. Generally not added to existing monitoring wells due to residuals that are not easily removed.	Currently utilized in more than 7,500 soil and groundwater restoration projects in the United States to treat chlorinated solvents. Access agreements with property owners are required and may be difficult to establish, limiting implementability.	Proprietary technology with only one vendor for the product. Cost of treatment material only, which can be high depending on the size of the area to be treated.	Requires some groundwater monitoring.	**RETAIN**

Table 3-4. Remedial Technology and Process Option Screening for Groundwater
Twins Inn Site – Engineering Evaluation/Cost Analysis

Process Option	Technology Description	Effectiveness	Implementability		Cost		Retained or Rejected
			Technical	Administrative	Capital	O&M	
Aerobic Biostimulation using ORC®	Indigenous aerobic microbes are stimulated to cometabolically degrade contaminants by adding oxygen.	Enhances natural processes without adding strong or harmful chemicals. Material alone is effective for hydrocarbon degradation but not for chlorinated solvent degradation. Aerobic degradation of chlorinated solvents is a cometabolic process and requires an additional source of carbon such as methane or toluene. Aerobic degradation is more effective than anaerobic degradation for some VOCs such as DCE, DCA, and vinyl chloride. Aerobic degradation is less effective than anaerobic degradation for some VOCs such as PCE, TCE, and TCA.	Passive, *in situ* approach avoiding substantial design, capital, and O&M costs. Minimal site disturbance. Using direct push as the preferred method of delivery, it can be applied very quickly and unobtrusively.	Accepted technology for treatment of fuel-based hydrocarbons, rather than chlorinated solvents. Access agreements with property owners are required and may be difficult to establish, limiting implementability.	Proprietary technology with only one vendor for the product. Cost of treatment material only, which can be significant.	Requires some groundwater monitoring.	Reject
Aerobic Biostimulation using iSOC/iMOX™	Aerobic bioremediation for chlorinated VOCs using a methane and oxygen infusion to degrade contaminants in groundwater through cometabolism.	Enhances natural processes without adding strong or harmful chemicals. Aerobic degradation of chlorinated solvents is a cometabolic process and requires an additional source of carbon such as methane or toluene. Aerobic degradation is more effective than anaerobic degradation for some VOCs such as DCE, DCA, and vinyl chloride. Aerobic degradation is less effective than anaerobic degradation for some VOCs such as PCE, TCE, and TCA. System effectiveness in the field is generally unknown.	Simple off-the-shelf system installed in a well. Gases only; no liquid chemicals to mix or inject. Requires no electrical power or moving parts. Requires flowing groundwater to transport gases. Requires on-site storage of compressed gas cylinders.	Innovative technology with limited performance data. Access agreements with property owners are required and may be difficult to establish, limiting implementability.	Only one vendor for equipment. Requires well(s) for installation.	Requires some O&M to check that the system is functioning properly. Requires some groundwater monitoring.	Reject
Aerobic Biostimulation using Bioventing	Indigenous aerobic microbes are stimulated to cometabolically degrade contaminants by adding oxygen and methane.	Enhances natural processes without adding strong or harmful chemicals. Aerobic degradation of chlorinated solvents is a cometabolic process and requires an additional source of carbon such as methane or toluene. Aerobic degradation is more effective than anaerobic degradation for some VOCs such as DCE, DCA, and vinyl chloride. Aerobic degradation is less effective than anaerobic degradation for some VOCs such as PCE, TCE, and TCA. Does not require changing oxidation-reduction condition of aerobic groundwater. Treatment is applicable to unsaturated and saturated soil in addition to groundwater.	System requires more engineered design and installation. Relies on gas diffusion in the subsurface. Gases only; no liquid chemicals to mix or inject. Requires electrical power. Requires on-site storage of compressed gas cylinders.	Accepted technology. Access agreements with property owners are required and may be difficult to establish, limiting implementability.	Costs for large-scale installation and widespread use can be high.	O&M requirements can be high.	Reject
Anaerobic Bioaugmentation	Anaerobic microbes, electron donor, and bio-nutrients are added to the subsurface to promote microbial growth and stability for contaminant biodegradation.	Anaerobic bioaugmentation can be highly effective for complete dechlorination of various chlorinated solvents such as PCE, TCE, DCE, and vinyl chloride, producing innocuous compounds (i.e., CO_2, ethene) in contrast to some indigenous anaerobic microbes that can only degrade to lesser chlorinated solvents (i.e., DCE). Relatively rapid rate of contaminant degradation. Effective for high contaminant concentrations (hundreds of parts per million). Effectiveness can depend on site-specific geochemical conditions.	Passive, *in situ* approach avoiding substantial design, capital, and O&M costs. Minimal site disturbance. Using direct push injection as the preferred method of delivery, it can be applied very quickly and unobtrusively. Requires a complex addition of electron donors, oxygen scavengers, and microbial nutrients to optimize the area for microbial growth and stability. May require bench-scale testing to optimize electron donor/chemical/nutrient mixture before full-scale application. Injection process must be performed under anaerobic conditions, creating the potential for oxygen contamination.	Technology is innovative with applications at a limited number of sites. Access agreements with property owners are required and may be difficult to establish, limiting implementability.	Proprietary technology with limited vendors.	Requires some groundwater monitoring.	**RETAIN**

Table 3-4. Remedial Technology and Process Option Screening for Groundwater
Twins Inn Site – Engineering Evaluation/Cost Analysis

Process Option	Technology Description	Effectiveness	Implementability		Cost		Retained or Rejected
			Technical	Administrative	Capital	O&M	
Anaerobic Biorecirculation	Anaerobic microbes, electron donor, and bio-nutrients are added to the subsurface through a groundwater recirculation loop to promote microbial growth and stability for contaminant biodegradation.	Enhances natural processes without adding strong or harmful chemicals. Anaerobic degradation is more effective than aerobic degradation for some VOCs such as PCE, TCE, and TCA. Can be highly effective for complete dechlorination of various chlorinated solvents such as PCE, TCE, DCE, and vinyl chloride, producing innocuous compounds (i.e., CO_2, ethene) in contrast to some indigenous anaerobic microbes that can only degrade to lesser chlorinated solvents (i.e., DCE). Relatively rapid rate of contaminant degradation. Effective for high contaminant concentrations (hundreds of parts per million). Provides source containment. May be able to treat capillary fringe above water table. Material is not microorganism-specific and may result in the stimulation of unwanted bacterial communities such as methanogens. Effectiveness can depend on site-specific geochemical conditions.	Extraction system components and experienced contractors readily available. Requires protection from freezing. Requires a complex addition of electron donors, oxygen scavengers, and microbial nutrients to optimize the area for microbial growth and stability. May require bench-scale testing to optimize electron donor/chemical/nutrient mixture before full-scale application. Reinjection process must be performed under anaerobic conditions, creating the potential for oxygen contamination.	Commonly used groundwater extraction technology. Technology is innovative with applications at a limited number of sites. Access agreements with property owners are required and may be difficult to establish, limiting implementability.	Requires system installation and equipment costs. Proprietary technology with limited vendors.	Requires some groundwater monitoring. Requires some O&M.	**RETAIN**
Phytoremediation	Contaminant degradation and hydraulic control using natural processes of trees, grasses, and legumes.	Root depth generally allows for its use in areas with water depths as great as 20 feet. Most effective in zones with moderate to high permeability. Faster than natural attenuation. May not be capable of degrading a variety of contaminants. High concentrations of hazardous materials could be toxic to plants. Slower than mechanical treatments.	Passive, solar-driven treatment through transformation by plants. Site cultivation is required. Eliminates the option of land development due to cultivated groves. Susceptible to destruction by animals, humans, and pests. Large surface area required for planting. Potential for draining nearby surface water features due to water uptake by tree roots. Requires approximately five or more years for trees to reach maturity and full treatment capacity. Non-existent air and water emissions compared to *ex situ*, engineered systems.	Accepted technology in some regions. High public acceptance due to aesthetics. Access agreements with property owners are required and may be difficult to establish, limiting implementability.	Cost of trees and plants is relatively low.	May require O&M, including nutrient addition and irrigation until maturation.	Reject
In Situ Chemical Oxidation using Potassium Permanganate	Injection of potassium permanganate chemical to oxidize contaminants.	Strong oxidizer, effectively destroys various contaminants. Chlorinated breakdown products are not formed through this oxidation reaction. Generally not effective for treating chlorinated ethanes such as TCA. Reaction does not have off-gassing as with Fenton's reagent. Releases a manganese dioxide precipitate that may reduce aquifer permeability. Addition of an oxidizer may temporarily mobilize metals already in soil. Increases turbidity and manganese concentrations in groundwater.	Need contact with contaminant and good distribution of the chemical. Carbon, sulfur, and metals in soil/water could consume quantities of the oxidizer, leaving less of the material for contaminant oxidation. Multiple applications are generally required. Solid chemical powder is easy to handle. Chemical may also be used as a groundwater tracer due to distinctive purple color. Using direct push as the preferred method of delivery, it can be applied very quickly and unobtrusively.	*In situ* chemical oxidation is an accepted technology for chlorinated ethenes. Access agreements with property owners are required and may be difficult to establish, limiting implementability.	Chemical costs are low.	Requires some groundwater monitoring.	Reject

Table 3-4. Remedial Technology and Process Option Screening for Groundwater
Twins Inn Site – Engineering Evaluation/Cost Analysis

Process Option	Technology Description	Effectiveness	Implementability		Cost		Retained or Rejected
			Technical	Administrative	Capital	O&M	
In Situ Chemical Oxidation using Fenton's modified Reagent	Injection of hydrogen peroxide, an iron sulfide catalyst, and a chelating agent to oxidize contaminants.	Strong oxidizer, able to degrade most organic contaminants to innocuous compounds. Contaminant degradation occurs at a very rapid rate. Chlorinated breakdown products are generally not formed through this oxidation reaction. Short-lived reaction with significant off-gassing. Chlelating agent controls the rate of reaction and limits off-gassing from H_2O_2 oxidation. Chelated Fenton's reagent does not require pH adjustments or cause a significant increase in temperature. Treatment applicable to saturated soil in addition to groundwater. Addition of an oxidizer could temporarily mobilize metals already in soil. Subsurface heterogeneities and variations in hydraulic conductivity can cause a non-uniform distribution of oxidant and therefore limit effectiveness. The distribution of mass between sorbed and dissolved phase can control effectiveness. The natural oxidant demand (NOD) of the soil consumes the oxidant leaving less for contaminant oxidation. Therefore, a larger quantity of oxidant is needed at sites with a high NOD. May not be appropriate at sites with high alkalinity due to aggressive reactions between carbonate species and hydrogen peroxide.	Need contact with contaminant and good distribution of chemical. Carbon, sulfur, and metals in soil/water could consume quantities of the oxidizer, leaving less of the material for contaminant oxidation. Multiple applications are generally required. Concentrated hydrogen peroxide can create chemical safety and handling concerns. The potential for oxidizer surfacing exists at sites with low permeability or limited pore space to contain reaction off-gassing. Using direct push as the preferred method of delivery, it can be applied very quickly and unobtrusively, although use is limited near structures.	*In situ* chemical oxidation is an accepted technology for chlorinated ethenes. Access agreements with property owners are required and may be difficult to establish, limiting implementability.	Cost of chemical is moderate. Chelated iron injection with Fenton's reagent is a proprietary system with limited vendors.	Requires some groundwater monitoring.	**RETAIN**
In Situ Chemical Oxidation using Sodium Persulfate	Injection of sodium persulfate, an iron sulfide catalyst, and a chelating agent to oxidize contaminants.	Strong oxidizer, able to degrade most organic contaminants to innocuous compounds. Chlorinated breakdown products are not formed through this oxidation reaction. Reaction does not have significant off-gas sing as with Fenton's reagent. Chlelating agent controls the rate of reaction. Does not require pH adjustments or cause a significant increase in temperature. Treatment applicable to saturated soil in addition to groundwater. Addition of an oxidizer could temporarily mobilize metals already in soil.	Need contact with contaminant and good distribution of chemical. Carbon, sulfur, and metals in soil/water could consume quantities of the oxidizer, leaving less of the material for contaminant oxidation, although consumption is not to the extent as with permanganate or hydrogen peroxide. Multiple applications are generally required. Solid chemical powder is easy to handle. Using direct push as the preferred method of delivery, it can be applied very quickly and unobtrusively, although use is limited near structures.	*In situ* chemical oxidation is an accepted technology for chlorinated ethenes. Access agreements with property owners are required and may be difficult to establish, limiting implementability.	Chemical costs are low. Chelated iron injection with sodium persulfate is a proprietary system requiring royalty payments to the patent holder.	Requires some groundwater monitoring.	**RETAIN**
In Situ Chemical Oxidation using Ozone Sparging	System of air sparging wells to inject air and ozone to oxidize contaminants.	Very strong oxidizer, able to degrade most organic contaminants to innocuous compounds. Contaminant degradation occurs at a very rapid rate. Chlorinated breakdown products are not formed through this oxidation reaction.	Gases are generated by a control unit; therefore, no liquids to mix or inject. Electrical power is required. Not usable near buildings except with SVE system. Ozone is highly corrosive to metals.	Accepted technology. Access agreements with property owners are required and may be difficult to establish, limiting implementability.	Costs of large-scale installation and widespread use can be high.	O&M requirements can be high.	Reject

Table 3-4. Remedial Technology and Process Option Screening for Groundwater
Twins Inn Site – Engineering Evaluation/Cost Analysis

Process Option	Technology Description	Effectiveness	Implementability		Cost		Retained or Rejected
			Technical	Administrative	Capital	O&M	
Electron Donor Biowall PRB	Indigenous anaerobic microbes are stimulated by adding a food grade carbon additive (electron donor) to wells installed in a linear pattern. The pattern creates a flow-through barrier where groundwater contaminants are degraded upon passing through the area of increased biological activity.	Enhances natural processes without adding strong or harmful chemicals. Anaerobic degradation is more effective than aerobic degradation for some VOCs such as PCE, TCE, and TCA. Anaerobic degradation is less effective than aerobic degradation for some VOCs such as DCE, DCA, and vinyl chloride. Complete dechlorination of contaminants may occur at a very slow rate, resulting in an excess of intermediate breakdown products. May require multiple applications. Material is not microorganism-specific and may result in the stimulation of unwanted bacterial communities such as methanogens. Containment technology does not address upgradient contamination.	Passive, *in situ* approach avoiding substantial design, capital, and O&M costs, unless long-term, multiple applications are required. Minimal site disturbance. Generally not added to existing monitoring wells due to residuals that are not easily removed.	Technology acceptance is unknown. Technology is innovative with applications at an unknown number of sites.	Costs of injection wells and treatment material only.	Requires some groundwater monitoring. Multiple applications are likely to be necessary.	Reject
Bark Mulch Biowall PRB	Anaerobic microbial degradation of contaminants through a combination of anaerobic processes in a trench filled with bark mulch.	Passive system requiring no groundwater extraction. Anaerobic degradation is more effective than aerobic degradation for some VOCs such as PCE, TCE, and TCA. Anaerobic degradation is less effective than aerobic degradation for some VOCs such as DCE, DCA, and vinyl chloride. May not be effective at treating a variety of chlorinated contaminants. Containment technology does not address upgradient contamination.	No chemicals or gases are required. May have a limited life span. Trenches limited to depths reached by excavating equipment; therefore, can be used only in shallow groundwater. Requires a large construction staging area and trench support. Construction intensive. Large volumes of IDW, both solid and liquid, to manage.	Innovative technology with limited field testing. May require solid and liquid storage permits for IDW, depending upon amount and concentrations of contaminants.	Installation costs are relatively high.	No O&M costs. Requires long-term groundwater monitoring.	Reject
Zero-Valent Iron PRB by Directional Injection	Chemical dechlorination by flow through injected iron panels installed through a system of borings.	Passive system requiring no groundwater extraction. Effective at treating various chlorinated contaminants. Longer period of time for treatment than active systems since technology relies on groundwater flow. Containment technology does not address upgradient contamination. Application in conjunction with a source control may be needed. High carbonate, nitrate, sulfate, dissolved organic carbon, or total dissolved solids in groundwater may shorten the life of the iron due to fouling, precipitation, or rapid corrosion, and potentially cause a loss in barrier permeability. Permeability loss could result in groundwater flowing around rather than through the barrier. The presence of iron and the substrates used for installation could support growth of anaerobic bacteria (iron and sulfate reducing and methanogenic) which may have effects of biostimulation (beneficial) or biofouling (deleterious).	Injected panels can be installed in areas with limited space such as locations of urban or industrial development.	Moderately accepted technology due to limited performance data. Sufficient time has not passed to confidently predict the lifespan of iron PRBs.	Proprietary technology with a licensing fee for the use of iron. The cost of the iron is relatively high. Installation costs for a shallow PRB are higher than for a trench-based system.	No O&M costs. Requires long-term groundwater monitoring.	Reject

Table 3-4. Remedial Technology and Process Option Screening for Groundwater
Twins Inn Site – Engineering Evaluation/Cost Analysis

Process Option	Technology Description	Effectiveness	Implementability		Cost		Retained or Rejected
			Technical	Administrative	Capital	O&M	
Zero-Valent Iron PRB by Trenching	Chemical dechlorination through trenches backfilled with iron filings.	Passive system requiring no groundwater extraction. Effective at treating various chlorinated contaminants. Longer period of time for treatment than active systems since technology relies on groundwater flow. Containment technology does not address upgradient contamination. Application in conjunction with a source control may be needed. High carbonate, nitrate, sulfate, dissolved organic carbon, or total dissolved solids in groundwater may shorten the life of the iron due to fouling, precipitation, or rapid corrosion, and potentially cause a loss in barrier permeability. Permeability loss could result in groundwater flowing around rather than through the barrier. The presence of iron and the substrates used for installation could support growth of anaerobic bacteria (iron and sulfate reducing and methanogenic), which may have effects of biostimulation (beneficial) or biofouling (deleterious).	Requires a large construction staging area and trench support. Construction intensive. Trench depth is limited to the depth reached by excavating equipment; therefore, can only be used for shallow groundwater treatment. Large volumes of IDW, both solid and liquid, to manage.	Accepted technology. Successful application has been completed at many sites and significant data on performance exist. May require solid and liquid storage permits for IDW, depending upon amount and concentrations of contaminants. Sufficient time has not passed to confidently predict the lifespan of iron PRBs.	Proprietary technology with a licensing fee for the use of iron. The cost of the iron is relatively high. Installation costs are relatively high.	No O&M costs. Requires long-term groundwater monitoring.	**RETAIN**
Electrical PRB (E-Barrier)	Physical dechlorination via flow through an electrically induced oxidation-reduction barrier.	Effective at treating various chlorinated contaminants Active system requiring no groundwater extraction. Containment technology does not address upgradient contamination.	No chemicals or gases required. Trench depth is limited to the depth reached by excavating equipment; therefore, can only be used for shallow groundwater treatment. Requires a large construction staging area and trench support. Construction intensive. Requires low-voltage electrical power.	Innovative technology with limited field testing and performance data. Currently, only one pilot-scale installation in place (Colorado State University and F.E. Warren Air Force Base joint research).	Proprietary technology with one vendor installation.	Low-voltage power requirement may be costly to install and operate at full scale. Requires long-term groundwater monitoring.	Reject
Air-sparging with SVE	*In situ* air sparging, then vapor extraction by vacuum applied to well casing.	Strips VOCs from groundwater without pumping. Can be limited due to high groundwater table.	Requires *ex situ* vapor treatment system. Requires protection from freezing. Has little impact on nearby wells or water rights.	Commonly used groundwater treatment technology for VOCs. Accepted technology. May require an emissions permit. Access agreements with property owners are required and may be difficult to establish, limiting implementability.	Requires waste stream treatment, system installation, and equipment costs.	Requires frequent O&M.	Reject
Groundwater Recirculation Wells with Vapor Extraction	*In situ* groundwater recirculation with *in situ* air stripping and vapor extraction by vacuum applied to upper well screen.	Strips VOCs from groundwater without pumping. Can effectively remove VOCs from shallow- and intermediate-depth groundwater. Not effective if fine-grained soils or lenses interfere with circulation cell.	Requires *ex situ* vapor treatment system. Requires protection from freezing. Has little impact on nearby wells or water rights.	May require an emissions permit. Nominally accepted technology. Access agreements with property owners are required and may be difficult to establish, limiting implementability.	Requires waste stream treatment, system installation, and equipment costs.	Requires frequent O&M.	Reject
Pumping	Groundwater extraction by conventional pumping wells.	May only be capable of removing contaminants to an asymptotic level, which could be greater than desired clean-up levels. May not be able to extract sorbed contaminants unless the system is run in cycles. Can be designed to provide hydraulic control of plume.	Extraction system components and experienced contractors readily available. May affect nearby wells or water rights if large volumes of water are to be removed. Requires protection from freezing. May require extraction of large volumes of water.	Presumptive remedy for chlorinated VOCs in groundwater. Accepted technology. Commonly used groundwater extraction technology. Access agreements with property owners are required and may be difficult to establish, limiting implementability.	Requires system installation and equipment costs.	Requires frequent O&M.	Reject

Table 3-4. Remedial Technology and Process Option Screening for Groundwater
Twins Inn Site – Engineering Evaluation/Cost Analysis

Process Option	Technology Description	Effectiveness	Implementability		Cost		Retained or Rejected
			Technical	Administrative	Capital	O&M	
Dual-Phase Extraction	Groundwater/soil vapor extraction by conventional pumping with vacuum applied to well casing to create greater hydraulic head.	Provides added vapor extraction to conventional pump-and-treat system. Can be designed to provide hydraulic control of plume.	Requires *ex situ* vapor and groundwater treatment. May affect nearby wells or water rights if large volumes of water are to be removed. Requires protection from freezing.	Accepted technology. May require permits for groundwater disposal and emissions. Access agreements with property owners are required and may be difficult to establish, limiting implementability.	Requires system installation and equipment costs.	Requires frequent O&M.	Reject
Two-Phase Extraction	Simultaneous groundwater and vapor extraction by vacuum applied to "straw" inside well casing.	Provides added vapor extraction to conventional pump-and-treat system. Can be designed to provide hydraulic control of plume. Able to significantly increase the pumping rate of low yield wells. Can remove vapors in addition to groundwater.	Requires *ex situ* vapor and groundwater treatment. May affect nearby wells or water rights if large volumes of water are to be removed. Requires protection from freezing.	Presumptive remedy for chlorinated VOCs in groundwater. Accepted technology. May require permits for groundwater disposal and emissions. Access agreements with property owners are required and may be difficult to establish, limiting implementability.	Requires system installation and equipment costs. Generally less costly than pumping or dual-phase extraction due to a single vacuum pumping system for groundwater and vapor.	Requires frequent O&M.	Reject
Groundwater Recirculation Wells with Biostimulation	*In situ* groundwater recirculation with electron donor amendments applied to reinjected groundwater to simulate anaerobic biodegradation.	Requires a continuous source of electron donors. Not effective if fine-grained soils or lenses interfere with circulation cell. Enhances natural processes without adding strong or harmful chemicals. Anaerobic degradation is more effective than aerobic degradation for some VOCs such as PCE, TCE, and TCA. Anaerobic degradation is less effective than aerobic degradation for some VOCs such as DCE, DCA, and vinyl chloride. Complete dechlorination of contaminants may occur at a very slow rate, resulting in an excess of intermediate breakdown products. Material is not microorganism-specific and may result in the stimulation of unwanted bacterial communities such as methanogens.	Requires pumping, groundwater extraction, and reinjection. Requires *ex situ* groundwater amendment with electron donors. Requires protection from freezing. Generally not added to existing monitoring wells due to residuals that are not easily removed.	Moderately accepted technology due to limited performance data. Access agreements with property owners are required and may be difficult to establish, limiting implementability.	Requires waste stream treatment, system installation, and equipment costs.	Requires frequent O&M.	Reject
Electrical Resistance Heating with SVE	Removal of VOCs from aquifers by heating the soil and groundwater to volatilize contaminants, followed by soil vapor extraction.	*In situ* process requiring no groundwater extraction. Able to remove sorbed-phase and liquid-phase VOCs. Functions best in fine-grained, low-permeability soils. Very rapid treatment relative to other technologies. Treatment applicable to saturated soil in addition to groundwater.	Vapor extraction and *ex situ* treatment system required. Limited application near buildings, utility lines, groundwater extraction systems, or infrastructure that could be impacted by heat or vapors.	Accepted technology. May require an emissions permit. Access agreements with property owners are required and may be difficult to establish, limiting implementability.	Requires system installation and equipment costs. Generally costly due to need for vapor extraction and *ex situ* treatment.	Power requirements are high and can be very costly for large treatment areas.	Reject
Steam Injection with SVE	Removal of VOCs from aquifers by injecting steam into soil and groundwater to heat and volatilize contaminants followed by soil vapor extraction.	*In situ* process requiring no groundwater extraction. Able to remove sorbed-phase and liquid-phase VOCs. Very rapid treatment relative to other technologies. Treatment applicable to saturated soil in addition to groundwater.	Steam generation area is required. Vapor extraction and *ex situ* treatment system required. Limited application near buildings, utility lines, groundwater extraction systems, or infrastructure that could be impacted by heat or vapors.	Accepted technology. May require an emissions permit. Access agreements with property owners are required and may be difficult to establish, limiting implementability.	Requires system installation and equipment costs. Generally costly due to need for vapor extraction and *ex situ* treatment.	Power requirements are high and can be very costly for large treatment areas.	Reject
Liquid/Vapor -Phase Bioreactor	Treatment of extracted groundwater or vapor by microbial processes.	Effective for biodegrading a variety of contaminants. May not be effective for high VOC concentrations.	Treatment system components are readily available. Generally used for liquid-phase treatment. To prevent fouling, pre-treatment may be required for groundwater containing high concentrations of minerals. Requires protection from freezing.	Moderately accepted technology. May require permits for groundwater disposal and emissions.	Limited number of equipment vendors available. Requires system installation and equipment costs.	Requires frequent O&M.	Reject

Table 3-4. Remedial Technology and Process Option Screening for Groundwater
Twins Inn Site – Engineering Evaluation/Cost Analysis

Process Option	Technology Description	Effectiveness	Implementability		Cost		Retained or Rejected
			Technical	Administrative	Capital	O&M	
Carbon Adsorption	Treatment of extracted groundwater or vapor through adsorption in carbon-filled canisters.	Effective for treating liquid- or vapor-phase VOCs. Limited capacity per pound of granular-activated carbon for removing VOCs.	Treatment system components are readily available. To prevent fouling, pre-treatment may be required for groundwater containing high concentrations of minerals. Requires protection from freezing.	Commonly used treatment technology. May require permits for groundwater disposal and emissions.	Requires system installation and equipment costs.	Requires frequent O&M. Recycling/recharge or carbon can be costly.	Reject
UV Oxidation	Treatment of extracted groundwater by oxidation from exposure to ultraviolet radiation.	Effective at treating high concentrations of VOCs in groundwater.	Treatment system components are readily available. Generally used for liquid-phase treatment. To prevent fouling, pre-treatment may be required for groundwater containing high concentrations of minerals. Requires protection from freezing.	Commonly used treatment technology.	Generally the most expensive treatment for VOCs. Requires system installation and equipment costs.	Requires frequent O&M.	Reject
Air Stripping	Treatment of extracted groundwater by high volume air circulation to induce volatilization.	Effective at treating high concentrations of VOCs in groundwater.	Treatment system components are readily available. To prevent fouling, pre-treatment may be required for groundwater containing high concentrations of minerals. Requires protection from freezing. Requires *ex situ* vapor treatment.	Commonly used treatment technology. May require an emissions permit.	Requires system installation and equipment costs.	Requires frequent O&M.	Reject
Discharge to POTW	Discharge of treated water to municipal treatment system.	Effective method of water discharge.	Requires nearby sewer system.	Commonly used wastewater discharge technique. Requires discharge permit.	Requires cost of waste stream transport system.	Requires frequent O&M.	Reject
Discharge to Surface Water	Discharge of treated water to nearby drainage.	Effective method of water discharge.	Gravity flow without pumps or pressurization is possible. Requires protection from freezing and control of vegetation at outfall.	Commonly used wastewater discharge technique. Requires NPDES Permit.	Requires cost of waste stream transport system.	Requires frequent O&M to maintain pipelines.	Reject
Discharge by Reinjection	Discharge of treated water to aquifer through injection wells or infiltration gallery.	Effective method of water discharge. Low-permeability soils reduce effectiveness of percolation/infiltration.	Requires protection from freezing.	Commonly used wastewater discharge technique. Requires injection permit.	Requires cost of injection wells and equipment.	Requires frequent O&M.	Reject
Alternate Water Supply and Institutional Controls	Provides a permanent alternate drinking water supply for properties where shallow wells are used for drinking water.	Effective by removing the point of exposure to groundwater.	Installation of service lines for commercial properties is implementable.	Implementable assuming property owners are amenable to having their properties annexed to the City of Arvada. Also, Thoro property owner has to agree to institutional controls.	Requires cost of property annexation, service line installation, well abandonment, and institutional controls.	Includes long-term monitoring.	**RETAIN**

Notes:

CO_2	=	Carbon Dioxide	O&M	=	Operation and Maintenance
DCA	=	Dichloroethane	ORC®	=	Oxygen Release Compound
DCE	=	Dichloroethene	PCE	=	Tetracholorethene
DNAPL	=	Dense Non-aqueous Phase Liquid	POTW	=	Publicly Owned Treatment Works
H_2O_2	=	Hydrogen Peroxide	PRB	=	Permeable Reactive Barrier
HRC®	=	Hydrogen Release Compound	SVE	=	Soil Vapor Extraction
IDW	=	Investigation-Derived Waste	TCA	=	Trichloroethane
iSOC/iMOX™	=	*In Situ* Submerged Oxygen Curtain/*In Situ* Cometabolic Oxidation	TCE	=	Trichloroethene
NOD	=	Natural oxidant demand	UV	=	Ultraviolet
NPDES	=	National Pollutant Discharge Elimination System	VOC	=	Volatile Organic Compound

Table 3-5. Assembled Remedial Alternatives
Twins Inn Site – Engineering Evaluation/Cost Analysis

Media	Alternative Number	Remedial Alternatives
Soil	SO1	No Action
	SO2	Institutional Controls
	SO3A	Excavation with Off-site Treatment and Disposal
	SO4A	Excavation with On-site Thermal Desorption
	SO5A	Soil Vapor Extraction
Groundwater	GW1	No Action
	GW2	Institutional Controls
	GW3	MNA and Institutional Controls
	GW4	Anaerobic Biorecirculation and MNA
	GW5	Zero-Valent Iron PRB by Trenching and MNA
	GW6A	Anaerobic Bioremediation (Biostiumulation and Bioaugmentation) and MNA
	GW7A	*In situ* Chemical Oxidation (using Fenton's Reagent and Sodium Persulfate) and MNA
	GW8	Alternate Water Supply and Institutional Controls

Notes:

SO = soil alternative
GW = groundwater alternative
A = indicates access to the Thoro property is required
MNA = monitored natural attenuation
PRB = permeable reactive barrier

Table 4-1. Waste Classification Analyses for Excavated Soil
Twins Inn Site – Engineering Evaluation/Cost Analysis

EPA Method	Analyses
SW846	Ignitability
SW846	Corrosivity
SW9045C	pH (soil)
SW9095A[a]	Paint Filter Liquid Test
SW846 and SW9010A/SW9014	Reactive Cyanide
SW846 and SW9030/SW9034	Reactivity-Total Sulfide
SW846 and SW1311	Toxicity Leaching procedure
SW8260	Volatile Organic Compounds

Notes:

[a] If the Paint Filter Liquid Test results in free liquid, then the free liquid must be separated from the solid waste and characterized for ignitability by Method SW1020A or SW1010 and corrosivity by Method SW1110.

EPA = U.S. Environmental Protection Agency
SW = EPA publication SW-846, entitled *Test Methods for Evaluation Solid Waste, Physical/Chemical Methods*

Table 5-1. Groundwater Alternative Monitoring Parameters
Twins Inn Site - Engineering Evaluation/Cost Analysis

Alternative Number	Groundwater Alternative	Parameters	Number of Wells	Frequency
GW3	MNA	VOCs	29	Quarterly for 5 years; annually for 10 years; once every 5 years for the remainder of the program
GW4	Anaerobic Biorecirculation	Field parameters[a] VOCs Sulfate and chloride Nitrate/nitrite Dissolved gases Electron donor	4	Baseline then quarterly for 5 years
GW5	ZVI PRB	Field parameters[a] VOCs Calcium Total iron Total manganese Alkalinity[b] Chloride	6	Baseline then quarterly for 2 years
GW6A	Anaerobic Bioremediation	Field parameters[a] VOCs Sulfate and chloride Nitrate/nitrite Dissolved gases Electron donor	7	Baseline then quarterly for 3 years
GW7A	*In situ* Chemical Oxidation	Field parameters[a] VOCs Sulfate and chloride Dissolved metals[c]	7	Baseline then quarterly for 1.5 years
GW8	Alternate Water Supply and Institutional Controls	VOCs	29	Annual monitoring for 5 years, then monitoring every 5 years dependent upon results.

Notes:
[a] Field parameters include pH, dissolved oxygen, oxidation-reduction potential, conductivity, and temperature.
[b] Alkalinity includes total bicarbonate and carbonate.
[c] Dissolved metals includes iron, manganese, chromium, arsenic, selenium, and lead.

GW = groundwater
MNA = monitored natural attenuation
PRB = permeable reactive barrier
VOCs = volatile organic compounds
ZVI = zero-valent iron

Table 6-1. Soil Alternative Screening
Twins Inn Site Engineering Evaluation/Cost Analysis

Alternative Number	Alternative	Effectiveness				Implementability		Alternative Cost (NPV)		Retain or Reject
		Protection of Human Health and Environment	Reduction of Toxicity, Mobility, or Volume	Short-term	Long-term	Technical	Administrative	Capital	O&M	
SO1	No Action	Low – No protection provided.	Low – Reduction based on natural processes and source is continuous.	Low – Not effective in achieving RAOs.	Low – Not effective in achieving RAOs.	High – Easily implemented.	Low – May not receive regulatory support.	$0M	$0M	**RETAIN**
SO2	Institutional Controls	Moderate – Provides near-term and long-term protection by preventing exposure. Soil does not leave the site but disturbance of subsurface soil would be prohibited.	Low – Reduction based on natural processes and source is continuous; however, soil contamination is not being moved and exposure to subsurface soil will not occur	Low – Similar to present exposure. As soon as the environmental covenants are finalized, alternative would be effective.	High – Manages the risk of subsurface soil contact.	Moderate – Owner of the Thoro property must agree to environmental covenants.	Moderate –Does not require physical access to the Thoro property, but does require cooperation from the property owner .	$0.1M	$0M	**RETAIN**
SO3A	Soil Excavation with Off-site Treatment and Disposal	High – Removes continuous source of contaminants to the downgradient groundwater plume, providing high level of protection.	High – Removes continuous source of contaminants to the downgradient groundwater plume, reducing toxicity, mobility, or volume.	High – Removes continuous source of contaminants to the downgradient groundwater plume and achieves RAOs. Some risk to workers during excavation activities.	High – Assuming soil contamination present under the building is removed, RAOs would be achieved.	Low – Access to the site for excavating equipment and waste hauling trucks is limited due to property size and locations of buildings.	Low – Access to the Thoro property is required.	$2.2M	$0M	**RETAIN**
SO4A	Soil Excavation with On-site Thermal Desorption	High – Removes continuous source of contaminants to the downgradient groundwater plume, providing high level of protection.	High – Removes continuous source of contaminants to the downgradient groundwater plume, reducing toxicity, mobility, or volume.	High – Removes continuous source of contaminants to the downgradient groundwater plume and achieves RAOs. Some risk to workers during excavation activities.	High – Assumes soil contamination present under the building is removed, therefore RAOs would be achieved.	Low – Access to the site for excavating equipment and high temperature treatment equipment is limited due to property size and location of buildings.	Low – Access to the Thoro property is required. Emission permit for high temperature gas treatment system may be required.	$2.9M	$0M	**RETAIN**
SO5A	Soil Vapor Extraction	Moderate – Clay and low permeability material in the vadose zone may limit or refuse vapor extraction, providing inadequate protection.	Low – Clay and low permeability material in the vadose zone may limit or refuse vapor extraction, providing inadequate reduction in toxicity, mobility, or volume.	Low – Clay and low permeability material in the vadose zone may limit or refuse vapor extraction and not achieve RAOs.	Low – Clay and low permeability material in the vadose zone may limit or refuse vapor extraction and not achieve RAOs.	Low – Clay and low permeability material in the vadose zone present difficulties for vapor extraction. Limited access to the site for system installation and vapor equipment. Depth to water in the South Pit area could require groundwater depression, which could affect nearby Ralston Creek.	Low – Access to the Thoro property is required. Emission permit for treatment system may be required.	$0.8M	$1.1M	Reject

Notes:
NPV = net present value
RAO = remedial action objective
SO = soil
A = requires access to Thoro property

Table 6-2a. Groundwater Alternative Screening
Without Soil Source Removal
Twins Inn Site Engineering Evaluation/Cost Analysis

Alternative Number	Alternative	Effectiveness				Implementability		Alternative Cost (NPV)		Retain or Reject
		Protection of Human Health and Environment	Reduction of Toxicity, Mobility, or Volume	Short-term	Long-term	Technical	Administrative	Capital	O&M/ Periodic	
GW1	No Action	Low – No protection provided.	Low – Assumes no reduction.	Low – Low risk of exposure, but not effective in achieving RAOs.	Low – Not effective in achieving RAOs.	High – Easily implemented.	Low – May not receive regulatory or public support.	$0M	$0M	**RETAIN**
GW2	Institutional Controls	Low – Multiple property owners in plume area can create difficulties in maintaining controls. Minimal protection provided.	Low – Some reduction may occur due to natural processes. However, because groundwater source continues, this alternative provides little reduction of toxicity, mobility, or volume.	Low – Low risk of exposure, but not effective in achieving RAOs.	Low – Not effective in achieving RAOs.	Moderate – Physical controls such as signs and fencing may be difficult to implement in the source area if access is not provided.	Low – May not receive regulatory or public support. Cooperation with the Thoro property owner may be required.	$0.1M	$0M	Reject
GW3	MNA	Low – Groundwater contamination may exist indefinitely because source is not addressed. Low protection provided.	Low – Some reduction may occur due to natural processes. However, because groundwater source continues, this alternative provides little reduction of toxicity, mobility, or volume.	Low – Low risk of exposure, but MNA is a long-term process that is unlikely to have substantial impacts in the short-term.	Low – Not effective in achieving RAOs due to continuous source.	High – Requires long-term groundwater sampling and reporting. Easily implemented.	Low – May not receive regulatory or public support since source remains.	$0.1M	$1.1M	Reject
GW4	Anaerobic Biorecirculation and MNA	High – Source containment and reduction provided.	High – Source containment and some reduction of toxicity, mobility, and volume in source area provided.	Moderate – Contaminated groundwater brought to surface requires engineering controls to limit exposure.	Low – Not effective in achieving RAOs due to continuous source. Need to operate system indefinitely.	Moderate – Continuously operating system requiring regular O&M.	Moderate – Access to the Thoro property is not required, but is preferable. May require resource removal and re-injection permit.	$0.6M	$1.9M	**RETAIN**
GW5	Zero-valent iron PRB by Trenching and MNA	Moderate – Source containment. Downgradient plume attenuation but source will remain. Protection is limited in the source area.	Moderate – Reduction of toxicity, mobility, and volume downgradient of POC. Limited to no effect in the source area upgradient of PRB.	Moderate – Contaminated soil brought to surface requires engineering controls to limit exposure.	Moderate – Achieves RAOs downgradient of PRB. Downgradient plume attenuation estimated to occur in 20 years. Lifespan of iron PRBs has not been confidently predicted.	Moderate – Construction intensive, but little O&M required.	Moderate – Access to Thoro property is **not** required, but access to other downgradient property is required. May not receive regulatory and public acceptance since source remains.	$0.6M	$1.2M	**RETAIN**
GW6A	Anaerobic Bioremediation and MNA	Moderate – Some source reduction, but not containment, provides some protection.	Moderate – Some reduction in toxicity, mobility, and volume in the source area, and the area immediately downgradient of the source area.	Moderate – *In situ* treatment greatly reduces exposure, but is a long-term process that may not have major impacts short-term.	Low – Not effective in achieving RAOs due to continuous source.	Moderate – Some drilling locations are limited due to buildings over the plume.	Low – Access to Thoro and Vintage Sales properties is required.	$0.7M	$0.5M	Reject
GW7A	*In Situ* Chemical Oxidation and MNA	Moderate – Some source removal in groundwater through chemical oxidation, but not containment, provides some protection.	Moderate – Some reduction in toxicity, mobility, and volume in the source area and the area immediately downgradient of the source area.	High – Works rapidly in the short-term. *In situ* treatment greatly reduces exposure, although there is some worker risk associated with field handling of chemical oxidants during injection	Low – Not effective in achieving RAOs due to continuous source.	Moderate– Some drilling locations are limited due to buildings over the plume.	Low – Access to Thoro and Vintage Sales properties is required.	$0.3M	$0.7M	Reject

Table 6-2a. Groundwater Alternative Screening
Without Soil Source Removal
Twins Inn Site Engineering Evaluation/Cost Analysis

Alternative Number	Alternative	Effectiveness				Implementability		Alternative Cost (NPV)		Retain or Reject
		Protection of Human Health and Environment	Reduction of Toxicity, Mobility, or Volume	Short-term	Long-term	Technical	Administrative	Capital	O&M/ Periodic	
GW8	Alternate Water Supply and Institutional Controls	High – Exposure to groundwater is prevented by providing an alternate water supply and institutional controls.	Moderate – Some reduction may occur due to natural processes. However, because groundwater source continues, this alternative provides little reduction of toxicity, mobility, or volume.	High – As soon as the commercial properties at the downgradient edge of the plume are connected to City of Arvada water, there would be no exposure to shallow groundwater.	High – No residences use groundwater as a drinking water source. Commercial facilities would be changed over to City of Arvada water which provides a permanent alternate water supply.	Moderate – Service pipe installation at the commercial businesses is implementable.	Moderate – Annexing of subject properties into the City of Arvada must be agreed to by the property owner. Owner of Thoro property must agree to institutional controls.	$0.3M	$0.3M	**RETAIN**

Notes:
GW = groundwater
O&M = Operation & Maintenance
NPV = net present value
RAO = remedial action objective
PRB = permeable reactive barrier
MNA = monitored natural attenuation
POC = Point of Compliance

Table 6-2b. Groundwater Alternative Screening
With Soil Source Removal
Twins Inn Site Engineering Evaluation/Cost Analysis

Alternative Number	Alternative	Effectiveness				Implementability		Alternative Cost (NPV)		Retain or Reject
		Protection of Human Health and Environment	Reduction of Toxicity, Mobility, or Volume	Short-term	Long-term	Technical	Administrative	Capital	O&M	
GW1	No Action	Low – No protection provided.	Low – Assumes no reduction.	Low – Low risk of exposure, but not effective in achieving RAOs.	Low – Not effective in achieving RAOs.	High – Easily implemented.	Low – May not receive regulatory or public support.	$0M	$0M	**RETAIN**
GW2	Institutional Controls	Low – Multiple property owners in plume area can create difficulties in maintaining controls. Minimal protection provided.	Moderate – Some reduction may occur due to natural processes.	Low – Low risk of exposure, but not effective in achieving RAOs.	Moderate – May not be effective in achieving RAOs.	Moderate – Physical controls such as signs and fencing may be difficult to implement in the source area if access is not provided.	Low – May not receive regulatory or public support. Cooperation with the Thoro property owner may be required, particularly for environmental covenants or deed restrictions.	$0.1M	$0M	Reject
GW3	MNA	Moderate – With source removed, concentrations in the plume will decrease over time.	Moderate – Reduction based on natural processes. Provides some reduction of toxicity, mobility, or volume.	Low – Low risk of exposure, but MNA is a long-term process that is unlikely to have substantial impacts in the short-term.	Moderate – May not be effective in achieving RAOs for all compounds.	High – Requires long-term groundwater sampling and reporting. Easily implemented.	Moderate – May not receive regulatory or public support.	$0.1M	$1.1M	**RETAIN**
GW4	Anaerobic Biorecirculation and MNA	High – Source containment and removal provided.	High – Source containment and removal provided.	Moderate – Contaminated groundwater brought to surface requires engineering controls to limit exposure.	High – Achieves RAOs. Downgradient and plume attenuation estimated to occur in 20 years.	Moderate – Continuously operating system requiring regular O&M.	Moderate – Access to the Thoro property is **not** required. May require resource removal and re-injection permit.	$0.6M	$1.2M	**RETAIN**
GW5	Zero-valent iron PRB by Trenching and MNA	Moderate – Source containment with downgradient plume attenuation.	Moderate – Reduction of toxicity, mobility, and volume downgradient of the POC.	Moderate – Contaminated soil brought to surface requires engineering controls to limit exposure.	Moderate – Downgradient plume attenuation estimated to occur in 22 years. Lifespan of iron PRBs has not been confidently predicted.	Moderate – Construction intensive, but little O&M required.	Moderate – Access to Thoro property is **not** required, but access to other property downgradient is required.	$0.6M	$1.2M	**RETAIN**
GW6A	Anaerobic Bioremediation and MNA	High – Source and the area immediately downgradient are treated.	High – Reduction in toxicity, mobility, and volume.	Moderate – *In situ* treatment greatly reduces exposure, but is a long-term process that may not have major impacts short-term.	High – Achieves RAOs. Source and downgradient plume attenuation estimated to occur in 26 years.	Moderate – Some drilling locations are limited due to buildings over the plume.	Low – Access to Thoro and Vintage Sales properties is required.	$0.7M	$0.5M	**RETAIN**
GW7A	*In Situ* Chemical Oxidation and MNA	High – Source and the area immediately downgradient are treated.	High – Reduction in toxicity, mobility, and volume.	High – Works rapidly in the short-term. *In situ* treatment greatly reduces exposure, although there is some worker risk associated with field handling of chemical oxidants during injection	High – Achieves RAOs. Source and downgradient plume attenuation estimated to occur in 22 years.	Moderate – Some drilling locations are limited due to buildings over the plume.	Low – Access to Thoro and Vintage Sales properties is required.	$0.4M	$0.7M	**RETAIN**

Notes:
GW = groundwater
MNA = monitored natural attenuation
NPV = net present value
RAO = remedial action objective
PRB = permeable reactive barrier
O&M = operation and maintenance

Table 6-3. Soil and Groundwater Estimated Cost Summary for Retained Alternatives
Twins Inn Site - Engineering Evaluation/Cost Analysis

Alternative Number	Alternative Description	Alternative Assumptions	Capital Cost (present value)	O&M Cost (present value)	Periodic Cost (present value)	Alternative Cost (present value)
Soil						
SO2	Institutional Controls	Requires cooperation from property owner.	$63,000	---	---	$63,000
SO3A	Soil Excavation with Off-site Treatment and Disposal (Main Thoro Building remains)	ASTs and concrete pads removed. Building left in place. North Tank area soil removed to 16 ft bgs in a 4800 square foot area. South Pit area soil removed to 10 ft bgs in 2000 square foot area. Soil transported off-site for disposal. Clean fill from off site used for backfill.	$2,189,657	---	---	$2,189,657
SO4A	Soil Excavation with On-site Thermal Desorption (Main Thoro Building removed)	ASTs and concrete pads removed. Building demolished and removed. North Tank area soil removed to 16 ft bgs in a 4800 square foot area. South Pit area soil removed to 10 ft bgs in 2000 square foot area. Soil treated on site. Clean fill from off site used for backfill.	$2,911,300	---	---	$2,911,300
Groundwater without Soil Source Removal						
GW4	Anaerobic Biorecirculation + MNA	Operation and monitoring for 20 years followed by an additional 30 years of groundwater monitoring.	$577,384	$1,850,008	$56,432	$2,483,824
GW5	ZVI PRB + MNA	1 iron replacement + 100 years of groundwater monitoring.	$632,365	$1,168,779	$51,436	$1,852,580
GW8	Alternate Water Supply and Institutional Controls	Annexation of subject properties to City of Arvada. Water service line installation to connect commercial properties to City of Arvada. Well abandonment of shallow wells. Annual monitoring for 5 years followed by monitoring every 5 years.	$303,000	$225,000	$58,000	$586,000

Table 6-3. Soil and Groundwater Estimated Cost Summary for Retained Alternatives
Twins Inn Site - Engineering Evaluation/Cost Analysis

Alternative Number	Alternative Description	Alternative Assumptions	Capital Cost (present value)	O&M Cost (present value)	Periodic Cost (present value)	Alternative Cost (present value)
Groundwater with Soil Source Removal						
GW3	MNA	20 years of MNA.	$116,745	$1,065,170	$59,393	$1,241,308
GW4	Anaerobic Biorecirculation + MNA	Operation and monitoring for 5 years followed by 15 years of MNA.	$577,384	$1,113,456	$58,507	$1,749,347
GW5	ZVI PRB + MNA	No iron replacement. Install PRB and perform 20 years of MNA.	$590,378	$1,138,369	$56,339	$1,785,086
GW6A	Anaerobic Bioremediation + MNA	Vertical direct push application of nutrients to a 0.5 acre area with treatment for 6 years followed by 14 additional years of MNA.	$732,966	$461,685	$64,332	$1,258,983
GW7A	Chemical Oxidation + MNA	Vertical direct push application of oxidant to a 0.5 acre area with treatment for 2 years followed by 18 additional years of MNA.	$361,222	$679,751	$64,332	$1,112,059

Notes:

Costs were estimated using RACER 2005. RACER 2010 used for SO2 and GW8.
O&M cost includes groundwater monitoring.
Periodic cost consists of costs that are not annual (e.g. 5-year reviews, site closeout)
Present value cost is calculated using a 7% discount factor.
Current dollar value is based on Environmental Cost Handling Options and Solutions (ECHOS 2003) cost databased available in RACER 2005. Prices are escalated to 01-Jan-05 in RACER to represent Current Dollar Value. The latest historical escalation rates used by RACER 2005 are provided by the Office of Mangement and Budget (OMB).

DPT = Direct push technology used in application
GW = Groundwater
MNA = Monitored natural attenuation
O&M = Operations and maintenance
PRB = Permeable reactive barrier
RACER = Remedial Action Cost Engineering and Requirements
SO = Soil
ZVI = Zero-valent iron

Table 10-1
Combined Alternatives with Comments
Twins Inn Site - Engineering Evaluation/Cost Analysis

ID	Soil Alternative	Groundwater Alternative	Combined Cost	Comments
Without Source Removal				
A	None	GW4 - Biorecirculation + MNA	$2.5 M	Source remains. Hydraulically contains source while system is operating. Depending on water table depth, plume may re-form after turning off system. Treats groundwater on Thoro and Vintage Sales property. Long-term cost may be higher than shown if system must be operated for more than 20 years.
B	None	GW5 - PRB + MNA	$1.9 M	Source remains. Contains the source upgradient of Lamar Street. Does not address groundwater on Thoro or Vintage Sales property. Long-term, low maintenance option. MNA is effective downgradient of PRB.
C	SO2 - Institutional Controls	GW8 - Alternate Water Supply and Institutional Controls	$0.6M	Source remains. Point of exposure to groundwater is removed by connecting properties to City of Arvada water. Shallow groundwater supply wells would be abandoned.
With Source Removal (SO3A)				
D	SO3A - Soil Excavation w/off-site Disposal	GW3 - MNA	$3.4 M	Main Thoro building remains on Thoro property. Short-term soil operations on Thoro property. MNA alone may be sufficient to address groundwater within 15 to 20 years after soil source is removed.
E	SO3A - Soil Excavation w/off-site Disposal	GW4 - Biorecirculation + MNA	$3.9 M	Main Thoro building remains on Thoro property. Short-term soil operations on Thoro property. Highly effective at reducing groundwater concentrations in the source area in 3 to 5 years. Addresses Vintage Sales groundwater. Requires access to properties adjacent to Thoro. O&M-intensive. MNA addresses downgradient groundwater in 15 to 20 years.
F	SO3A - Soil Excavation w/off-site Disposal	GW5 - PRB + MNA	$4.0 M	Main Thoro building remains on Thoro property. Short-term soil operations on Thoro property. Requires access along Lamar Street in front of gymnastics school. PRB is probably unnecessary if source soils are removed. Downgradient plume addressed within about 15 to 20 years.
G	SO3A - Soil Excavation w/off-site Disposal	GW6 - Bioremediation + MNA	$3.4 M	Main Thoro building remains on Thoro property. Short-term soil operations on Thoro property. Requires multiple Geoprobe drilling events on Thoro and Vintage Sales properties to inject nutrients. Reduces groundwater concentrations in source area in about 6 years, with downgradient plume addressed within about 15 to 20 years.
H	SO3A - Soil Excavation w/off-site Disposal	GW7A - In Situ Chemical Oxidation with MNA	$3.3M	Main Thoro building remains on Thoro property. Short-term soil operations on Thoro property. Requires multiple Geoprobe drilling events on Thoro and Vintage Sales properties to inject oxidant. Reduces groundwater concentrations in source area in about 2 years. Geochemical change may impact effectiveness of MNA in downgradient plume. Downgradient plume addressed within about 15 to 20 years.

Table 10-1
Combined Alternatives with Comments
Twins Inn Site - Engineering Evaluation/Cost Analysis

With Source Removal (SO4A)				
I	SO4A - Soil Excavation w/on-site Thermal Desorption	GW3 - MNA	$4.2 M	Main Thoro building demolished. Long-term soil operations on Thoro property with associated maintenance and safety issues. MNA alone may be sufficient to address groundwater within 15 to 20 years after soil source is removed.
J	SO4A - Soil Excavation w/on-site Thermal Desorption	GW4 - Biorecirculation + MNA	$4.7 M	Main Thoro building demolished. Long-term soil operations on Thoro property with associated maintenance and safety issues. Highly effective at reducing groundwater concentrations in the source area in 3 to 5 years. Addresses Vintage Sales groundwater. Requires access to properties adjacent to Thoro. O&M-intensive. MNA addresses downgradient groundwater in 15 to 20 years.
K	SO4A - Soil Excavation w/on-site Thermal Desorption	GW5 - PRB + MNA	$4.8 M	Main Thoro building demolished. Long-term soil operations on Thoro property with associated maintenance and safety issues. Requires access along Lamar Street in front of gymnastics school. PRB probably unnecessary if source soils are removed. Downgradient plume addressed within about 15 to 20 years.
L	SO4A - Soil Excavation w/on-site Thermal Desorption	GW6A - Bioremediation + MNA	4.2 M	Main Thoro building demolished. Long-term soil operations on Thoro property with associated maintenance and safety issues. Requires multiple Geoprobe drilling events on Thoro and Vintage Sales properties to inject nutrients. Reduces groundwater concentrations in source area in about 6 years, with downgradient plume addressed within about 15 to 20 years.
M	SO4A - Soil Excavation w/on-site Thermal Desorption	GW7A - In Situ Chemical Oxidation with MNA	$4.0 M	Main Thoro building demolished. Long-term soil operations on Thoro property with associated maintenance and safety issues. Requires multiple Geoprobe drilling events on Thoro and Vintage Sales properties to inject oxidant. Reduces groundwater concentrations in source area in about 2 years. Geochemical change may impact effectiveness of MNA in downgradient plume. Downgradient plume addressed in about 15 to 20 years.

Notes:

GW = groundwater
MNA = monitored natural attenuation
PRB = permeable reactive barrier
SO = soil