Armando Martinez
Operations Lead, Portfolio Operations Central

VIA ELECTRONIC MAIL

April 9, 2025
New Mexico Oil Conservation Division, District I
1625 N. French Drive
Hobbs, New Mexico 88240

Re: Donaldson Com A Well 1
Soil Remediation Work Plan/Variance Request
Case No. 2RP-4412, 2RP-4579, & 2RP-4605
Incident No. nAB1727056966, nAB1802537084, & nAB1803756772
Eddy County, New Mexico

To whom it concerns,

Please find enclosed for your files, copies of the following:

- Donaldson Com A Well 1 – 2025 Soil Remediation Work Plan/Variance Request

The 2025 Soil Remediation Work Plan/Variance Request was prepared by Arcadis U.S., Inc. (Arcadis) on behalf of Chevron Environmental Management Company (CEMC).

Please do not hesitate to call Sarah Johnson with Arcadis at 432.227.0266 or myself at 575.586.7639, should you have any questions.

Sincerely,

Armando Martinez

Encl. Donaldson Com A Well 1 – 2025 Soil Remediation Work Plan/Variance Request

cc. Amy Barnhill, Chevron/MCBU

Armando Martinez
Operations Lead Central
Portfolio Operations - Central
354 State Highway 38, Questa, NM 87556-0469
Tel 575 586 7639 Mobile 505 690 5408 Fax 575 586 0811
amarti@chevron.com

New Mexico Oil Conservation Division
District I
1625 N. French Drive
Hobbs, New Mexico 88240

Arcadis U.S., Inc.
1330 Post Oak Blvd.
Suite 2250
Houston, TX 77056
United States
Phone: 713 953 4800
www.arcadis.com

TX Engineering License # F-533
TX Geoscientist License # 50158

Date: April 9, 2025

Subject: Donaldson Com A Well 1
Soil Remediation Work Plan/Variance Request
Case No. 2RP-4412, 2RP-4579, & 2RP-4605
Incident Nos. NAB1727056966, NAB1802537084, & NAB1803756772
Eddy County, New Mexico

To whom it concerns,

Arcadis U.S., Inc. (Arcadis) has prepared this Work Plan/Variance Request for Chevron Environmental Management Company (CEMC) on behalf of Chevron U.S.A. Inc., through its division Chevron North America Exploration and Production Company to perform environmental remediation services for the Donaldson Com A Well 1 (Site), located in Bureau of Land Management (BLM) legal land description Unit F, Section 23, Township 23 South, Range 28 East, in Eddy County, New Mexico on privately owned land. Environmental remediation at the Site is required by the New Mexico Oil Conservation Division (NMOCD).

Project Summary

On October 17, 2024, CEMC and Arcadis met virtually with the NMOCD to discuss the previous site assessment activities and proposed alternative remediation plan at the Site. The presentation including a summary of previous site assessment activities and the proposed alternative remediation methods is included as **Attachment 1**.

Following the 2023 soil assessment activities, the landowner constructed a large barn within the eastern portion of the release area. CEMC will coordinate with the landowner to remove the barn prior to remediation activities.

Variance Request

Analytical data collected during assessment activities confirm that soil within the release area has been horizontally defined for chloride, benzene, toluene, ethylbenzene, and total xylenes (BTEX), and total petroleum hydrocarbons (TPH) in the first four feet to the New Mexico Administrative Code (NMAC) closure screening levels for the specific analytical constituents specified in Table 1 – Closure Criteria for Soils Impacted by a Release within revised Rule 19.15.29 for sites with groundwater less than 50 feet below ground surface (bgs). Chloride impact has been confirmed in soil at depths exceeding 4 feet bgs above the applicable screening level of 600 mg/kg, but no BTEX or TPH constituents were detected in soil at these depths. A cumulative summary of the soil analytical results is included as Table 1. A cumulative summary of the groundwater analytical results is included

NMOCD
April 9, 2025

as Table 2. Evaluation of groundwater conditions at the site confirm chloride and total dissolved solids (TDS) concentrations mirror the surrounding area and indicate that site groundwater has not been impacted by the releases from vertical downward migration.

Impacted soil will be excavated to the maximum extent practicable accompanied with confirmation soil sample analysis. The excavation will be stepped into three different zones: Zone 1 (two feet bgs), Zone 2 (six feet bgs), and Zone 3 (10 feet bgs) with the installation of an engineered clay or geosynthetic liner within this zone.

Excavation within Zone 1 to approximately 2 feet bgs will remove all soil with chloride concentrations above 600 mg/kg. Excavation within Zone 2 to approximately 6 feet bgs will remove all soil with chloride concentrations about 600 mg/kg. Excavation to the maximum extent practicable (estimated at approximately 10 feet bgs) will remove the majority of soil with chloride concentrations above 600 mg/kg and the installation of a clay or geosynthetic liner with the addition of soil amendments (gypsum) will eliminate any future potential vertical migration of chloride remaining in-situ that would pose a risk to groundwater, human health, or the environment.

The potential for future residual chloride loading to groundwater with no engineering controls was evaluated by Arcadis utilizing Graphical Solutions provided in America Petroleum Institute's (API) Publication 4758 (Additional Data and Remedial Alternatives Evaluation – see Attachment 2). The potential for residual chloride loading to groundwater with no additional engineering controls (i.e., clay or geosynthetic liner within Zone 3) was calculated to be 85 milligrams per liter (mg/L), and not a significant risk to the quality of site groundwater confirmed to naturally contain chloride ranging from 1,790 – 2,130 mg/L which is within the documented range of multiple background regional groundwater sample analytical results for chloride.

Field screening of soils for chloride and petroleum hydrocarbons will be performed to guide excavation activities and obtain confirmation samples. Arcadis field geologists will collect confirmation soil samples from the sidewalls and bases of the excavation area. Subsequently, the excavation will be backfilled with clean fill material similar to the surrounding area. The proposed excavation boundary and zones is presented in Figure 1.

As such, Arcadis is requesting approval of the following Variance for soil remediation activities:

- Prior to mobilizing equipment to the Site, a New Mexico 811 utility notification will be made at least 48-hours prior to mobilization.
- Arcadis will contract GPRS to locate subsurface utilities prior to starting any digging.
- Arcadis is requesting a variance to limit excavation activities to include only removing impacted soil affected above the NMOCD Reclamation Standards present within the Zone 3 release area to the extent practicable.
- Soils will be field screened for chloride during excavation activities utilizing Hach chloride test strips and for volatile organic compounds (VOCs) utilizing a photo-ionization detector (PID).
- Excavated soils will be stored on bermed plastic sheeting during excavation activities.
- Five-point composite confirmation soil samples will be collected from the excavation floor and sidewalls at 400 square foot intervals for laboratory analysis.
- The confirmation samples will be collected in clean, laboratory-supplied sample containers, labeled, placed on ice, cooled to approximately 4 degrees Celsius and delivered to Eurofins Xenco Laboratory in Midland, Texas under chain-of-custody protocol. Soil samples will be analyzed for the following analyses:
    - o BTEX by USEPA Method 8021B;
    - o TPH-GRO by USEPA Method 8015;

  - o TPH-DRO by USEPA Method 8015;
  - o TPH-ORO by USEPA by Method 8015; and
  - o Chloride by USEPA Method 300.
- It is anticipated that approximately 6,065 cubic yards (cy) of soil will be excavated.
- Arcadis requests approval to install an engineered clay or geosynthetic liner atop the impacted area exhibiting chloride concentrations above the NMOCD Closure Criteria remaining in-situ (Zone 3 only). This engineering control is designed to inhibit the vertical migration of chloride in soil to groundwater along with the upward migration of chloride to further support revegetation of the remediated area.
- Following excavation of impacted soil and installation of the liner, a layer of gypsum and/or a desalination product will be installed on the floor of the excavated area atop of the proposed liner. This control is designed to inhibit the upward migration of chloride remaining in-situ, protect the sodium absorption ratio (SAR) of the overlying soil and promote successful revegetation.
- Excavated soils will be transported to a state approved facility for disposal.
- The excavation will then be backfilled with similar material to the surrounding native area.

Groundwater Closure Request

During the meeting conducted on October 17, 2024, the NMOCD verbally agreed that given the regional irrigation practices, natural salinity content of the Pecos River, and soil analytical results collected during assessment activities, groundwater at the Site has not been impacted by the releases from the Donaldson Com A Well 1. Therefore, CEMC requests No Further Action regarding groundwater at the Site.

Reporting

A report summarizing the soil remediation activities completed at the Site will be submitted to the NMOCD. The report will summarize the results of the remediation activities and will include a sample location map, tabulation of the soil analytical results, excavation boundaries map, and photographic documentation.

Work Plan/Variance Approval Request

Arcadis is prepared to initiate the scope of work within 90 days of receiving written approval from the NMOCD. If you have any questions or comments with regards to this work plan, please do not hesitate to contact Sarah Johnson at (931) 436-0316 or sarah.johnson@arcadis.com or Armando Martinez with CEMC at (505) 690-5408 or amarti@chevron.com. Your timely response to this correspondence is appreciated.

Sincerely,
Arcadis U.S., Inc.

NMOCD
April 9, 2025

Sarah Johnson
Certified Project Manager

Email: sarah.johnson@arcadis.com
Direct Line: (931) 436-0316

CC. Armando Martinez

Enclosures:

Table 1.	Summary of Cumulative Soil Analytical Data
Table 2.	Summary of Cumulative Groundwater Analytical Data
Figure 1.	Proposed Excavation Area Map
Attachment 1.	Soil Remediation Discussion Presentation
Attachment 2.	API Strategies for Addressing Salt Impacts of Produced Water Releases to Plants, Soil, and Groundwater

Table 1
Summary of Cumulative Soil Analytical Data
Chevron Environmental Management Company
Donaldson Com A Well 1
Eddy County, New Mexico

ARCADIS

Sample I.D. No.	Sample Depth (feet bgs)	Date	Total BTEX (mg/kg)	Total TPH (mg/kg)	Chloride (mg/kg)
NMAC Standards			50	100	600
SS-1	0 - 6"	03/30/20	<0.00133	***338***	***7,310***
	2'	04/09/20	0.01095 J	***291***	***8730 F1***
SS-2	0 - 6"	03/30/20	<0.00142	***120***	***10,200***
	2'	04/09/20	<0.00131	60	***4,880***
	3'	04/09/20	<0.00148	58	***6,840***
SS-3	0 - 6"	03/30/20	<0.00135	67	***2,390***
	1'	03/30/20	<0.00143	37	***9,070***
	2'	04/09/20	0.00346 J	65	***5,650***
	4'	04/09/20	0.00391 J	49	***4,200***
SS-4	0 - 6"	03/30/20	<0.00139	***371***	57
	1'	03/30/20	<0.00145	***225***	93
	2'	04/09/20	0.00628 J	61	118
	4'	04/09/20	<0.00120	50	586
	6'	04/09/20	<0.00142	***169***	***860***
SS-5	0 - 6"	03/30/20	<0.00139	***943***	***1,620***
	2'	04/09/20	<0.00569	54	***1,690***
	4'	04/09/20	0.00924 J	41	***2,270***
SS-6	0 - 6"	03/30/20	<0.00136	***112***	***6,600***
	2'	04/09/20	<0.00138	46	***4,630***
	4'	04/09/20	<0.00142	51	***3,760***
SS-7	0 - 6"	03/30/20	<0.00137	***341***	***1,250***
	2'	04/09/20	0.00721 J	46	***2,070***
	4'	04/09/20	<0.00138	<7.286	***1,520***
	6'	04/09/20	<0.00143	<7.242	***1,280***
SS-8	0 - 6"	03/30/20	<0.00132	***1,939***	***6720 H F1***
	1'	03/30/20	<0.00135	***2,227***	***10,600***
SS-9	0 - 6"	03/30/20	<0.00129	***110***	20
SS-10	2'	04/09/20	0.00173 J	37	***3,890***
	3'6"	04/09/20	0.00553 J	80	***3,500***
SS-11	2'	04/09/20	0.00489 J	38	***7,920***
	4'	04/09/20	0.00173 J	37	***4,300***
SS-12	2'	04/09/20	0.00786 J	37	***674***
	4'	04/09/20	0.00554 J	47	***3,980***
SS-13	2'	04/09/20	0.00140 J	7	***658***
	4'	04/09/20	0.00166 J	31	***1,190***
SS-14	2'	04/09/20	0.00999 J	34	255
SB-1	0 - 1'	11/30/21	0.005385 J	14.5947	***2020.00***
	3-4'	11/30/21	0.004722 J	9.03	589.00
	9-10'	11/30/21	0.005151	1.55 J	107.00
SB-2	0-1'	11/30/21	0.002382 J	18.36	135
	3-4'	11/30/21	0.005918	2.81 J	269
	9-10'	11/30/21	0.008533	59	173
	14-15'	11/30/21	0.006411	1.39 J	220
	19-20'	11/30/21	0.006208	0.64 J	285
SB-3	0-1'	11/30/21	0.001963 J	35	***1140***
	3-4'	11/30/21	0.003011 J	1.78 J	146
	9-10'	11/30/21	0.002766 J	0.961 J	55.2
	14-15'	11/30/21	0.007138	0.0550 J	128
	19-20'	11/30/21	0.006972	1.60 J	98.5
SB-4	0-1'	12/01/21	0.003031 J	5.24 J	***782***
	3-4'	12/01/21	0.002572 J	12	494
	9-10'	12/01/21	0.005799	0.67 J	263
	11-12'	12/01/21	0.007636	1.20 J	196

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Chevron Environmental Management Company
Donaldson Com A Well 1
Eddy County, New Mexico

ARCADIS

Sample I.D. No.	Sample Depth (feet bgs)	Date	Total BTEX (mg/kg)	Total TPH (mg/kg)	Chloride (mg/kg)
NMAC Standards			50	100	600
SB-5	0-1'	12/01/21	0.003662 J	5.18 J	***7470***
	3-4'	12/01/21	0.002864 J	7.12 J	***5850***
	9-10'	12/01/21	0.015400	1.19 J	409
	14-15'	12/01/21	0.008140	0.0719 J	***1480***
	19-20'	12/01/21	0.006080	0.99 J	***1230***
SB-6	0-1'	12/01/21	0.002934 J	1.00 J	***2530***
	3-4'	12/01/21	0.004051 J	1.29 J	***2280***
	9-10'	12/01/21	0.003107 J	<1.71	***704***
	14-15'	12/01/21	0.000902 J	1.01 J	571
	19-20'	12/01/21	0.008266	1.42 J	190
SB-7	0-1'	12/01/21	0.000629 J	6.67	***2470***
	3-4'	12/01/21	0.001051	<1.70	***782***
	9-10'	12/01/21	0.005997	0.0436 J	129
	14-15'	12/01/21	0.007951	0.34	33.5
	19-20	12/01/21	0.008613	0.35	77.2
SB-8	0-1'	12/01/21	0.002062 J	<2.97	***1150***
	3-4'	12/01/21	0.001225 J	<1.72	***1380***
	9-10'	12/01/21	0.005790	0.0359 J	157
	14-15'	12/01/21	0.004948	0.0334 J	301
	19-20'	12/01/21	0.009410	0.0753 J	216
SB-9	0-1'	12/01/21	0.000732 J	3.51 J	461
	3-4'	12/01/21	<0.000495	<1.73	207
	9-10'	12/01/21	0.010778	0.6145 J	17.2
	11-12'	12/01/21	0.007424	0.0422 J	57.7
SB-10	0-1'	12/01/21	0.015886	***412***	***2410***
	3-4'	12/01/21	0.003342	13	***1180***
	9-10'	12/01/21	0.003659	2.11 J	***1580***
	14-15'	12/01/21	0.004807	6.08 J	***1930***
	19-20'	12/01/21	0.006877	6.6	***1150***
SB-11	0-1'	12/01/21	0.002414 J	13.02	***5650***
	3-4'	12/01/21	0.0021 J	48.3	409
	9-10'	12/01/21	0.002723 J	2.32 J	***2310***
	14-15'	12/01/21	0.006869	1.63	***2080***
	19-20'	12/01/21	0.008481	1.12 J	***1800***
SB-12	0-1'	12/01/21	0.001925 J	1.10 J	***822***
	3-4'	12/01/21	0.002719 J	2.98 J	***2400***
	9-10'	12/01/21	0.000834	0.748 J	***2570***
	14-15'	12/01/21	0.004872 J	0.41 J	188
	19-20'	12/01/21	0.007137	0.70 J	235
SB-13	0-1'	12/01/21	<0.000537	1.32 J	***961***
	3-4'	12/01/21	0.003086 J	5.40 J	***901***
	9-10'	12/01/21	0.000925	0.584 J	***750***
	14-15'	12/01/21	0.002394 J	<1.78 J	213
	19-20'	12/01/21	0.002731 J	<1.79	434
SB-14	0-1'	12/01/21	0.003398 J	2.23 J	462
	3-4'	12/01/21	<0.000522	0.901 J	131
	9-10'	12/01/21	0.003562 J	<1.76	107
	14-15'	12/01/21	0.00511 J	0.0361 J	127
	19-20'	12/01/21	0.007669	0.0525 J	174

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Chevron Environmental Management Company
Donaldson Com A Well 1
Eddy County, New Mexico

ARCADIS

Sample I.D. No.	Sample Depth (feet bgs)	Date	Total BTEX	Total TPH	Chloride
			(mg/kg)	(mg/kg)	(mg/kg)
NMAC Standards			50	100	600
SB-15	0-1'	12/01/21	0.004102 J	0.0294 J	***752***
	3-4'	12/01/21	0.009254	19.9	116
	9-10'	12/01/21	0.007349	12	93.6
	14-15'	12/01/21	0.008573	4.76 J	266
	19-20'	12/01/21	0.008488	3.50 J	212
TMW-1	0-1'	11/30/21	0.005941	39	***2480***
	3-4'	11/30/21	0.007237	5.60 J	***732***
	9-10'	11/30/21	0.006224	0.94 J	599
	19-20'	11/30/21	0.006962	2.07 J	134
	29-30'	11/30/21	0.008442	1.10 J	299
	39-40'	11/30/21	0.007574	3.40 J	***1220***
	49-50'	11/30/21	0.006479	0.52 J	57.2
	59-60'	11/30/21	0.004895 J	0.4	299
SB-16	4'	8/21/2023	--	--	347
	10'	8/21/2023	--	--	352
	15'	8/21/2023	--	--	***880***
	20'	8/21/2023	--	--	294
	20' [DUP]	8/21/2023	--	--	***1610***
SB-17	4'	8/21/2023	--	--	29.7
	10'	8/21/2023	--	--	48.7
	15'	8/21/2023	--	--	115
	20'	8/21/2023	--	--	85.8
SB-18	4'	8/21/2023	--	--	336 J6
	10'	8/21/2023	--	--	310
	15'	8/21/2023	--	--	264
	20'	8/21/2023	--	--	218
SB-19	4'	8/21/2023	--	--	355
	10'	8/21/2023	--	--	306
	15'	8/21/2023	--	--	***779***
	20'	8/21/2023	--	--	***829***
SB-20	4'	8/21/2023	--	--	***908***
	10'	8/21/2023	--	--	543
	15'	8/21/2023	--	--	***665***
	20'	8/21/2023	--	--	561
SB-21	4'	8/21/2023	--	--	306
	10'	8/21/2023	--	--	307
	15'	8/21/2023	--	--	88.4
	20'	8/21/2023	--	--	27.9

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Chevron Environmental Management Company
Donaldson Com A Well 1
Eddy County, New Mexico

ARCADIS

Sample I.D. No.	Sample Depth (feet bgs)	Date	Total BTEX (mg/kg)	Total TPH (mg/kg)	Chloride (mg/kg)
NMAC Standards			**50**	**100**	**600**
TW-2	**4'**	8/21/2023	--	--	11.4 J
	10'	8/21/2023	--	--	14.4 J
	15'	8/21/2023	--	--	14.5 J
	20'	8/21/2023	--	--	12.3 J
	25'	8/21/2023	--	--	<21.6
	30'	8/21/2023	--	--	35.3
	35'	8/21/2023	--	--	18.7 J
	40'	8/21/2023	--	--	20.6 J
	45'	8/21/2023	--	--	35.5
	50'	8/21/2023	--	--	22
	55'	8/21/2023	--	--	24.3

Legend:
BOLD and *italicized* = Analyte Results exceeds NMAC Standards
mg/kg: Milligram per Kilogram
NMAC : New Mexico Administration Code
J: Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value
F1: MS and/or MSD recovery exceeds control limits
H: Sample was prepared or analyzed beyond the specified holding time
J6: The sample matrix interfered with the ability to make any accurate determination; spike value is low.
BTEX : Benzene, Toluene, Ethylbenzene, and Total Xylenes
TPH GRO: Total Petroleum Hydrocarbons Gasoline Range Organics
TPH MRO: Total Petroluem Hydrocarbons Motor Oil Range Organics
TPH DRO: Total Petroleum Hydrocarbon Diesel Range Organics
Analytes exceeding NMAC Standards are indicated in yellow
bgs: below ground surface
SS : Soil sample
SB: Soil Boring Sample Point Location
BG : background sample
DUP: Duplicate Sample
'<' Indicates the analyte was not detected at or above the Method Detection Limit (MDL)
" ' " : Indicates one foot
" " ": Indicated inches
" -- " Indicates Not Analyzed or Not Applicable

Notes:
1. Chloride analyzed by EPA Method 300
2. TPH analyzed by EPA Method 8015 M
3. BTEX analyzed by EPA Method 8260B
4. Closure Criteria New Mexico Administrative Code 19.15.29.12.E(2)

Table 2
Summary of Cumulative Groundwater Analytical Data
Chevron Environmental Management Company
Donaldson Com A Well 1
Eddy County, New Mexico

Sample I.D. No.	Date	Groundwater Quality													
		Chloride	Total Dissolved Solids	Sulfate	Calcium	Magnesium	Potassium	Sodium	Benzene	Toluene	Ethylbenzene	Total Xylenes	TPH GRO	TPH DRO	Total TPH
NMWQCC Human Health Standards for Groundwater[1]															
		250	**1,000**	**--**	**--**	**--**	**--**	**--**	**0.005**	**1**	**0.7**	**0.62**	**--**	**--**	**--**
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
TMW-1	12/22/2021	***2,130***	***5,030***	--	--	--	--	--	0.000470 J	<0.000412	<0.000160	<0.000510	<0.0314	0.0697 J	0.153
TW-2	8/24/2023	***1,700***	***5,270***	1,800	712	213	5.96	765	--	--	--	--	--	--	--

Notes:

Bold and Italicise cells indicate that concentration exceeds NMWQCC standard.

NMWQCC Human Health Standards Per NMAC 20.6.2.3103A.

mg/L: Milligram per Litre

NMAC: New Mexico Administration Code

USEPA: United States Environmental Protection Agency

NMWQCC: New Mexico Water Qaulity Control Commision

J: Indicates an estimated concentration detected below the quantitation limit.

" -- " Indicates Not Analyzed or Not Applicable

'<' Indicates the analyte was not detected at or above the Method Detection Limit (MDL)

TPH GRO indicates Total Petroleum Hydrocarbons Gasoline Range Organics

TPH DRO indicates Total Petroleum Hydrocarbons Diesel Range Organics

Methods used:

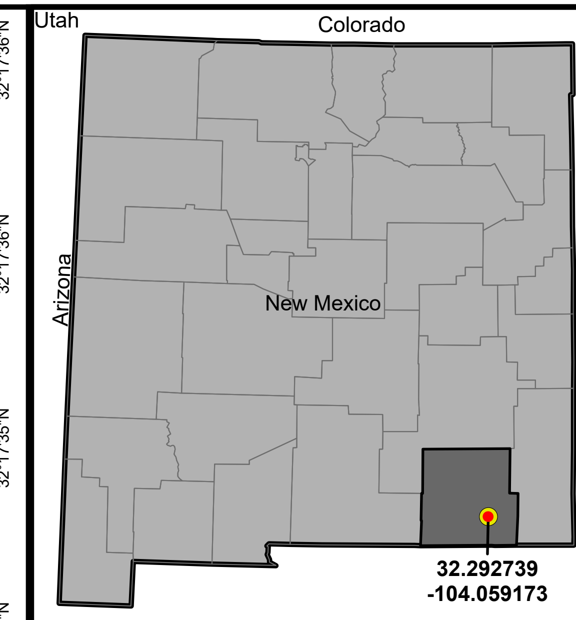
1. Chloride and Sulfate analyzed by USEPA Method 300.0
2. Closure Criteria New Mexico Administrative Code 19.15.29.12.E(2)
3. Total Dissolved Solids (TDS) analyzed by SM2540C
4. Calcium, Magnesium, Potassium, Sodium analyzed by USEPA Method 6020

TPH-GRO analyzed by USEPA Method 8015M

TPH-DRO analyzed by USEPA Method 8015M

Total petroleum hydrocarbons [sum of gasoline range organics (C6-C10), diesel range organics (C10-C28), and C28-C36].

BTEX analyzed by USEPA Method 8260B



Legend

- 2021Temporary Monitoring Well Location
- 2020 Soil Sample Locations
- 2021 Soil Sample Locations
- 2023 Soil Sample Locations
- 2023 Temporary Monitoring Well Location
- Release Area

NOTES:
1. SB : Soil boring.
2. TMW : Temporary Monitoring Well
3. Closure Criteria New Mexico Administrative Code 19.15.29.12.E(2).

0 50 100
SCALE IN FEET

CHEVRON ENVIRONMENTAL MANAGEMENT COMPANY
DONALDSON COM A
EDDY COUNTY, NEW MEXICO

CUMULATIVE SOIL SAMPLE AND MONITORING WELL LOCATION MAP

ARCADIS

FIGURE
1

Path: T:_ENV\Chevron_Donaldson COM A\MXD\2023\SET2\Chevron_Donaldson COM A_SET2.aprx User : wberry Date: 8/5/2024

ARCADIS

Donaldson Com A Well 1

Soil Remediation Discussion

Incident IDs: nAB1727056966, nAB1802537084, & nAB1803756772

Remediation Permit Nos: 2RP-4412, 2RP-4579, & 2RP-4605

18 October 2024

Incident Summary

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nAB1727056966

On September 8, 2017, a 2-inch diameter baylon ball valve on the discharge side of a triplex pump washed out, releasing 8 barrels (bbls) of produced water. Upon discovery, the ball valve was replaced and approximately 8 bbls of standing fluid were recovered. The Initial C-141 Form was submitted to the New Mexico Oil Conservation Division (NMOCD) on September 19, 2017, and assigned remediation permit number 2RP-4412.

nAB1802537084

On January 15, 2018, a packing seal failure on the triplex pump plunger released 80 bbls of produced water inside the earthen berm surrounding the triplex pump. Upon discovery, a vacuum truck recovered approximately 79 bbls of standing fluid. The Initial C-141 Form was submitted to the NMOCD on January 22, 2018, and assigned remediation permit number 2RP-4579.

nAB1803756772

On January 22, 2018, an electrical shortage on the saltwater pump control box caused the produced water storage tank to overflow and release approximately 110 bbls of produced water into the lined secondary containment. Upon discovery, the electrical boxes were repaired, and a vacuum truck recovered approximately 109 bbls of standing fluid. The Initial C-141 Form was submitted to the NMOCD on February 5, 2018, and assigned remediation permit number 2RP-4605.

2020 Initial Shallow Soil Assessment

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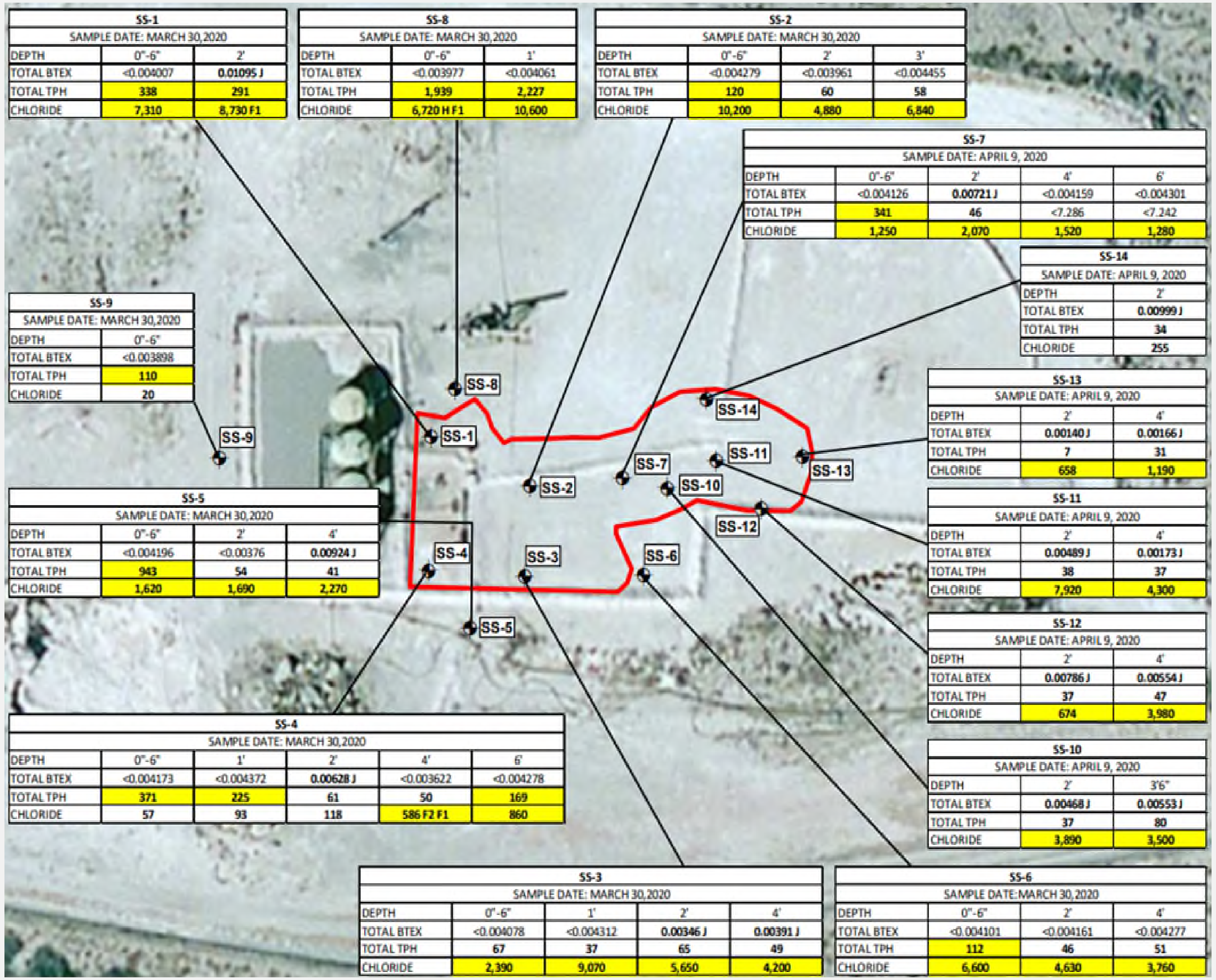
- Between March 30 and April 9, 2020, Arcadis personnel collected soil samples from fourteen locations (SS-1 through SS-14) within the release areas.
- Soil samples were collected at depths ranging from the surface to 6 feet bgs.
- Soil samples were analyzed for chloride, TPH, and BTEX.
- Chloride exceedances ranged from 658 mg/kg at SS-13 (2-feet bgs) to 10,600 mg/kg at SS-8 (1-foot bgs).
- Total TPH exceedances ranged from 110 mg/kg at SS-9 (0 – 6 inches bgs) to 2,227 mg/kg at SS-8 (1-foot bgs).
- BTEX concentrations were reported below the NMAC standard of 50 mg/kg at all sample locations.



SS-1		
SAMPLE DATE: MARCH 30,2020		
DEPTH	0"-6"	2'
TOTAL BTEX	<0.004007	0.01095 J
TOTAL TPH	338	291
CHLORIDE	7,310	8,730 F1

SS-8		
SAMPLE DATE: MARCH 30,2020		
DEPTH	0"-6"	1'
TOTAL BTEX	<0.003977	<0.004061
TOTAL TPH	1,939	2,227
CHLORIDE	6,720 H F1	10,600

SS-2			
SAMPLE DATE: MARCH 30,2020			
DEPTH	0"-6"	2'	3'
TOTAL BTEX	<0.004279	<0.003961	<0.004455
TOTAL TPH	120	60	58
CHLORIDE	10,200	4,880	6,840

SS-7				
SAMPLE DATE: APRIL 9, 2020				
DEPTH	0"-6"	2'	4'	6'
TOTAL BTEX	<0.004126	0.00721 J	<0.004159	<0.004301
TOTAL TPH	341	46	<7.286	<7.242
CHLORIDE	1,250	2,070	1,520	1,280

SS-14	
SAMPLE DATE: APRIL 9, 2020	
DEPTH	2'
TOTAL BTEX	0.00999 J
TOTAL TPH	34
CHLORIDE	255

SS-9	
SAMPLE DATE: MARCH 30,2020	
DEPTH	0"-6"
TOTAL BTEX	<0.003898
TOTAL TPH	110
CHLORIDE	20

SS-13		
SAMPLE DATE: APRIL 9, 2020		
DEPTH	2'	4'
TOTAL BTEX	0.00140 J	0.00166 J
TOTAL TPH	7	31
CHLORIDE	658	1,190

SS-5			
SAMPLE DATE: MARCH 30,2020			
DEPTH	0"-6"	2'	4'
TOTAL BTEX	<0.004196	<0.00376	0.00924 J
TOTAL TPH	943	54	41
CHLORIDE	1,620	1,690	2,270

SS-11		
SAMPLE DATE: APRIL 9, 2020		
DEPTH	2'	4'
TOTAL BTEX	0.00489 J	0.00173 J
TOTAL TPH	38	37
CHLORIDE	7,920	4,300

SS-12		
SAMPLE DATE: APRIL 9, 2020		
DEPTH	2'	4'
TOTAL BTEX	0.00786 J	0.00554 J
TOTAL TPH	37	47
CHLORIDE	674	3,980

SS-4					
SAMPLE DATE: MARCH 30,2020					
DEPTH	0"-6"	1'	2'	4'	6'
TOTAL BTEX	<0.004173	<0.004372	0.00628 J	<0.003622	<0.004278
TOTAL TPH	371	225	61	50	169
CHLORIDE	57	93	118	586 F2 F1	860

SS-10		
SAMPLE DATE: APRIL 9, 2020		
DEPTH	2'	3'6"
TOTAL BTEX	0.00468 J	0.00553 J
TOTAL TPH	37	80
CHLORIDE	3,890	3,500

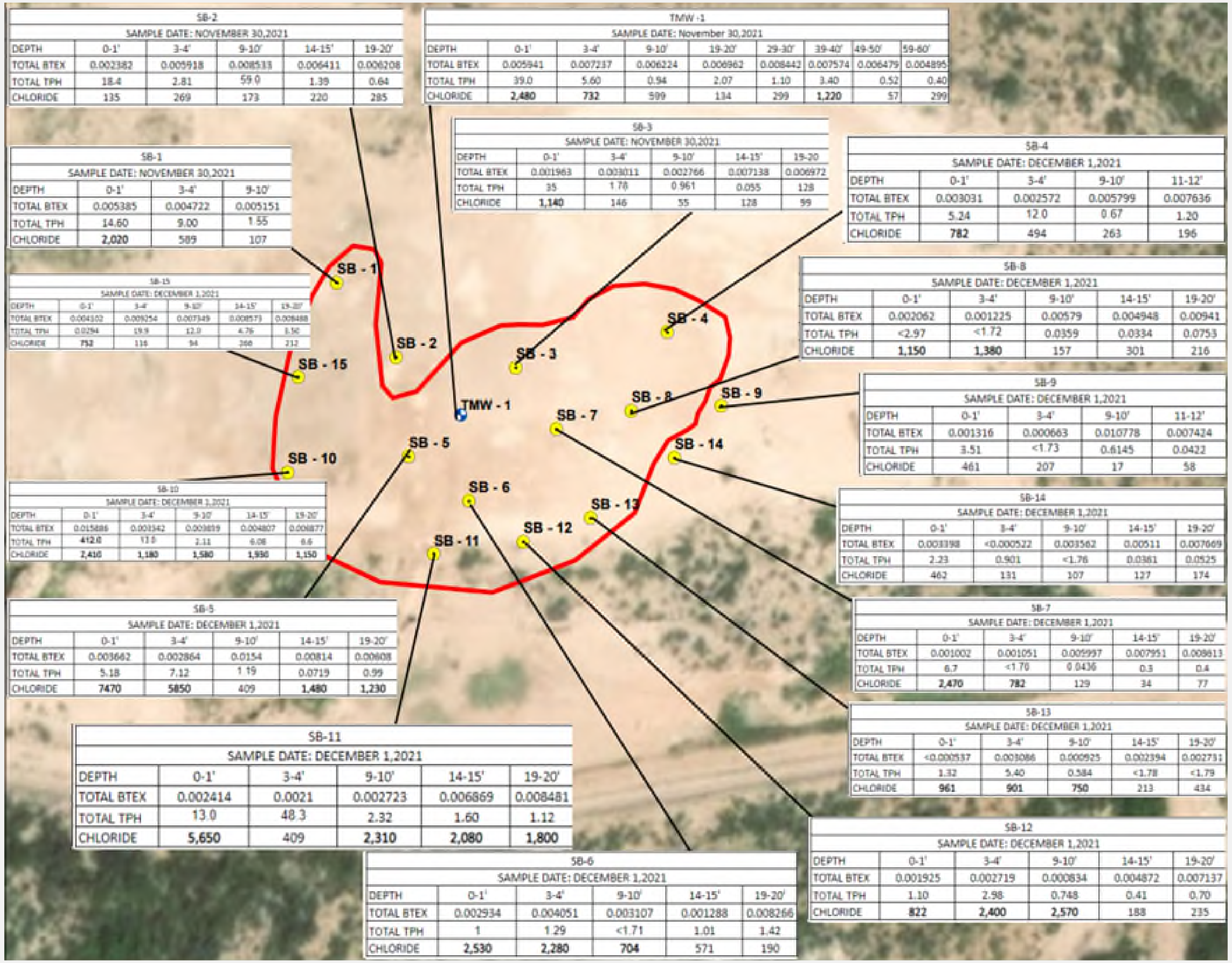
SS-3				
SAMPLE DATE: MARCH 30,2020				
DEPTH	0"-6"	1'	2'	4'
TOTAL BTEX	<0.004078	<0.004312	0.00346 J	0.00391 J
TOTAL TPH	67	37	65	49
CHLORIDE	2,390	9,070	5,650	4,200

SS-6			
SAMPLE DATE:MARCH 30,2020			
DEPTH	0"-6"	2'	4'
TOTAL BTEX	<0.004101	<0.004161	<0.004277
TOTAL TPH	112	46	51
CHLORIDE	6,600	4,630	3,760

2021 Subsequent Assessment (Soil and GW)

ARCADIS

- Between November 30 and December 1, 2021, soil samples were collected from 16 locations (SB-1 through SB-15 and TMW-1) within the release areas and one groundwater sample from TMW-1.
- Soil samples were collected at depths ranging from the surface to 20 feet bgs.
- Soil samples were analyzed for chloride, total TPH, and BTEX.
- Soil Analytical Results Summary:
  - Chloride: exceedances ranging from 704 mg/kg at SB-6 (9-10 feet bgs) to 7,470 mg/kg at SB-5 (0–1 foot bgs).
  - Total TPH: one exceedance of 412 mg/kg at SB-10 (0–1 foot bgs).
  - BTEX: no exceedances



SB-2 — SAMPLE DATE: NOVEMBER 30,2021

DEPTH	0-1'	3-4'	9-10'	14-15'	19-20'
TOTAL BTEX	0.002382	0.005918	0.008533	0.006411	0.006208
TOTAL TPH	18.4	2.81	59.0	1.39	0.64
CHLORIDE	135	269	173	220	285

TMW -1 — SAMPLE DATE: November 30,2021

DEPTH	0-1'	3-4'	9-10'	19-20'	29-30'	39-40'	49-50'	59-60'
TOTAL BTEX	0.005941	0.007237	0.006224	0.006962	0.008442	0.007574	0.006479	0.004895
TOTAL TPH	39.0	5.60	0.94	2.07	1.10	3.40	0.52	0.40
CHLORIDE	**2,480**	**732**	599	134	299	**1,220**	57	299

SB-3 — SAMPLE DATE: NOVEMBER 30,2021

DEPTH	0-1'	3-4'	9-10'	14-15'	19-20
TOTAL BTEX	0.001963	0.003011	0.002766	0.007138	0.006972
TOTAL TPH	35	1.78	0.961	0.055	128
CHLORIDE	**1,140**	146	55	128	99

SB-1 — SAMPLE DATE: NOVEMBER 30,2021

DEPTH	0-1'	3-4'	9-10'
TOTAL BTEX	0.005385	0.004722	0.005151
TOTAL TPH	14.60	9.00	1.55
CHLORIDE	**2,020**	589	107

SB-4 — SAMPLE DATE: DECEMBER 1,2021

DEPTH	0-1'	3-4'	9-10'	11-12'
TOTAL BTEX	0.003031	0.002572	0.005799	0.007636
TOTAL TPH	5.24	12.0	0.67	1.20
CHLORIDE	**782**	494	263	196

SB-15 — SAMPLE DATE: DECEMBER 1,2021

DEPTH	0-1'	3-4'	9-10'	14-15'	19-20'
TOTAL BTEX	0.004102	0.009254	0.007349	0.008573	0.008488
TOTAL TPH	0.0294	19.9	12.0	4.76	3.50
CHLORIDE	**752**	116	94	266	212

SB-8 — SAMPLE DATE: DECEMBER 1,2021

DEPTH	0-1'	3-4'	9-10'	14-15'	19-20'
TOTAL BTEX	0.002062	0.001225	0.00579	0.004948	0.00941
TOTAL TPH	<2.97	<1.72	0.0359	0.0334	0.0753
CHLORIDE	**1,150**	**1,380**	157	301	216

SB-9 — SAMPLE DATE: DECEMBER 1,2021

DEPTH	0-1'	3-4'	9-10'	11-12'
TOTAL BTEX	0.001316	0.000663	0.010778	0.007424
TOTAL TPH	3.51	<1.73	0.6145	0.0422
CHLORIDE	461	207	17	58

SB-10 — SAMPLE DATE: DECEMBER 1,2021

DEPTH	0-1'	3-4'	9-10'	14-15'	19-20'
TOTAL BTEX	0.015886	0.003342	0.003819	0.004807	0.006877
TOTAL TPH	**412.0**	13.0	2.11	6.08	6.6
CHLORIDE	**2,410**	**1,180**	**1,580**	**1,930**	**1,150**

SB-14 — SAMPLE DATE: DECEMBER 1,2021

DEPTH	0-1'	3-4'	9-10'	14-15'	19-20'
TOTAL BTEX	0.003398	<0.000522	0.003562	0.00511	0.007669
TOTAL TPH	2.23	0.901	<1.76	0.0361	0.0525
CHLORIDE	462	131	107	127	174

SB-5 — SAMPLE DATE: DECEMBER 1,2021

DEPTH	0-1'	3-4'	9-10'	14-15'	19-20'
TOTAL BTEX	0.003662	0.002864	0.0154	0.00814	0.00608
TOTAL TPH	5.18	7.12	1.19	0.0719	0.99
CHLORIDE	**7470**	**5850**	409	**1,480**	**1,230**

SB-7 — SAMPLE DATE: DECEMBER 1,2021

DEPTH	0-1'	3-4'	9-10'	14-15'	19-20'
TOTAL BTEX	0.001002	0.001051	0.005997	0.007951	0.008613
TOTAL TPH	6.7	<1.70	0.0436	0.3	0.4
CHLORIDE	**2,470**	**782**	129	34	77

SB-13 — SAMPLE DATE: DECEMBER 1,2021

DEPTH	0-1'	3-4'	9-10'	14-15'	19-20'
TOTAL BTEX	<0.000537	0.003086	0.000925	0.002394	0.002731
TOTAL TPH	1.32	5.40	0.584	<1.78	<1.79
CHLORIDE	**961**	**901**	**750**	213	434

SB-11 — SAMPLE DATE: DECEMBER 1,2021

DEPTH	0-1'	3-4'	9-10'	14-15'	19-20'
TOTAL BTEX	0.002414	0.0021	0.002723	0.006869	0.008481
TOTAL TPH	13.0	48.3	2.32	1.60	1.12
CHLORIDE	**5,650**	409	**2,310**	**2,080**	**1,800**

SB-12 — SAMPLE DATE: DECEMBER 1,2021

DEPTH	0-1'	3-4'	9-10'	14-15'	19-20'
TOTAL BTEX	0.001925	0.002719	0.000834	0.004872	0.007137
TOTAL TPH	1.10	2.98	0.748	0.41	0.70
CHLORIDE	**822**	**2,400**	**2,570**	188	235

SB-6 — SAMPLE DATE: DECEMBER 1,2021

DEPTH	0-1'	3-4'	9-10'	14-15'	19-20'
TOTAL BTEX	0.002934	0.004051	0.003107	0.001288	0.008266
TOTAL TPH	1	1.29	<1.71	1.01	1.42
CHLORIDE	**2,530**	**2,280**	**704**	571	190

2021 Groundwater Assessment

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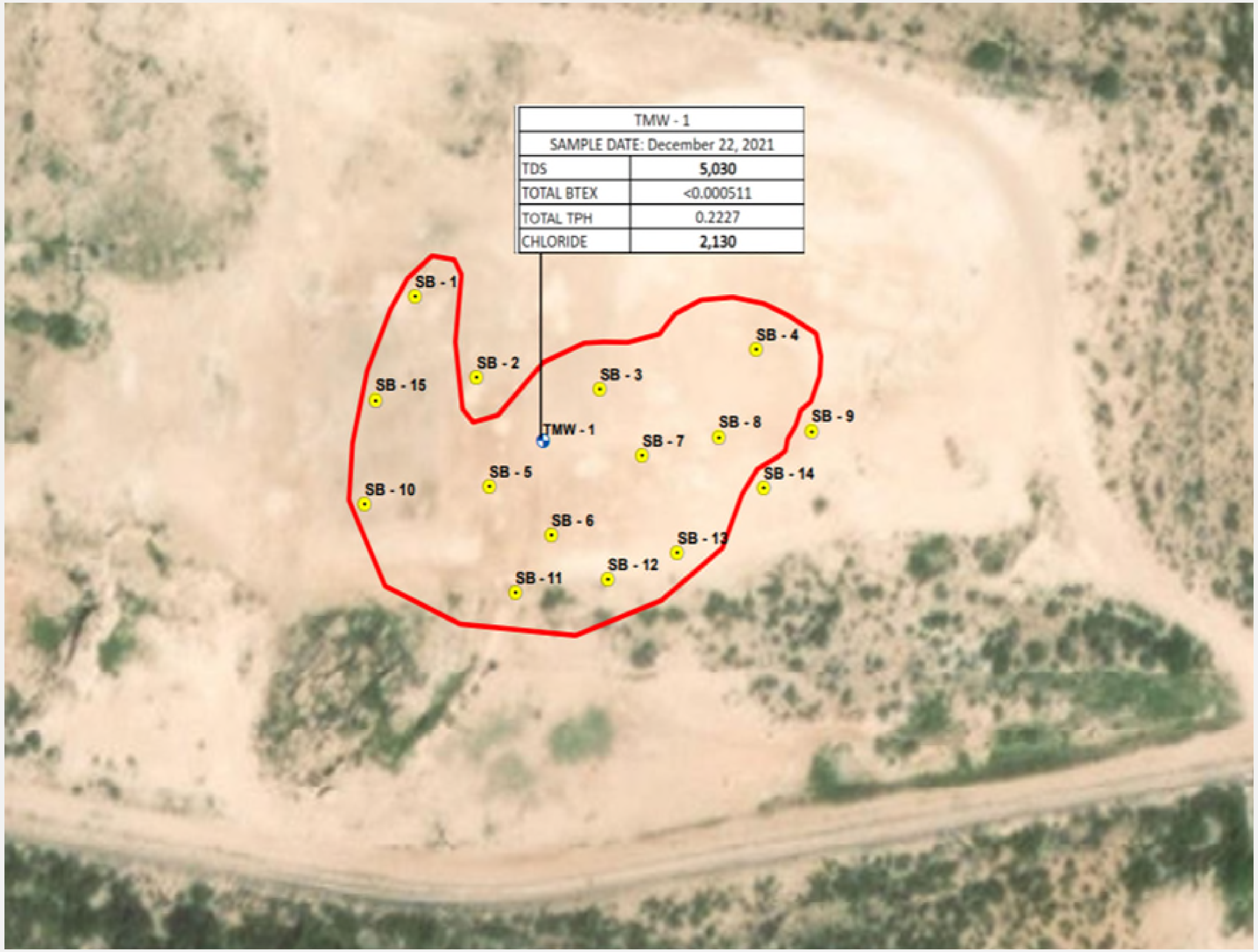
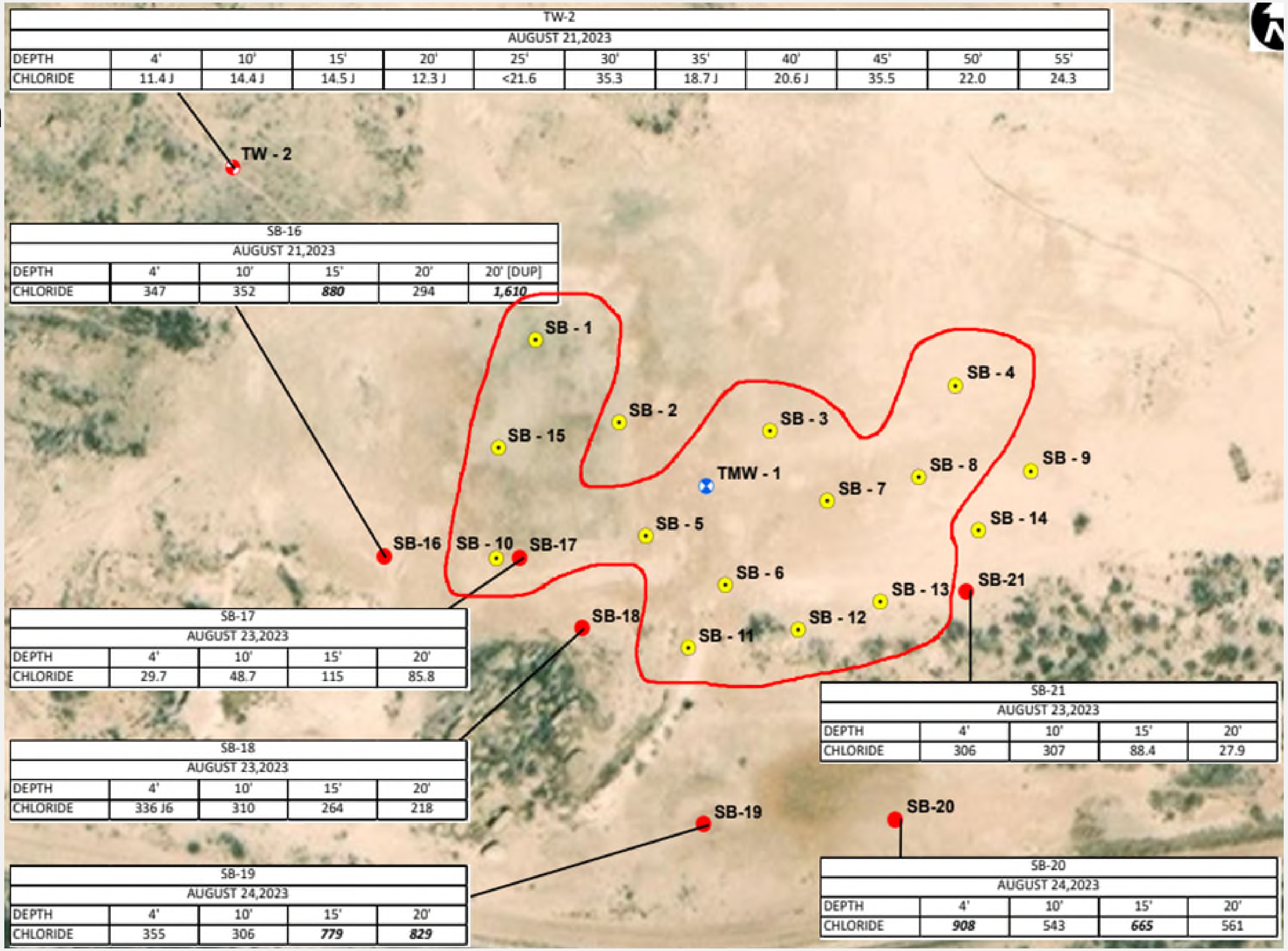
- Following the installation of TMW-1, Arcadis collected a groundwater sample via low flow methodologies.
- Depth to groundwater at TMW-1 was determined to be 50.91 feet bgs from the top of casing.
- The groundwater sample was analyzed for chloride, TPH, BTEX, and TDS.
- Groundwater Analytical Results Summary:
  - Chloride: 2,130 mg/L
  - TPH: 0.2227 mg/L
  - TDS: 5,030 mg/L
  - BTEX: no detections



2023 Subsequent Assessment (background)

ARCADIS

- Between August 21 and August 24, 2023, soil samples were collected from seven locations (SB-16 through SB-21 and TMW-2) within the release area and one groundwater sample from background location TMW-2.
- Soil samples were collected at depths ranging from the surface to 55 feet bgs.
- Soil samples were analyzed for chloride.
- Soil Analytical Results Summary:
  - Chloride: exceedances ranging from 665 mg/kg at SB-20 (15 feet bgs) to 880 mg/kg at SB-16 (15 feet bgs).



TW-2											
AUGUST 21,2023											
DEPTH	4'	10'	15'	20'	25'	30'	35'	40'	45'	50'	55'
CHLORIDE	11.4 J	14.4 J	14.5 J	12.3 J	<21.6	35.3	18.7 J	20.6 J	35.5	22.0	24.3

SB-16					
AUGUST 21,2023					
DEPTH	4'	10'	15'	20'	20' [DUP]
CHLORIDE	347	352	***880***	294	***1,610***

SB-17				
AUGUST 23,2023				
DEPTH	4'	10'	15'	20'
CHLORIDE	29.7	48.7	115	85.8

SB-18				
AUGUST 23,2023				
DEPTH	4'	10'	15'	20'
CHLORIDE	336 J6	310	264	218

SB-19				
AUGUST 24,2023				
DEPTH	4'	10'	15'	20'
CHLORIDE	355	306	***779***	***829***

SB-21				
AUGUST 23,2023				
DEPTH	4'	10'	15'	20'
CHLORIDE	306	307	88.4	27.9

SB-20				
AUGUST 24,2023				
DEPTH	4'	10'	15'	20'
CHLORIDE	***908***	543	***665***	561

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2023 Subsequent Background GW Assessment

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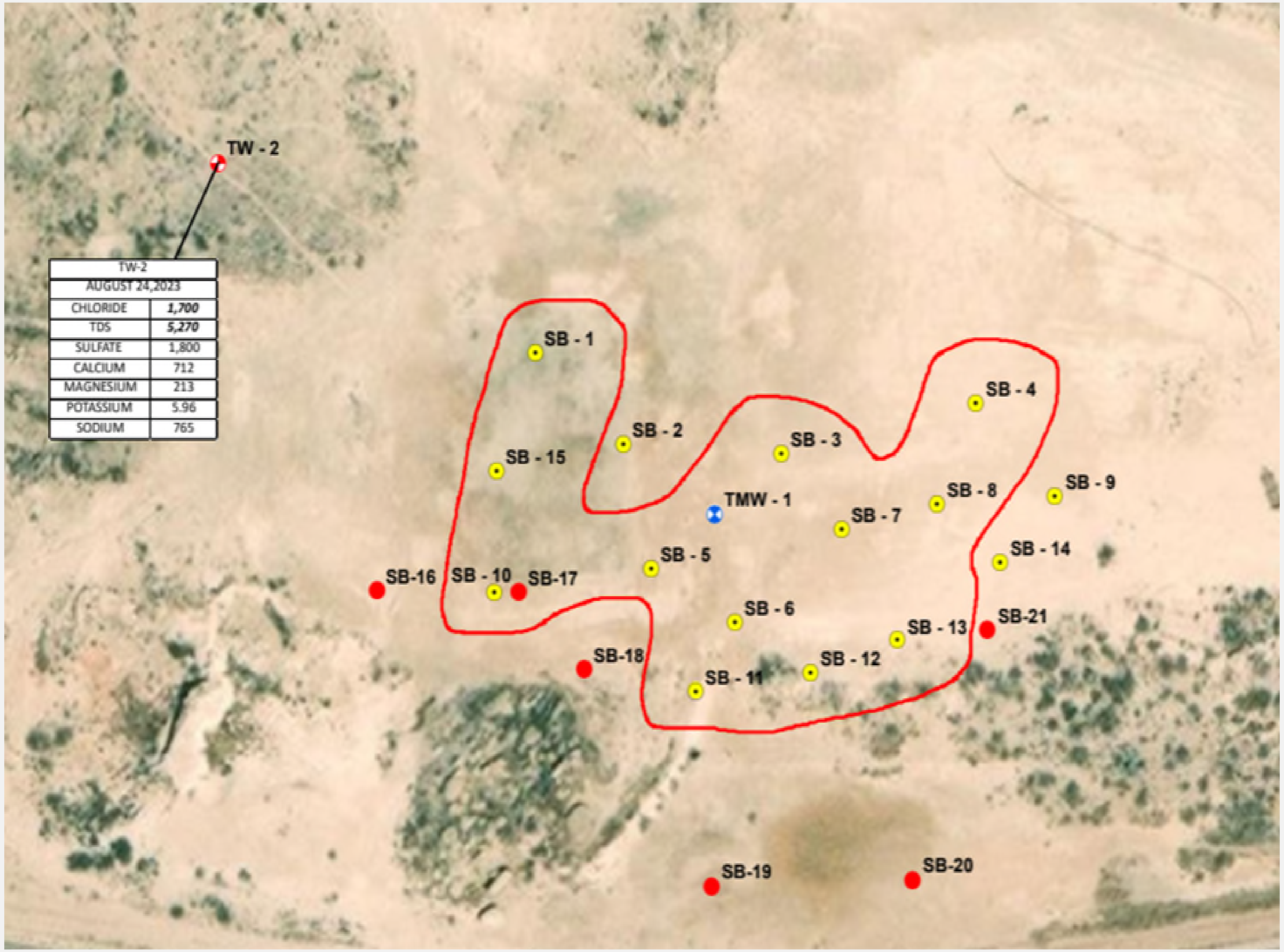
- A temporary monitoring well was installed northwest of the release area to assess background conditions. Following installation, one groundwater sample was collected from TMW-2.
- The groundwater sample was analyzed for chloride, select cations and anions, and TDS.
- Depth to groundwater at TMW-2 was determined to be 49.51 feet bgs from top of casing.
- Groundwater Analytical Results Summary:
  - Chloride: 1,700 mg/L
  - TDS: 5,270 mg/L



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Regional Irrigation Practices

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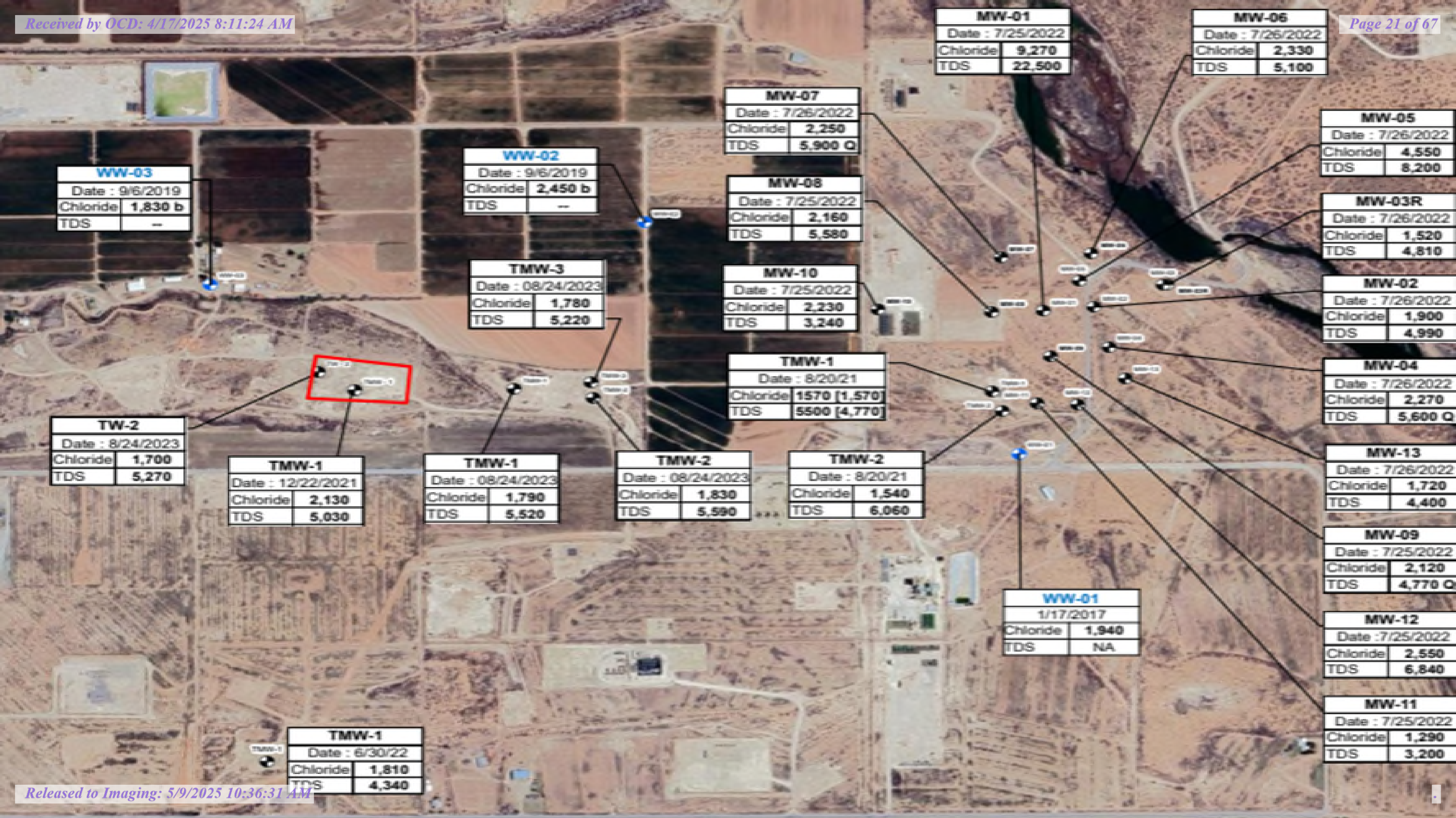
- Irrigation practices in the Loving, New Mexico area consist of pumping and distributing surface water from the Pecos River in conjunction with groundwater. According to the NMOSE database, there are multiple permitted irrigation pumps associated with intertwined irrigation canals leading out and across the area proximate to the Site.
- According to the USGS database, the salinity of the Pecos River exceeds 1,000 mg/L in many reaches of the study area within relative proximity to the Site (Ryder, 1996). Due to the naturally occurring high levels of chloride in the Pecos River, and its use as an irrigation water source over a duration of nearly 90 years, the chloride concentrations in groundwater and soil in the surrounding irrigated agricultural areas are anticipated to contain elevated concentrations of chloride and other TDS constituents.
- Groundwater conditions are also anticipated to be influenced by the connectivity of the Pecos River to the Pecos Alluvial Aquifer system.

Regional Groundwater Sampling

ARCADIS

- Arcadis collected groundwater samples from two stock and irrigation water wells (WW-2 and WW-3) in May and September 2019. The water wells are located within a 0.75-mile radius of the Site, and screened intervals are confirmed to be within the shallow groundwater bearing unit.
- The average chloride concentration in groundwater samples collected from the water wells is 2,170 mg/L. These concentrations align with groundwater sampling results reported from temporary monitoring well sampling results at the Donaldson site during recent assessment activities.
- Additionally, analytical data collected from nearby groundwater monitoring sites further supports the evidence that groundwater in this region contains elevated TDS and chloride concentrations.


MW-01
Date : 7/25/2022
Chloride 9,270
TDS 22,500
MW-06
Date : 7/26/2022
Chloride 2,330
TDS 5,100
MW-07
Date : 7/26/2022
Chloride 2,250
TDS 5,900 Q
MW-05
Date : 7/26/2022
Chloride 4,550
TDS 8,200
WW-02
Date : 9/6/2019
Chloride 2,450 b
TDS --
WW-03
Date : 9/6/2019
Chloride 1,830 b
TDS --
MW-08
Date : 7/25/2022
Chloride 2,160
TDS 5,580
MW-03R
Date : 7/26/2022
Chloride 1,520
TDS 4,810
TMW-3
Date : 08/24/2023
Chloride 1,780
TDS 5,220
MW-10
Date : 7/25/2022
Chloride 2,230
TDS 3,240
MW-02
Date : 7/26/2022
Chloride 1,900
TDS 4,990
TMW-1
Date : 8/20/21
Chloride 1570 [1,570]
TDS 5500 [4,770]
MW-04
Date : 7/26/2022
Chloride 2,270
TDS 5,600 Q
TW-2
Date : 8/24/2023
Chloride 1,700
TDS 5,270
TMW-1
Date : 12/22/2021
Chloride 2,130
TDS 5,030
TMW-1
Date : 08/24/2023
Chloride 1,790
TDS 5,520
TMW-2
Date : 08/24/2023
Chloride 1,830
TDS 5,590
TMW-2
Date : 8/20/21
Chloride 1,540
TDS 6,060
MW-13
Date : 7/26/2022
Chloride 1,720
TDS 4,400
MW-09
Date : 7/25/2022
Chloride 2,120
TDS 4,770 Q
WW-01
1/17/2017
Chloride 1,940
TDS NA
MW-12
Date :7/25/2022
Chloride 2,550
TDS 6,840
MW-11
Date : 7/25/2022
Chloride 1,290
TDS 3,200
TMW-1
Date : 6/30/22
Chloride 1,810
TDS 4,340

Initial Remediation Work Plan Submittal

ARCADIS

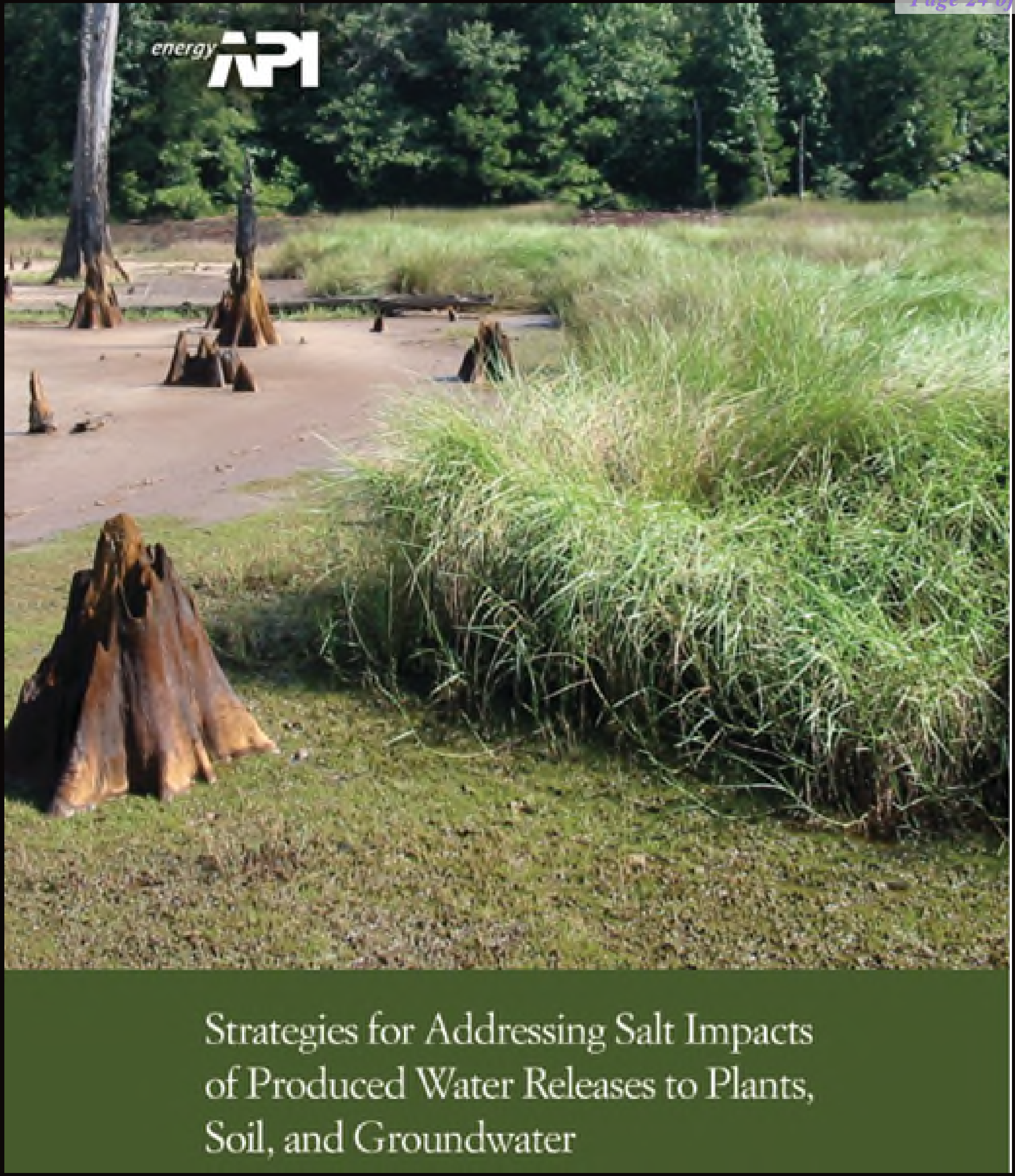
- Chevron submitted a Remediation Work Plan with a Variance Request to the NMOCD on April 10, 2024. The Variance Request consisted of the following:
  - Excavation of impacted soil to a depth of 4 feet bgs, the addition of soil amendments (gypsum), and to install a liner to prohibit further vertical migration of chloride left in-situ within the soil column.
  - Chloride concentrations in soil proposed to be left in-situ at depths greater than 4 feet bgs are not at concentrations believed to pose risk of impacting groundwater at concentrations higher than what occur naturally in this region. The proposed liner would prevent further vertical migration of chloride within the soil column and the proposed soil amendments would further mitigate impacts to soil remaining in-situ.

NMOCD Work Plan Rejection

- The Remediation Work Plan was rejected by the NMOCD on April 16, 2024, for the following reasons:
  - *As of January 1, 2024, no more liners will be approved <u>except under extenuating circumstances</u>.*
  - *Additionally, the Donaldson Com A Well 1 Site must have Grab, not composite, soil sample(s) gathered in areas undisturbed by oil and gas activities, nominally uphill from the release area.*
  - *Background samples should never be taken on or near a road and no closer than 50 feet and no farther than 100 feet from the lateral and horizontal extents of this release's impact.*
  - *The background sampling should be representative of the horizontal and vertical extents of the release.*
  - *Lastly, groundwater flow direction was not demonstrated in this report. Groundwater flow direction must be established to determine groundwater background concentrations for chloride and TDS.*

Additional Data and Remedial Alternatives Evaluation

API Publication 4758



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Estimate of Chloride Migration to Groundwater

Utilizing Graphical Solutions in API Publication 4758

“Strategies for Addressing Salt Impacts of Produced Water Releases to Plants, Soil, and Groundwater”

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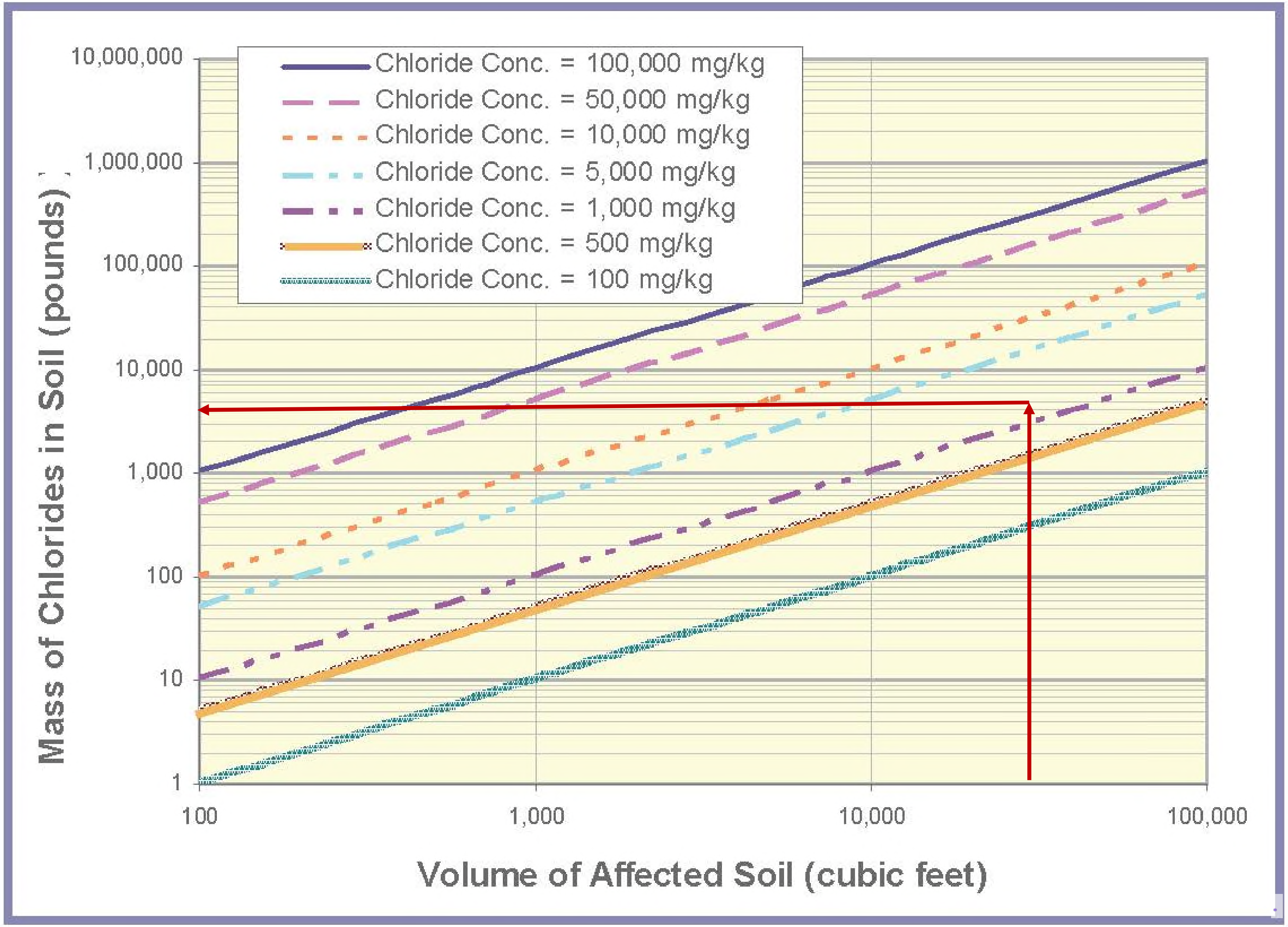
Step 1 – Estimate of Mass of Chloride in Soil

Volume of Effected Soil Below 10 Foot Depth:

33,000 Cubic Feet

Average Chloride Concentration - 1,400 mg/kg

Chloride Mass is 4,800 Pounds

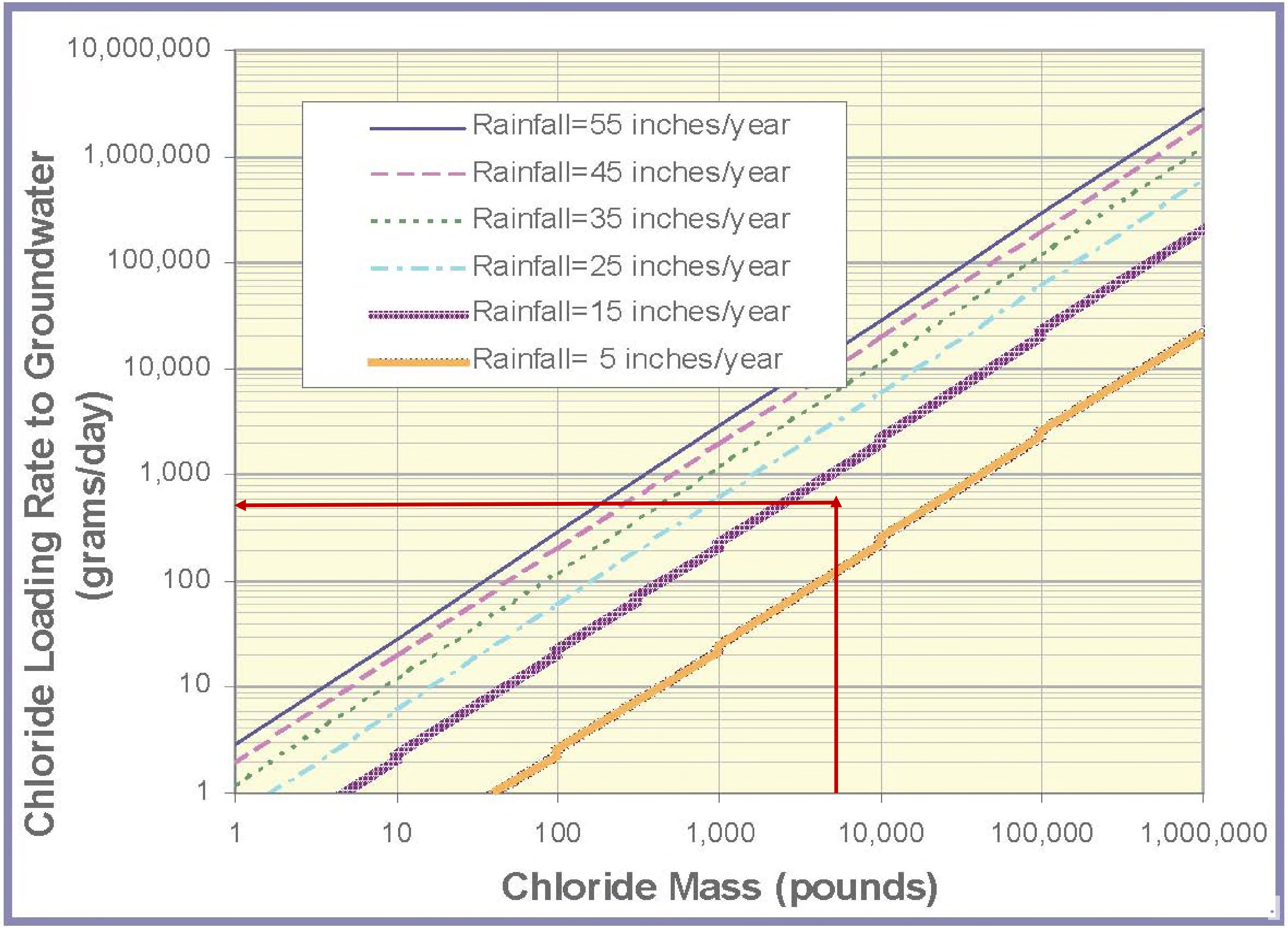


Step 2 – Estimate of Chloride Loading Rate to Groundwater

Mass of Chloride - 4,800 Pounds

Yearly Rainfall - 13 Inches

620 grams Chloride per Day Loading into Groundwater

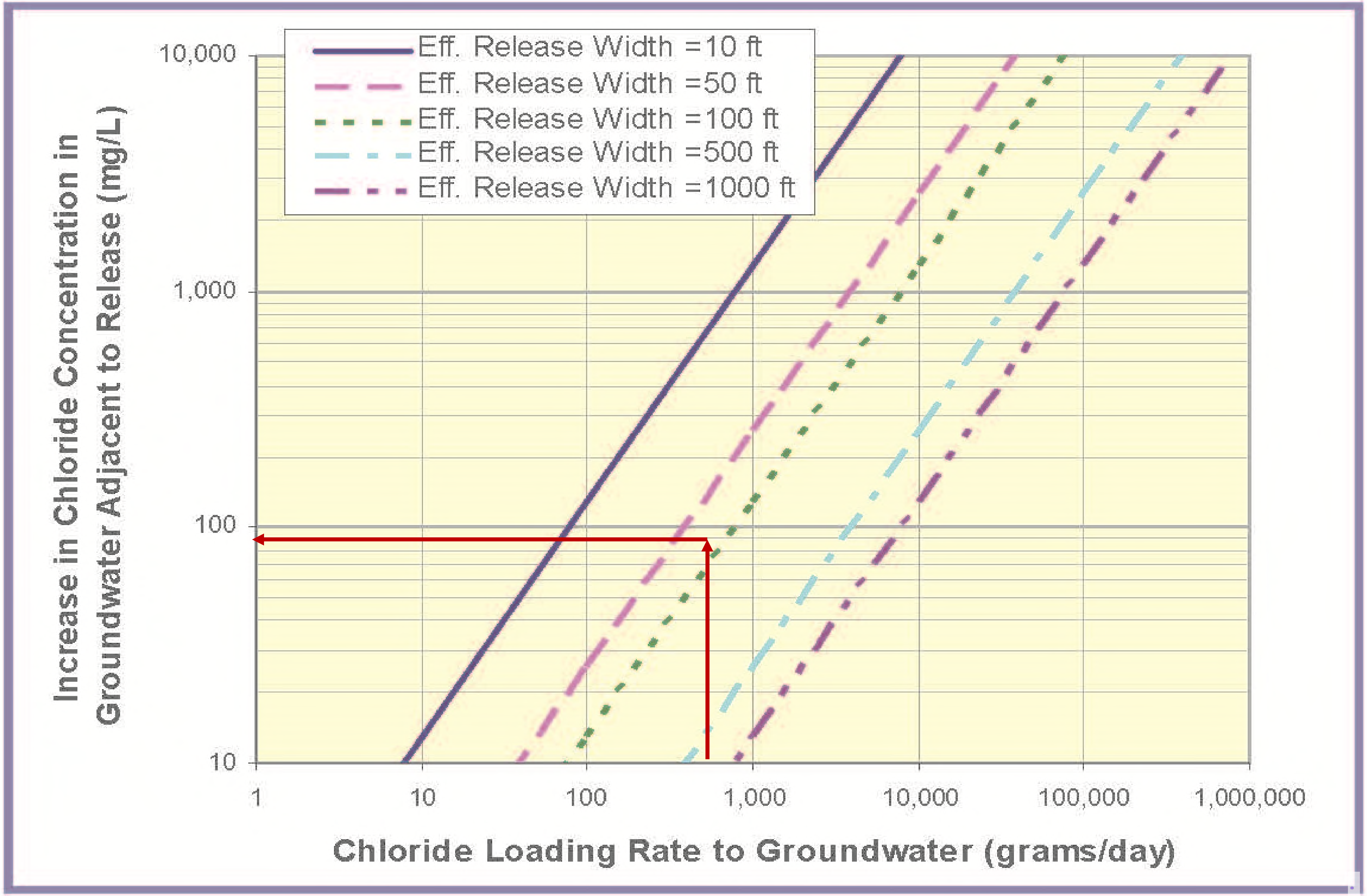


Step 3 – Estimate Increase in Chloride Concentration in Groundwater Adjacent to the Release

Chloride Loading Rate - 620 grams per day

Effective
Release Width - 100 Feet

85 mg/L Chloride Increase in Groundwater



Proposed Stepped Excavation to 10 Feet with Clay Liner

ARCADIS

Evaluation of soil analytical data collected throughout the release area indicates that a stepped excavation to depths up to approximately 10 feet bgs would remove chloride impacted soil with concentrations above 600 mg/kg within the majority of the release area. **Installation of an engineered clay liner within Zone 3 would eliminate the migration risk of remaining chloride in soil to groundwater.**

Total Soil Volume to 20 Feet 456,753 Ft^3

Total Chloride Mass 25,719 kg

Zone 1 - Excavate to 2 Feet (<600 mg/kg)

Zone 2 - Excavate to 6 Feet (<600 mg/kg)

Zone 3 - Excavate to 10 Feet (<600 to 10 feet bgs and install engineered clay liner)

Percent of Chloride Mass Removed

- 77%

Percent of Soil Volume Removed

- 35%

Risk of chloride migration to groundwater

- **0%**

Potential Residual Chloride Loading to Groundwater with No Additional Engineering Controls (i.e., clay liner)

Stepped Excavation to 10 Feet

- Zone 1 - Excavate to 2 Feet
- Zone 2 - Excavate to 6 Feet
- Zone 3 - Excavate to 10 Feet (no liner)

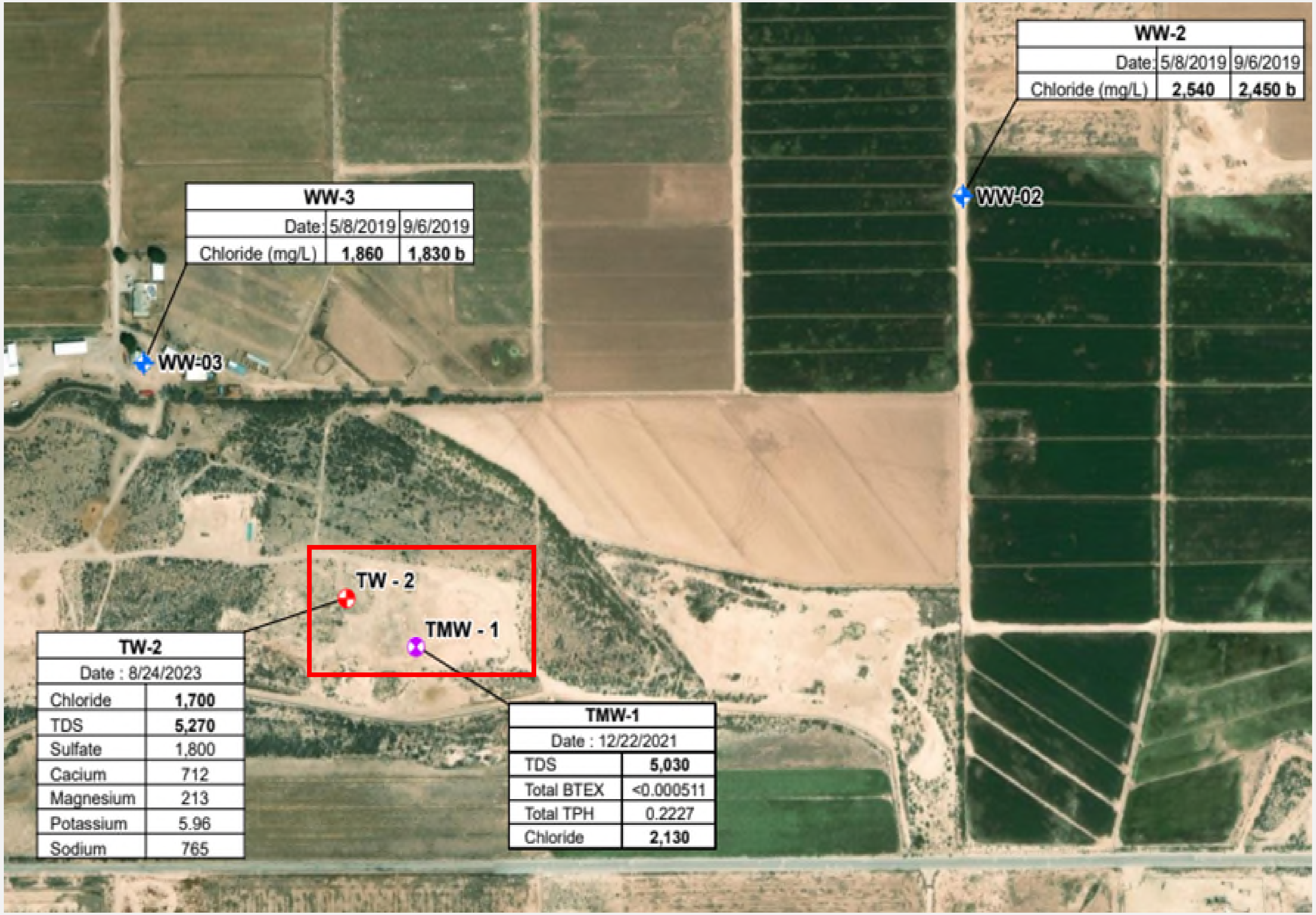
- Potential Increase in Chloride Concentration in Groundwater
  - 85 mg/L

*API Publication Number 4758 graphical methods were used for the above calculations. Accommodations for irreversible absorption of chloride in the vadose zone were utilized.

Summary

ARCADIS

- Evaluation of site data suggests that the chloride mass proposed to be left in-situ at depths greater than 10 feet bgs with additional engineering controls would pose no significant risk to groundwater, human health, or the environment.
- Evaluation of groundwater conditions at the site confirm chloride and TDS concentrations mirror the surrounding area and indicate that site groundwater has not been impacted by the releases from vertical downward migration.
- Proposed mitigation engineering controls would eliminate the potential risk of future vertical migration of chloride.



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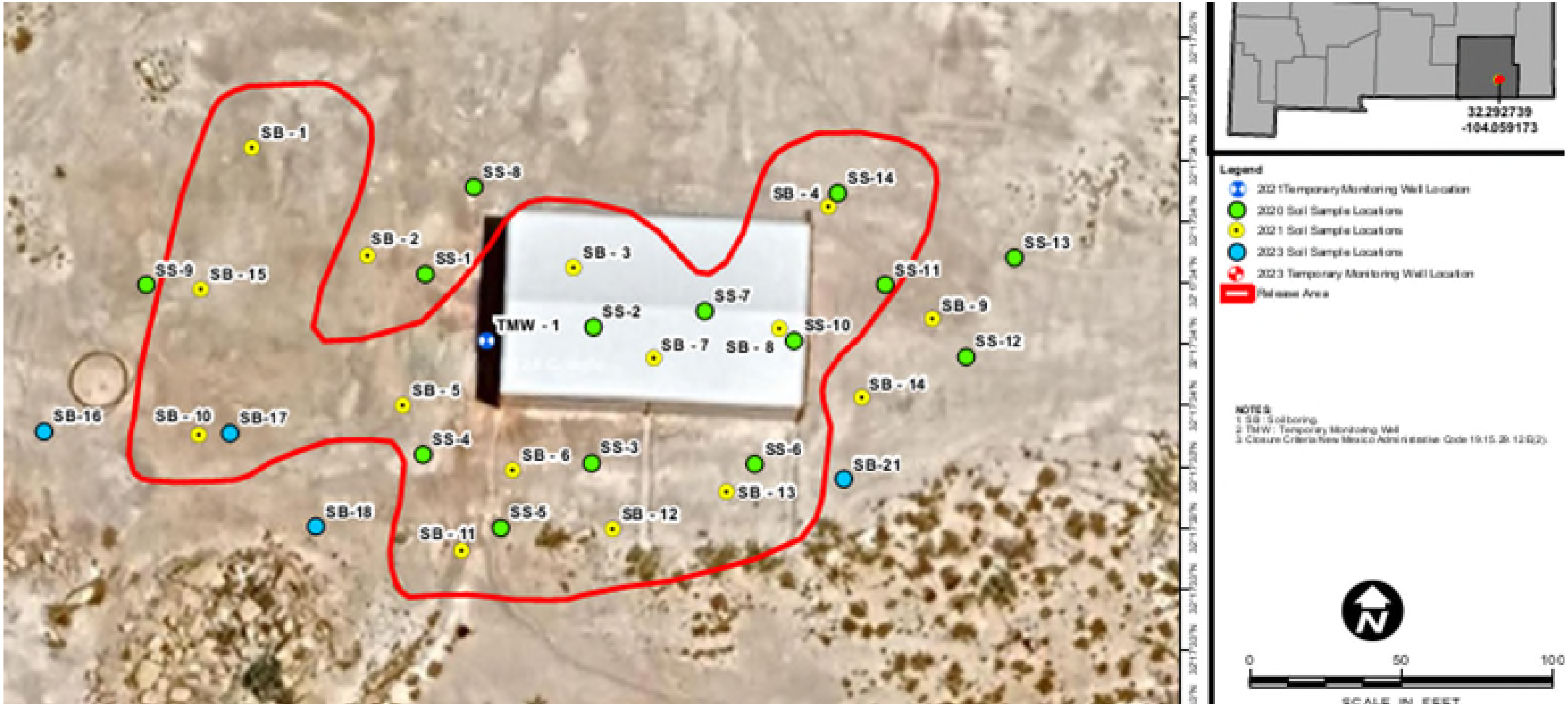
ARCADIS

Update – The landowner has recently constructed a new barn



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Strategies for Addressing Salt Impacts of Produced Water Releases to Plants, Soil, and Groundwater

SEPTEMBER 2006
PUBLICATION 4758

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Cover photo:

A produced water-impacted plot (left) contrasts with an adjoining salt-flat remediation plot (right) where the thriving halophyte, marsh hay cordgrass (Spartina sp.), was planted as plugs about five years previously in the Smackover oilfield of south Arkansas.

Photo courtesy of David J. Carty, GreenBridge EarthWorks

SEPTEMBER 2006
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Strategies for Addressing Salt Impacts of Produced Water Releases to Plants, Soil, and Groundwater

CHARLES J. NEWELL AND JOHN A. CONNOR
GROUNDWATER SERVICES, INC.

PURPOSE OF THIS GUIDE

The exploration and production (E&P) industry uses great care during the handling and disposal of the produced water that is generated as part of oil and gas production. However, unintentional releases can occur. Depending on the chemical composition of the produced water and the nature of the local environment, salts associated with such releases can impair soils, vegetation, and water resources.

This guide provides a collection of simple rules of thumb, decision charts, models, and summary information from more detailed guidance manuals to help you address the following assessment and response issues:

1) *Will a produced water release cause an unacceptable impact on soils, plants, and/or groundwater?*
2) *In the event of such an impact, what response actions are appropriate and effective?*

HOW TO USE THIS GUIDE

Determining when a response action will likely be needed to protect soil, plants, or groundwater.	• ***Protecting Soil/Plants:*** *See Rules of Thumb on Page 2 and more detailed decision charts on Pages 4 to 5.* • ***Protecting Groundwater:*** *See Rules of Thumb on Page 3 and Planning Model on Pages 9 to 14.*
Selecting and implementing an appropriate remedial measure for impacted soils or plants.	• ***Remedy Selection:*** *See decision charts on Pages 4 to 5.* • ***Remedy Implementation:*** *See simple guidelines for natural remediation, in-situ chemical amendments, and mechanical remediation on Pages 6, 7, and 8, respectively.*
Evaluating potential impacts on groundwater resources.	• ***Planning Model:*** *See simple procedures for assessing potential effects on groundwater quality on Pages 9 to 14.* • ***Beneficial Use Criteria:*** *See general criteria for evaluating the potential use of water resources on Page 15.*
Background information on produced water and its potential effects.	• ***Produced Water Production and Disposal in the U.S.:*** *Page 16* • ***Definition/ Measurement of Key Parameters:*** *Pages 17 and 21* • ***Potential Impacts on Plants:*** *Page 18* • ***Potential Impacts on Soil:*** *Page 19* • ***Key Factors for Assessing Groundwater Impacts:*** *Page 20* • ***Example Site Assessment:*** *Pages 22 and 23*

SOIL/PLANT IMPACT RULES OF THUMB

Evaluating Impacts - SOIL

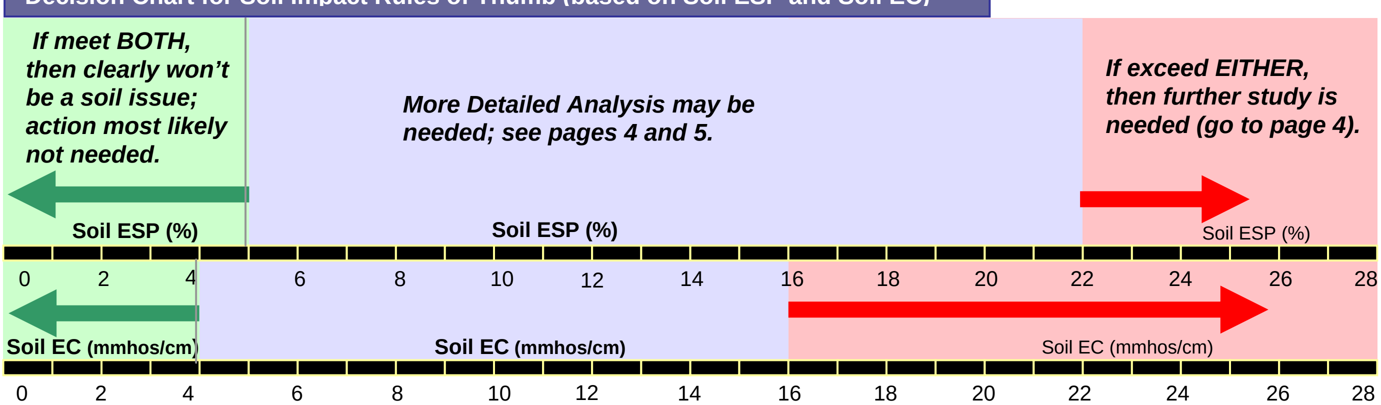
Information from API Publication 4663, *Remediation of Salt-Affected Soils at Oil and Gas Production Facilities* and other sources was compiled to develop the following “Rules of Thumb” for response to impacts by produced water. Each Rule of Thumb describes a set of conditions associated with a produced water release and the typical response to such conditions. These Rules of Thumb are for typical rangeland and farmland areas, but may not be applicable to environments with naturally high salinity. For further discussion of conditions not covered by these Rules of Thumb, please go to page 4.

TECH TIP:

See Page 17 for definitions of EC, CEC, TDS, ESP, and SAR .

IF THESE SOIL CONDITIONS RESULT FROM PRODUCED WATER RELEASE….	RULE OF THUMB IS:
CASE 1 Affected Soil EC > 16 mmhos/cm *OR* Affected Soil ESP > 22% (SAR > 20)	**FURTHER STUDY MAY BE NEEDED; GO TO PAGE 4** *Source: API Publication 4663*
CASE 2 Produced Water TDS < 3000 mg/L *AND* Affected Soil ESP < 12% (SAR < 10)	**A RELEASE WILL MOST LIKELY NOT HARM SOILS AND/OR PLANTS**
CASE 3 Produced Water TDS < 600 mg/L *AND* Affected Soil ESP < 12% (SAR < 10)	**CLEARLY WILL NOT BE A SOIL FERTILITY ISSUE** *Source: API Publication 4663*
CASE 4 Affected Soil EC < 4 mmhos/cm *AND* Affected Soil ESP < 5% (SAR < 5)	**CLEARLY WILL NOT BE A SOIL FERTILITY ISSUE** *Source: API Publication 4663*

Decision Chart for Soil Impact Rules of Thumb (based on Soil ESP and Soil EC)



GROUNDWATER IMPACT RULES OF THUMB

Evaluating Impacts - GROUNDWATER

The following Rules of Thumb for response to groundwater impacts by produced water were developed as guidance using information from API Publication 4734, *Modeling Study of Produced Water Release Scenarios*. In that study, the authors performed several hundred computer simulations with the HYDRUS-1D model to determine the sensitivity of groundwater underlying a produced water release to various factors such as release volume, chloride concentration of the produced water, depth to groundwater, soil type, rainfall and hydrology of the area, and other factors. Each Rule of Thumb describes a set of site conditions associated with a produced water release and assesses the likelihood of an impact to groundwater. These Rules of Thumb may not be applicable to environments with naturally high salinity or areas with multiple releases over several years. For cases not covered by these Rules of Thumb, go to page 9.

CASE 1

Produced Water Release Volume > 100 bbls

AND

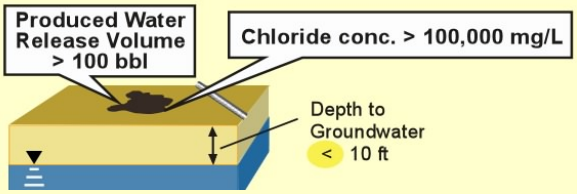
Produced Water With Chloride Greater Than ~100,000 mg/L

AND

Depth to Groundwater < 10 ft

AND

Unsaturated Soil Zone is Sandy



HAS POTENTIAL TO IMPACT GROUNDWATER QUALITY. FURTHER STUDY NEEDED - GO TO PAGE 9.

CASE 2

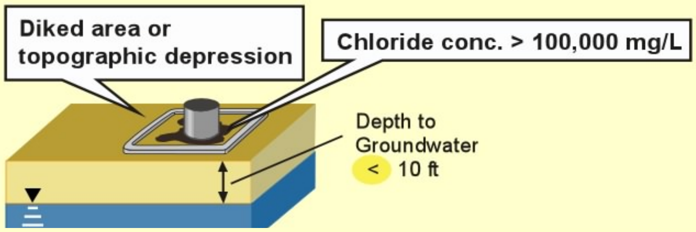
Entire Produced Water Release Collects in Bermed Area or Topographic Low, Causing Infiltration

OR

Produced Water With Chloride Greater Than ~100,000 mg/L

OR

Depth to Groundwater < 10 ft



THESE SITE FACTORS MAY INCREASE LIKELIHOOD OF IMPACTING GROUNDWATER - SEE PAGES 9 AND 20 FOR MORE INFORMATION.

CASE 3

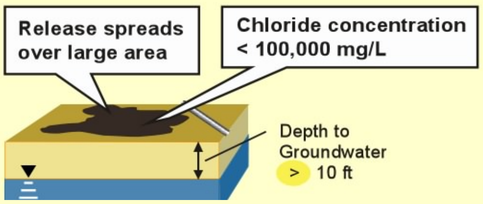
Produced Water With Chloride Less Than ~100,000 mg/L)

AND

Release Spreads over a Large Area
[e.g., Volume release (bbls) ÷ Area (sq. ft) < 0.015]

AND

Depth to Groundwater > 10 ft

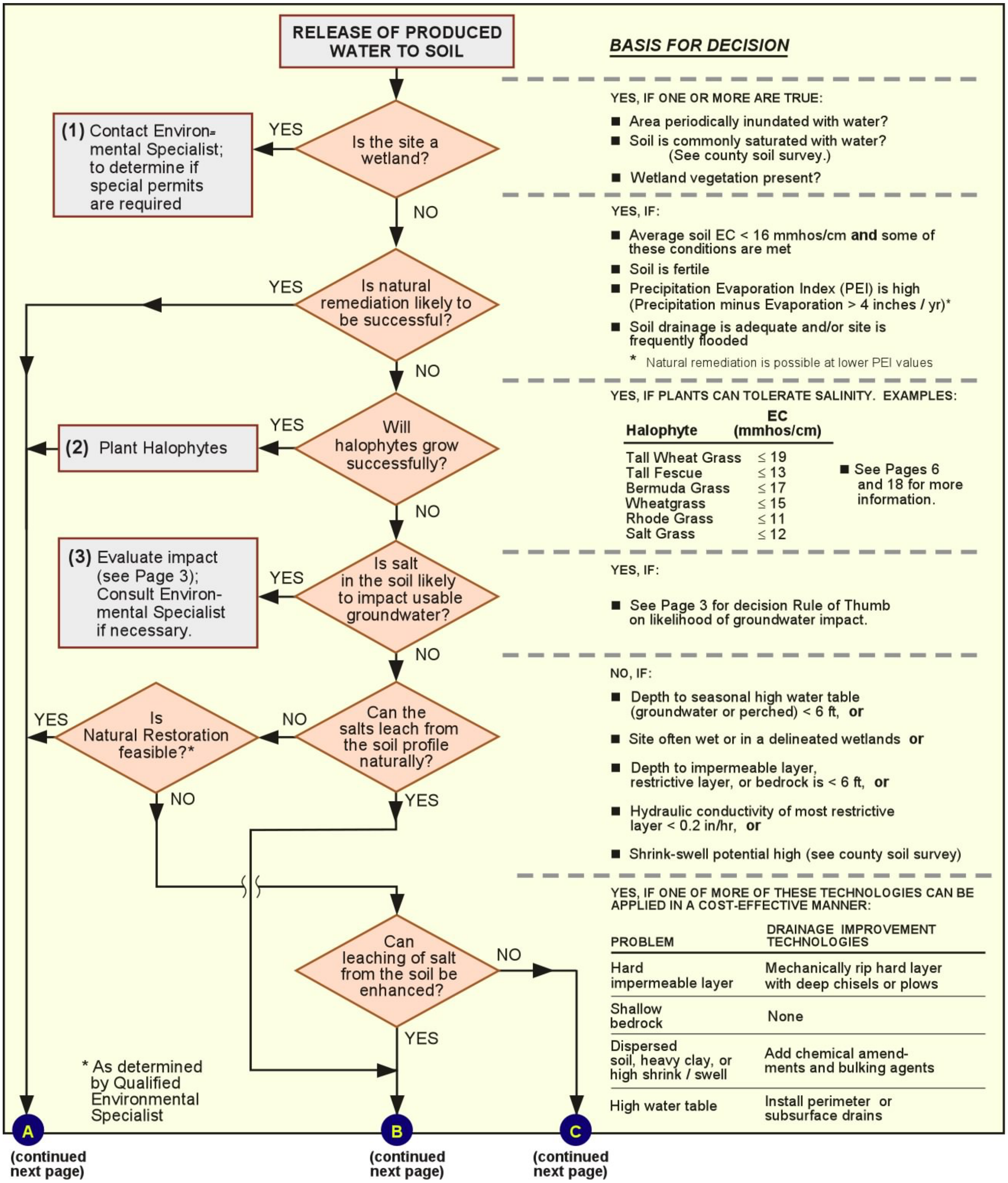


LESS LIKELY TO IMPACT GROUNDWATER.

DECISION CHART FOR SOIL / PLANT IMPACTS

Evaluating Impacts - SOIL

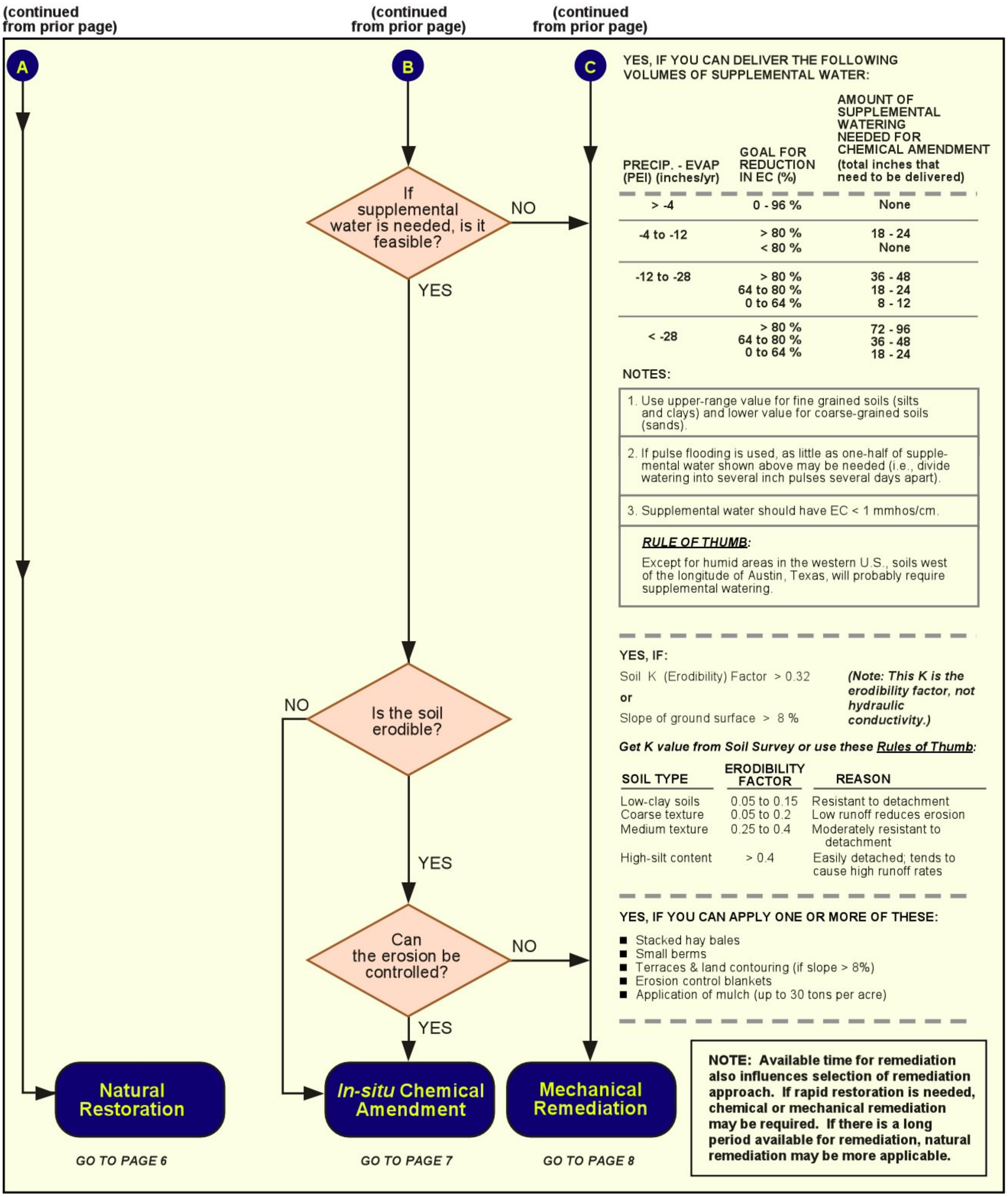
For those sites where produced water impacts to soils requires a corrective action, the following decision chart can be used to select appropriate remedial measures. More detail on specific technologies is provided on pages 7 – 8.



Decision Chart for Salt-Impacted Soils (Adapted from API Publication 4663)

DECISION CHART FOR SOIL / PLANT IMPACTS (Continued)

Evaluating Impacts - SOIL



YES, IF YOU CAN DELIVER THE FOLLOWING VOLUMES OF SUPPLEMENTAL WATER:

PRECIP. - EVAP (PEI) (inches/yr)	GOAL FOR REDUCTION IN EC (%)	AMOUNT OF SUPPLEMENTAL WATERING NEEDED FOR CHEMICAL AMENDMENT (total inches that need to be delivered)
> -4	0 - 96 %	None
-4 to -12	> 80 % < 80 %	18 - 24 None
-12 to -28	> 80 % 64 to 80 % 0 to 64 %	36 - 48 18 - 24 8 - 12
< -28	> 80 % 64 to 80 % 0 to 64 %	72 - 96 36 - 48 18 - 24

NOTES:

1. Use upper-range value for fine grained soils (silts and clays) and lower value for coarse-grained soils (sands).
2. If pulse flooding is used, as little as one-half of supplemental water shown above may be needed (i.e., divide watering into several inch pulses several days apart).
3. Supplemental water should have EC < 1 mmhos/cm.

RULE OF THUMB:

Except for humid areas in the western U.S., soils west of the longitude of Austin, Texas, will probably require supplemental watering.

YES, IF:

Soil K (Erodibility) Factor > 0.32

or

Slope of ground surface > 8 %

(Note: This K is the erodibility factor, not hydraulic conductivity.)

Get K value from Soil Survey or use these Rules of Thumb:

SOIL TYPE	ERODIBILITY FACTOR	REASON
Low-clay soils	0.05 to 0.15	Resistant to detachment
Coarse texture	0.05 to 0.2	Low runoff reduces erosion
Medium texture	0.25 to 0.4	Moderately resistant to detachment
High-silt content	> 0.4	Easily detached; tends to cause high runoff rates

YES, IF YOU CAN APPLY ONE OR MORE OF THESE:

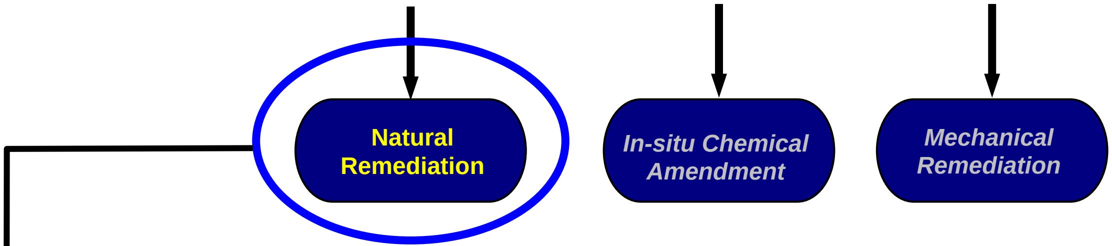
- Stacked hay bales
- Small berms
- Terraces & land contouring (if slope > 8%)
- Erosion control blankets
- Application of mulch (up to 30 tons per acre)

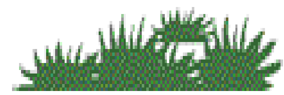
NOTE: Available time for remediation also influences selection of remediation approach. If rapid restoration is needed, chemical or mechanical remediation may be required. If there is a long period available for remediation, natural remediation may be more applicable.

Decision Chart for Salt-Impacted Soils - *Continued* **(Adapted from API Publication 4663)**

NATURAL REMEDIATION OF SOIL IMPACTS

Responding to Impacts - SOIL





Soil Remediation Alternative 1: *Natural Remediation*

Concept: Use plants and natural water flushing to restore salt-impacted soils. This option is preferable in cases where remediation equipment can create additional soil damage (such as wetlands).

OPTION A. Monitored Natural Revegetation

Approach: Allow natural revegetation to occur over 1-to 3-year time period and monitor the revegetation process. The affected area should be monitored for barren zones and stressed vegetation over time. If monitoring shows revegetation process is too slow, consider other methods. This method works best with sandy soils and soils containing limited clay. In some cases adding mulch, fertilizer, and water (see Option B, below) can speed up revegetation.

OPTION B. Plant Salt-Tolerant Vegetation

Approach: Plant halophytic vegetation that is suitable for the climate and the soil conditions and that can tolerate elevated salinity (see table below for examples of halophytic grasses). Add mulch and fertilizer as necessary:

Mulch Rule of Thumb: *Till in 2 to 4 inches of mulch over affected area (less for coarse soils, more for fine-grained soils; about five 60-lb bales of hay for every 1000 sq. feet).*

Fertilizer Rule of Thumb: *Add about 28 pounds of 13-13-13 fertilizer for every 1000 sq. feet. (For more detail, see API Publication 4663) (Don't add too much fertilizer in a soil; fertilizers can act like salts.)*

Watering Rule of Thumb: ***GENERALLY DO NOT ADD WATER BY ITSELF IF SALT IMPACT HAS ALREADY ENTERED SOILS CONTAINING CLAY. IF YOU ARE GOING TO ADD WATER, FIRST ADD CHEMICAL AMENDMENTS (see next page).***

For more detailed information on mulch / fertilizer addition, see API Publication 4663.

Halophyte-assisted natural remediation
Photo Courtesy of David Carty

EXAMPLES OF GRASSES THAT MAY BE USED FOR REVEGETATION

GRASS	HABIT	ACCEPTABLE PRECIPITATION RATES Min (in/yr)	Max (in/yr)	SOIL TYPE L-M-H	U.S. PLANTING SEASON	SEEDING RATE (lbs/ac PLS drilled)	SEEDING DRILL DEPTH (inches)
Alkali Sacaton	Bunch	8	18	L-M-H	Summer	$^{1}/_{5}$	$^{1}/_{4}$
Basin Wildrye	Bunch	9	Irrigation OK	L-M-H	Late Fall/Spring	5	1
Western Wheatgrass	Sod	10	20	M-H	Early Fall/Spring	8	$^{1}/_{2}$ - 1
Beardless Wildrye	Sod	20	Irrigation OK	M-H	Late Fall/Spring	8	$^{3}/_{4}$
Tall Wheatgrass	Bunch	5	20	L-M-H	Spring	8	$^{1}/_{2}$ - 2

NOTES: This table only presents a few of the grasses that can be used for revegetation. A number of other grasses (such as Bermuda grass) are presented in API Publication 4663 and other literature.

SOIL TYPE: L = LIGHT - sands, loamy fine sands, sandy loams
M = MEDIUM - silty loams, loams, very fine sandy loams, sandy clay loams
H = HEAVY - clay loams, silty clays, clay

PLS = Pure Live Seeds.

IN-SITU CHEMICAL AMENDMENT OF SOIL IMPACTS

Natural Remediation | **In-situ Chemical Amendment** | Mechanical Remediation

Add Gypsum or Other Amendment

Soil Remediation Alternative 2: *In-Situ Chemical Amendment*

Concept: Add a calcium-containing compound, such as gypsum, which serves to replace sodium (which changes the structure and porosity of clays in salt-impacted soils) with calcium and restores the structure of the soil. (See page 19.)

Approach:

1) Improve drainage, if necessary.
2) Calculate how much gypsum to add using Calculation Method 1 or Method 2 (below) or use this *Rule of Thumb*:
   Add 13 pounds of gypsum per 100 sq. feet of impacted soil
3) Add chemical amendments to affected soil.
   - Solid Amendment: Incorporate from surface to depth of 1 to 2 ft using plow. Make sure amendment is in powdered or granular form.
   - Liquid Amendment: Apply over soil surface with or without mechanical incorporation.
4) Adding mulch and fertilizer may enhance rapid restoration (see page 6).
5) Use perimeter berms to contain rainfall or use sprinkler irrigation in affected area to increase infiltration and leach salts (sodium) from affected soils.

Rules of Thumb:

- *ADD CHEMICAL AMENDMENTS BEFORE IRRIGATION OR A PERIOD OF HEAVY RAIN.*
- *Pulse flooding (watering with a few inches of water every few days) can reduce water requirements by half.*
- *A final top dressing of gypsum or mulch can protect the soil surface from dispersing after a rainfall or water event.*
- *See **page 5** for amount of supplemental irrigation that is needed.*
- *Install erosion controls, if necessary.*

Addition of Chemical Amendment
Photo Courtesy of David Carty

TECH TIP 1:

If soil pH is between 5.5 and 8.5, and if chloride or nitrate will not impact groundwater, you can replace gypsum with:

- *Calcium Chloride* [$CaCl_2$:$2H_20$] at 0.85 pounds per pound gypsum requirement
- *Calcium Nitrate* [$Ca(NO_3)_2$] at 0.95 pounds per pound gypsum requirement

TECH TIP 2:

Adding more than the calculated amount of calcium will not hurt the soil.

Calculation Method 1: Amount of Gypsum Needed Based on Soil ESP and CEC

Formula:

No. of lbs of gypsum to add per square foot of impacted soil – [ESP - 5] x [CEC] x [0.00078]

(in pounds / ft²) *(in %)* *(in meq/100 grams)*

Calculation Steps:

1. Perform calculation for 0 to 1 ft layer.
2. Perform calculation again for 1 to 2 ft layer.
3. Add lbs per sq. ft. numbers together.
4. Multiply lbs of gypsum per sq. ft. by area of spill in sq. ft. to get lbs of gypsum.
5. If soil pH is <5.5, then may need to add $CaCO_3$ to replace some of the gypsum. See API Publication 4663.
6. If soil pH > 8.5, then may need to add sulfur or alternative chemical to decrease pH. See API Publication 4663.

Calculation Method 2: Amount of Gypsum Needed Based on Sodium Concentration in Produced Water Release

Formula:

No. of lbs of gypsum to add to affected area – [sodium concentration] x [6.94] x [volume spilled] x [0.00019]

(in pounds)

(sodium concentration in mg/L)
(volume spilled in bbl; 42 gallons per bbl)

Calculation Steps:

1. Calculate lbs of gypsum to add using formula shown above.
2. Note that sodium typically comprises 20-35% of the TDS concentration, and can be estimated as (0.2 to 0.35) x TDS (mg/L).

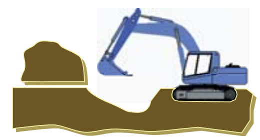
Natural Remediation | *In-situ Chemical Amendment Remediation* | **Mechanical Remediation**

Soil Remediation Alternative 3: *Mechanical Remediation*

Concept: Mechanical Remediation refers to a number of remediation techniques that involve mechanical mixing, spreading, or relocation of the affected soil.

OPTION A. Land Spreading

Approach: Spread salt-affected soil over a large area and mix with unaffected soils to reduce the salt concentration to an acceptable level. Use front-end loader or backhoe for small spills; use dozers, trackhoes for larger spills.



Use the following method to calculate the required area and thickness for land spreading:

Formula 1:

$$\text{Area required for spreading} \;-\; \frac{\text{[Volume of salt-affected soil to be spread] x [(spill soil EC) – (receiving soil EC)] x 2.6*}}{\text{[(final soil EC goal) – (receiving soil EC)]}}$$

(in square feet) *(Volume in cubic feet. EC in mmhos/cm)*

* This equation assumes 1.3 times expansion factor and a 0.5 foot mixing thickness.

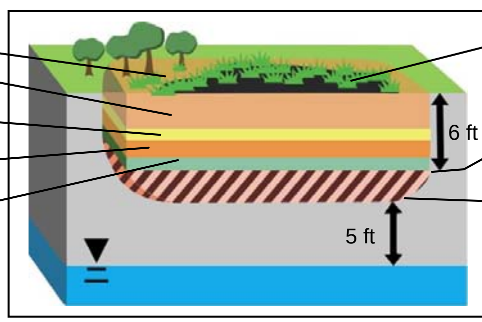
Formula 2:

$$\text{Thickness of salt-affected soil to be spread on received soil} \;-\; \frac{\text{[Volume of salt-affected soil]}}{\text{[Area required for spreading]}}$$

(in feet) *(Volume in cubic feet. Area in square feet)*

OPTION B. Burial

Approach: Construct burial vault that may have <u>*one or more of the following*</u> features (*Source: API Publication 4663*):



OPTION C. Road Spreading

Approach: Check with regulatory agencies to determine how road spreading may be performed. If acceptable, apply salt-affected soils so that salt does not damage the road bed, roadside vegetation, or significantly affect runoff water (same as with land spreading).

OPTION D. Soil Washing

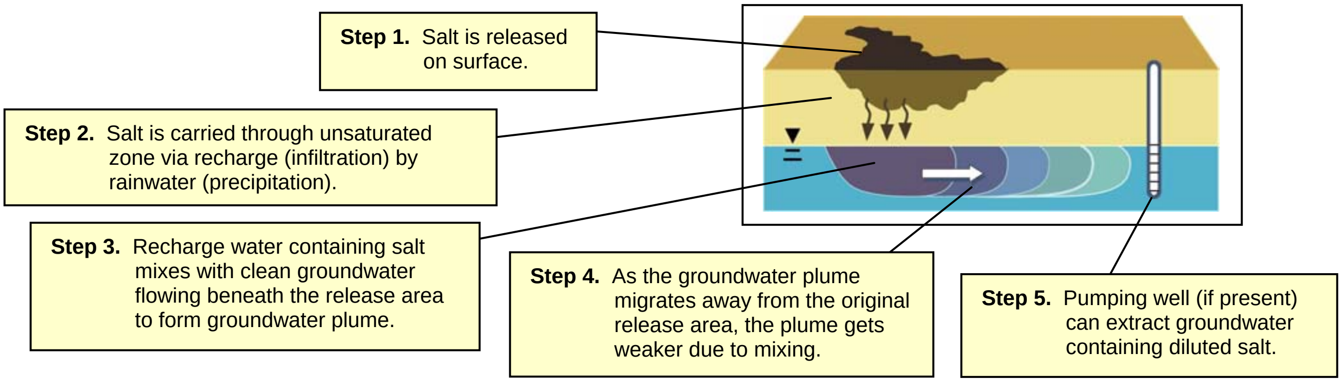
Approach: Use soil washing contractor to mix water with salt-affected soil to decrease salinity. Collect rinse water for treatment or disposal. Note this option is likely to be more costly than other options.

OPTION E. Off-Site Disposal

Approach: Excavate and transport salt-affected soil to approved landfill as an exploration and production waste. Transport manifests may be required by some regulatory agencies. Fill excavation with clean fill and plant appropriate vegetation.

Chloride Transport Pathway

Chloride associated with a produced water release to the surface can impact surface soils and be transported to underlying groundwater. The transport process can be separated into four separate steps as shown below. This guide provides a Planning Model (see below and pages 10-14), that can be used to evaluate this migration process. Information on Beneficial Uses of groundwater is provided on page 15. A summary of key parameters that influence chloride transport to groundwater are shown on page 21.



Using the Planning Model

Results of this modeling are combined with other site-specific information to determine the *potential effects on groundwater*.

To use the Planning Model, perform the following steps:

Step 1: Estimate *Mass of Chloride* using volume and chloride concentration of a produced water release, *OR*
Estimate *Mass of Chloride* using the area of produced water release (area of affected soil) and the chloride concentration of the soil (page 10)
Step 2: Estimate *Chloride Loading Rate to Groundwater* using the Annual Precipitation, (page 11)
Step 3A: Estimate *Increase in Chloride Concentration in Groundwater at the Release Point* using the width of the release area, (page 12)
Step 3B: Refine the estimate from Step 3A using site-specific information (either the site location, or more detailed hydrogeologic info), (page 13)
Step 4: (Optional) Estimate the *Increase in Chloride Concentration in Groundwater at a Downgradient Point* using the distance from the release area (and other parameters), (page 14)

Key assumptions and limitations of the Planning Model include: 1) salts are mixed evenly throughout the soil; 2) the *percentage* of the rainfall that infiltrates through the soil to groundwater is proportional to the amount of rainfall; 3) the recharge rate is the 80th percentile of recharge rates from data compiled from API Publication 4643; 4) almost all the salts in affected soils can be flushed out with 12 inches of recharge (from API 4663); 5) no capillary effects, evaporation, or other transport processes except advection, mixing, and dispersion in the saturated zone are present; 6) no density effects are assumed in transport of chloride in groundwater; 7) salt is mixed throughout the water-bearing unit; 8) a 2x safety factor is assumed; and 9) potential impacts only apply to the uppermost water-bearing unit, and NOT to deeper, regional aquifers. When applied to site conditions presented in API Publication 4734, the Planning Model was more likely to show higher chloride concentrations in groundwater than chloride concentrations predicted by HYDRUS, a much more sophisticated leaching model.

Other Methods

Other approaches can also be used to provide more accurate estimates of chloride migration. Key resources include:

- ***API Publication 4734:*** In this study, the authors performed several hundred computer simulations with the HYDRUS model to determine the sensitivity of groundwater underlying a produced water release to various factors such as release volume, chloride concentration of the produced water, depth to groundwater, soil type, rainfall and hydrology of the area, and other factors. Review of this document can provide additional information regarding the impact of produced water releases on groundwater.
- ***More Detailed Computer Models:*** Models such as VADSAT or HYDRUS can be applied to investigate potential groundwater impacts from produced water releases.
- ***Site Investigation:*** A groundwater site investigation involving the collection of groundwater samples from monitoring wells or direct push sampling techniques can show if a produced water release has actually affected groundwater at a given site.

Factors That May Influence Remediation of Saltwater Releases

For the purposes of this guide, the principal objective of groundwater remediation is to *maintain the beneficial use of the groundwater resource*. However, remediation of saltwater releases can be influenced by a variety of non-technical factors that are not directly addressed in this guide. These **non-technical factors** include (API Publication 4663):

- Landowner claims
- Lease agreements
- Federal, state, and local regulations
- Reduction of long-term liabilities
- Company policies

GROUNDWATER EFFECTS: PLANNING MODEL STEP 1

Evaluating Impacts - GROUNDWATER

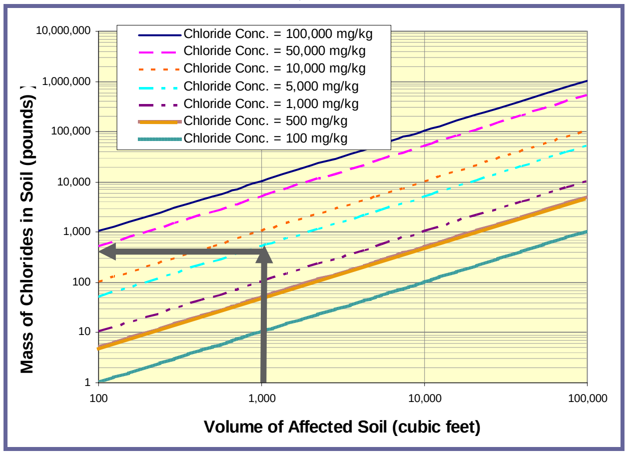
STEP 1: Estimate **MASS OF CHLORIDE RELEASED** by either Method A or Method B below:

METHOD A. You know Volume of Affected Soil and its Chloride Concentration…

OR

METHOD B. You know Volume of Produced Water Release and its Concentration…

USE THIS GRAPH



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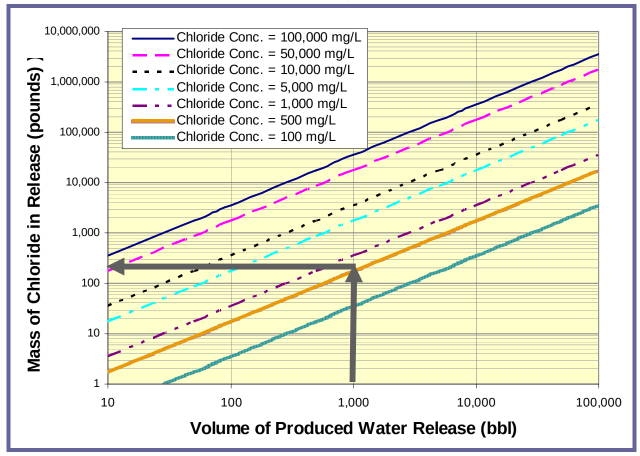


OR USE THIS EQUATION

Mass Chloride (*in lbs chloride*) = (Area of Affected Soil (*in sq feet*)) x (Depth of Affected Soil (*in feet*)) X (Chloride Conc. of Affected Soil (*in mg/kg*)) ÷ (9500)

OR USE THIS EQUATION

Mass Chloride (*in lbs chloride*) = (Volume Released (*in barrels*)) x (Chloride Concentration (*in mg/L or ppm*)) ÷ (2900)

GO TO STEP 2 WITH MASS OF CHLORIDE

METHOD A EXAMPLE

Example: Mass of chloride in 50 ft x 10 ft area of affected soil with 5000 ppm chloride in soil to 2 feet deep.

Mass Chloride = (50 ft) x (10 ft) x (2 ft) x (5000 ppm) ÷ (9500)
(*lbs chloride*)

Mass Chloride = 526 pounds

METHOD B EXAMPLE

Example: Mass of chloride from 1000 bbl release with 500 mg/L chloride:

Mass Chloride = (1000 bbl) x (500 mg/L) ÷ (2900)
(*lbs chloride*)

Mass Chloride = 172 pounds

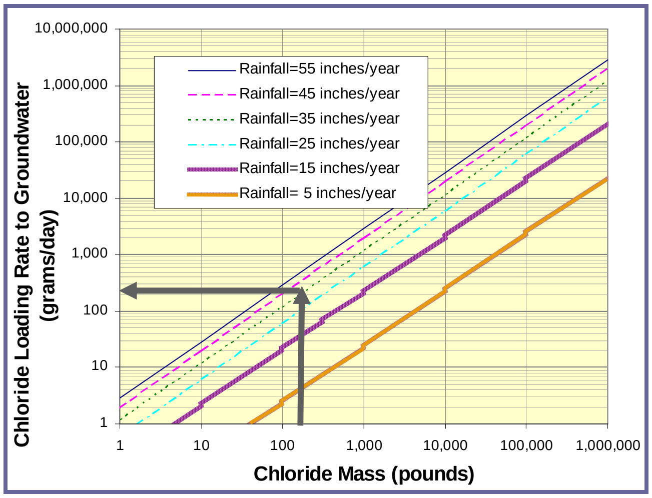
BACKGROUND

These graphs and equations are based on conventional mass calculations for affected water and soil. See page 9 for more information about the assumptions and limitations related to the Planning Model. NOTE: 1 bbl = 42 gallons = 159 liters.

STEP 2: Estimate the **CHLORIDE LOADING RATE** TO GROUNDWATER (in grams per day):

Start with CHLORIDE MASS...

USE THIS GRAPH



OR USE THIS EQUATION

__Chloride Loading__
Rate to GW = (Mass Chloride) x (Annual Rainfall)^2 ÷ 1000
(in grams/day) (in lbs) (in in/yr)

(Note: Using the square of the rainfall is correct; the higher the annual rainfall, the higher the fraction of rainfall that reaches groundwater. GW = groundwater)

THEN ADJUST THE ANSWER FOR SOIL TYPE

If SANDY SOIL:
Use *chloride loading rate shown in the graph or equation.*

If SILTY SOIL:
Divide the *chloride loading rate from graph or equation* by 2 (i.e., ÷ 2).

If CLAYEY SOIL:
Divide the *chloride loading rate from graph or equation* by 10 (i.e., ÷ 10).

GO TO STEP 3A WITH CHLORIDE LOADING RATE

BACKGROUND:

This graph and this equation are based on:

1) An empirical equation to estimate the recharge rate to groundwater due to rainfall developed by Connor et al., 1997, for the Texas Commission on Environmental Quality. The recharge equation was derived from a study of numerous recharge studies in API Publication 4643, and represents a conservative estimate for recharge (i.e., overpredicts).

2) It is assumed that the excess salinity in an affected soil can be fully flushed from soil by 12 inches of recharge (API Publication 4643).

3) A safety factor has been applied (i.e., the chloride loading rate is increased by a factor of 2 to ensure that the planning model generally overpredicts results compared to the HYDRUS model).

4) See Page 9 for more information about the assumptions and limitations associated with the Planning Model.

EXAMPLE

Example: Take results from Example B on page 10. Assume SILTY SOIL and 40 inches per year of rainfall.

__Chloride Loading__
Rate to GW = (172 lbs) x (40 in/yr)^2 ÷ (1000) ÷ (2)
(in grams/day)

__Chloride Loading Rate to GW__ = 138 grams per day
(about 0.3 pounds per day)

GROUNDWATER EFFECTS: PLANNING MODEL STEP 3A

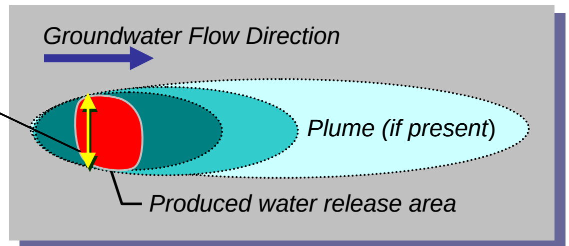
Evaluating Impacts - GROUNDWATER

Step 3A: Estimate the increase in concentration of chloride in groundwater next to the release (at a generic site) by dividing the chloride loading rate by an estimate of the groundwater flow that mixes with the chloride:

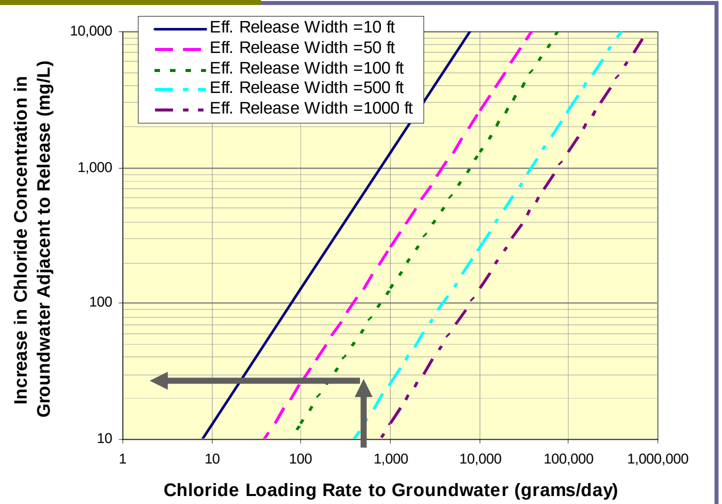
Start with CHLORIDE LOADING RATE…

DETERMINE THE WIDTH OF THE RELEASE AREA

Effective Width of Release Area Perpendicular to Groundwater Flow



USE THIS GRAPH



OR USE THIS EQUATION

Increase in Chloride Conc. = { (Chloride Loading Rate) ÷ (Eff. Width) } x (13)
at a Generic Site *(in mg/L)* *(in g/day)* *(in ft)*

Note: *This assumes a national average groundwater Darcy velocity from a statistical study of 400 hazardous waste sites (from API Publication 4476). For more information regarding uncertainty and differences in discharge rate between regions, see* ***page 13.***

GO TO STEP 3B WITH INCREASE IN CHLORIDE CONCENTRATION

BACKGROUND

To estimate the increase in chloride concentration in groundwater, the chloride loading rate is divided by an estimate of the groundwater flow that mixes with the chloride. The groundwater flow is assumed to be the groundwater Darcy velocity (hydraulic conductivity times hydraulic gradient) multiplied by the estimated mixing zone thickness for the water-bearing unit underlying the release area. For this method, a typical value for groundwater discharge of 1000 cubic feet per year per foot of water-bearing unit width was derived from: i) a statistical study of 400 hazardous waste sites prepared by API (API Report No. 4476) when a mid-range Darcy groundwater velocity of 33 ft/yr was indicated; and ii) an estimated value for the mixing zone thickness of 30 feet.

EXAMPLE

Assume a chloride loading rate of 138 grams per day and a release area effective width of 100 ft:

Increase in Chloride Conc. (mg/L) = [(138 grams/day) ÷ (100 ft)] x (13)
at a Generic Site

Increase in Chloride Concentration (mg/L) = 18 mg/L

See Page 9 for more information about the assumptions and limitations of the Planning Model.

STEP 3B: Adjust the increase of concentration in chloride to account for more site-specific groundwater conditions:

METHOD A, Regional Estimate: You want to account for regional differences in groundwater velocity…

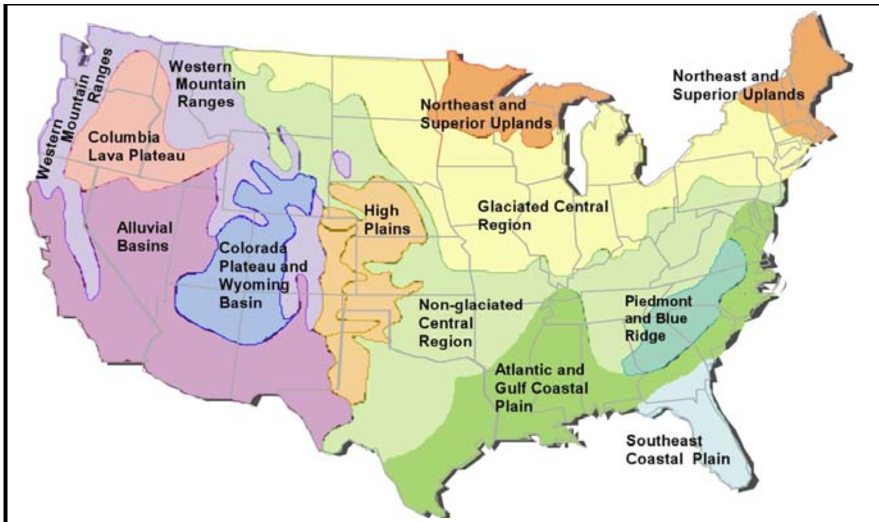
USE THIS CHART TO GET GROUNDWATER (GW) FLOWRATE

METHOD B, Site-Specific Estimate: You know groundwater velocity and water-bearing unit thickness…

USE THIS EQUATION

Adjusted Increase in Chloride Conc. *(mg/L)* = (Increase in Chloride Conc. from **Step 3A**) *(mg/L)* ÷ (Groundwater Velocity) *(Darcy Velocity, ft/yr)* ÷ (WBU Thickness) *(WBU: water-bearing unit, ft)* x (1000)

GO TO NEXT STEP (STEP 4)



	GW Flow Rate (ft^3 / yr / ft width)		
	Median Value	*25th Percentile*	*75th Percentile*
Western Mountain Ranges	6000	800	22000
Alluvial Basins	1000	180	4800
Colorado Plateau and Wyoming Basin	600	300	7600
High Plains	600	300	7600
Non-Glaciated Central	600	150	1100
Atlantic and Gulf Coastal Plain	200	40	900
All Other Regions	1000	---	---

THEN USE GW FLOWRATE IN THIS EQUATION

Adjusted Increase in Chloride Concentration (mg/L) = Increase in Chloride Concentration (mg/L) from **Step 3A** ÷ Value from Chart x 1000

BACKGROUND

The groundwater dilution capacity estimate can be improved by utilizing groundwater velocity and water-bearing unit thickness several ways:

- **METHOD A:** Use regional values derived from the HGDB Hydrogeologic Database (Newell et al., 1990), a statistical study of 400 hazardous waste sites prepared by API (API Report No. 4476). Median values and upper-range (75th percentile) and lower-range (25th percentile) values are presented. This method assumes a 30-ft mixing zone thickness and the effective source width entered during STEP 3A (see the previous page).
- **METHOD B:** Use site-specific data from near-by water supply or monitoring wells.

EXAMPLE

Option A. Assume site is in Atlantic and Gulf Coastal Plain.

Adjusted Increase in Chloride Conc. = (Increase in Chloride Conc. from **Step 3A** ÷ Value from Chart) x 1000

Adjusted Increase in Chloride Conc. = (18 mg/L ÷ 200) x 1000

Adjusted Increase in Chloride Conc. = 90 mg/L

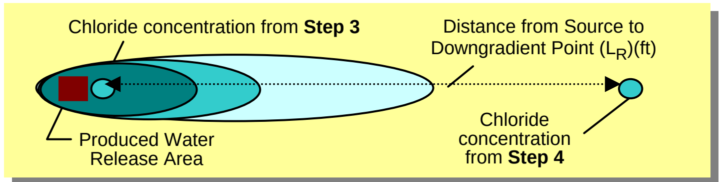
NOTE: This is likely to over-estimate the increase in chloride concentration. See Page 9.

See Page 9 for more information about the assumptions and limitations of the Planning Model.

GROUNDWATER EFFECTS: PLANNING MODEL STEP 4

Evaluating Impacts - GROUNDWATER

STEP 4 (Optional): Estimate the change in concentration in groundwater after it has mixed with groundwater at a point downgradient of the release area:

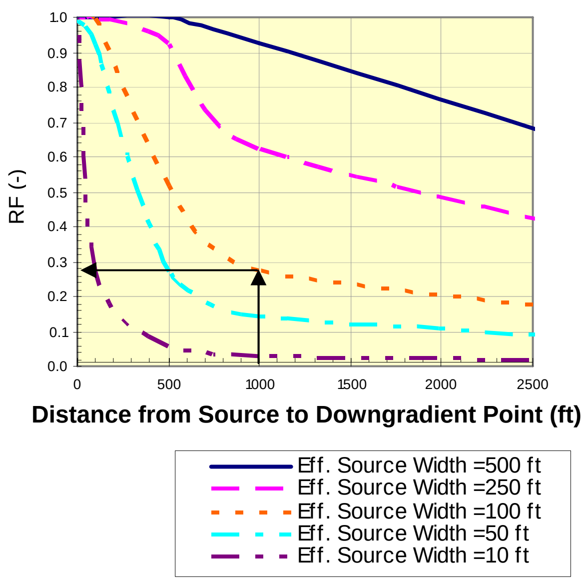


METHOD A. You only know distance to downgradient point…

OR

OTHER METHODS….

USE THIS GRAPH



RF = "Reduction Factor"

Several methods are available to account for the effect of the mixing (dispersion and other processes) of chloride plumes as they migrate downgradient:

Graphical Methods: API Publication 4659 *Graphical Approach for Determining Site-Specific Dilution-Attenuation Factors (DAFs)* uses the Domenico analytical solution to develop graphical approach for estimating Dilution Attenuation Factors (DAFs). Note that

$$DAF = \frac{1}{RF}$$

where RF is the Reduction Factor.

Groundwater Models: Groundwater model such as BIOSCREEN, MT3D, etc., can be used to model the dispersion caused by the movement of the chloride plume to a downgradient location. To use these models, the hydrogeologic characteristics of the water-bearing unit (hydraulic conductivity, gradient, effective porosity) and key transport parameters (dispersivity, source characteristics) must be measured or estimated.

Site Investigation: A groundwater site investigation involving the collection of groundwater samples from monitoring wells or direct push sampling techniques can show if a produced water release has actually affected groundwater at a given site.

FINAL ANSWER	Increase in Chloride Concentration at Downgradient Point	= [Increase in Chloride Concentration from Step 3] x [RF]

BACKGROUND

METHOD A: The steady-state Domenico analytical transport model was used to develop a family of computer simulations. Two-dimensional aquifer conditions were assumed. Longitudinal dispersivity was assumed to be equal to 10% of the modeled distance. Transverse dispersion was assumed to be 10% of longitudinal dispersion.

EXAMPLE

To predict the groundwater concentration at a point 1000 ft downgradient of a release area that is 100 ft wide and has increased the chloride concentration by 90 mg/L:

Increase in Chloride Concentration (mg/L) = 90 mg/L x RF

RF 1000 ft downgradient from Method A Chart = 0.28

Increase in Chloride Concentration (mg/L) = 90 mg/L x 0.28 (from METHOD A chart)

1000 ft downgradient = 25 mg/L

Beneficial Uses of Groundwater

If an increase in the chloride concentration in groundwater is known or estimated (i.e., by using the Planning Model, more sophisticated model, or sampling wells), the impact on the beneficial use of the groundwater can be determined. Beneficial uses MAY include:

- drinking water supply;
- industrial water supply;
- irrigation or livestock water; and
- discharge to surface water (aquatic life).

KEY POINT:
There is no impairment to the resource unless the actual beneficial use of the water is restricted or impaired.

The applicability of a given groundwater resource for these beneficial uses may depend, in part, on the concentrations of salt-related constituents, such as chloride and/or total dissolved solids (TDS). In the United States, groundwater is often regulated by the state governments on the basis of the use of the groundwater. Examples of beneficial uses are shown below:

Drinking Water and Industrial Uses

The Safe Drinking Water Act sets standards for drinking water quality to be achieved for public water supplies. Total dissolved solids and chloride are not considered by the U.S. EPA *to present a risk to human health at the Secondary Maximum Concentration Level (SMCL)* but are considered "nuisance chemicals" and have the following SMCLs:

Constituent	Secondary MCL * (mg/L)	Noticeable Effects Above Secondary MCL
Total Dissolved Solids (TDS)	500	hardness; deposits; colored water; staining; salty taste
Chloride	250	salty taste

** The U.S. EPA does not consider these constituents to present a risk to human heath at these levels. These levels are established only as guidelines to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, odor, and color.*

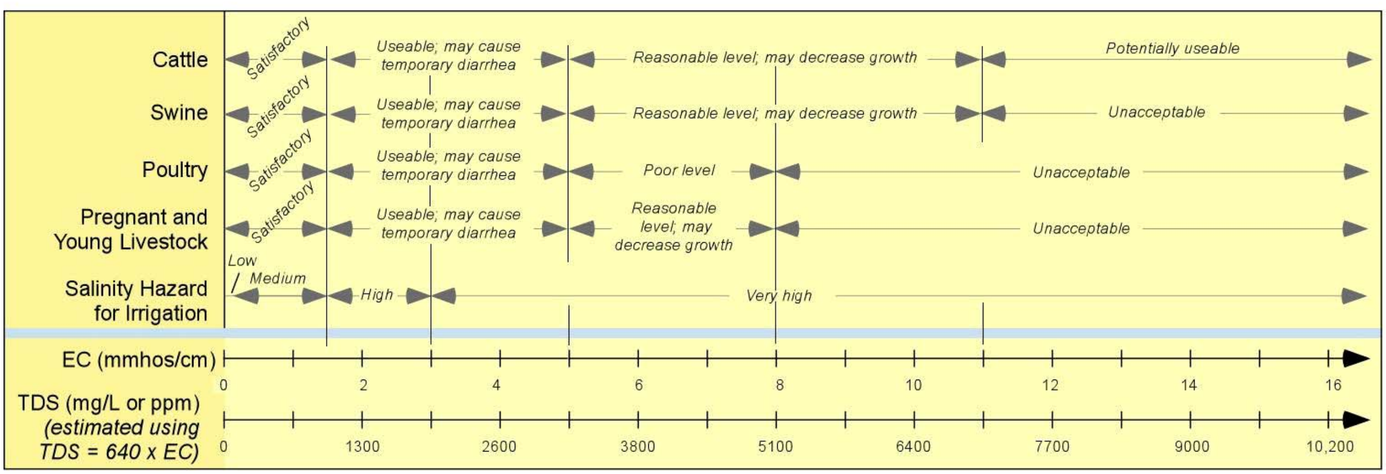
Industrial water quality requirements vary significantly, depending on the particular industry. For most industries, the acceptable concentrations of chloride and TDS are significantly higher than drinking water standards in most cases.

Aquatic Life Protection

The U.S. EPA (1988; 2006) developed ambient aquatic life criteria for chloride for acute exposures (860 mg/L) and chronic exposure (230 mg/L). Several states developed aquatic life criteria for non-priority pollutants including TDS that range from 250 mg/L to 2500 mg/L (Iowa, 2003).

Agricultural Uses of Water

There is a wide variety of research that summarizes the effect of salinity on livestock and irrigation. Data compiled by USDA-NCRS and presented in API Publication 4663 is summarized below:



Groundwater Response Actions

If groundwater is impacted adversely, there are a wide variety of approaches that can be taken to manage the problem, including installation of an engineered solution, providing an alternative water supply, implementing a passive remediation approach, evaluating the actual risk associated with the impact and/or combining approaches. Example technologies include: Natural Attenuation; Alternative Water Supply; Plume or Source Containment; Point of Use Treatment; and Groundwater Pump and Treat.

Produced Water

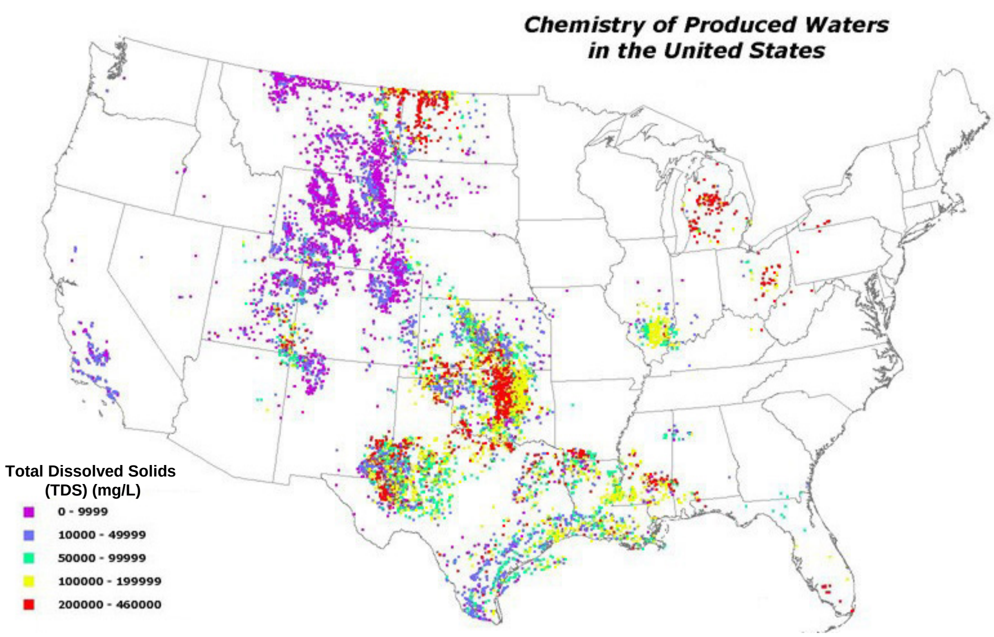
Produced water refers to water from underground geologic formations that is brought to the surface (or "produced") in the process of oil or natural gas production. This formation water has been in contact with the geologic strata for many thousands of years and, as a result, may contain elevated concentrations of natural minerals that have dissolved from the rock or soil. The resulting chemical composition of the produced water can vary from fresh to very saline, as follows (USGS):

- ***Brine*** *(total dissolved solids (TDS) greater than 35,000 mg/L (ppm))*
- ***Highly saline*** *(TDS between 10,000 and 35,000 mg/L)*
- ***Moderately saline*** *(TDS between 3,000 and 10,000 mg/L)*
- ***Slightly saline*** *(TDS between 1,000 and 3,000 mg/L)*
- ***Freshwater*** *(TDS less than 1,000 mg/L)*

The E&P industry uses great care during the handling and disposal of produced water. However, unintentional releases do occur.

How Does Produced Water Quality Vary Across The U.S.?

This map from the U.S. Geological Survey (Breit and Otton, 2002) based on almost 60,000 produced water analyses taken across the country, shows the Total Dissolved Solids (TDS) content to vary significantly among the various oil and gas regions of the U.S. Such variations are explained by the age, geochemistry, and hydrology of the specific formation(s) from which the water comes. In the Powder River Basin of Wyoming, gas production zones can yield produced water with a TDS < 1000 mg/L, corresponding to freshwater, while in some areas of Oklahoma and West Texas, the TDS content can exceed 200,000 mg/L, corresponding to strong brine.



Key Produced Water Statistics

HOW MUCH PRODUCED WATER IS GENERATED IN THE U.S.?

18 billion barrels *of water* in 1996, down from 21 billion barrels in 1985 (API, 2000).
For comparison, U.S. oil production in 1996: *2.4 billion barrels of oil*.

HOW IS IT MANAGED?

In the United States in 1995, produced waters were managed in accordance to state regulations (API, 2000).

92% ***Injected*** (three-fourths for enhanced oil recovery, one fourth in Class II injection wells)

3% ***Discharged*** to surface water (mostly low salinity water from coalbed methane production)

3% ***Disposed*** (in percolation pits, on-site evaporation, and treatment plants)

2% ***For Beneficial Use***

> ***TECH TIP:***
> Concentrations of salts in groundwater are usually reported in **milligrams per liter** ("mg/L").
>
> For water samples, this is approximately the same as a "part per million" (ppm). The difference between "mg/L" and "ppm" increases as the salt concentration of the water sample increases.

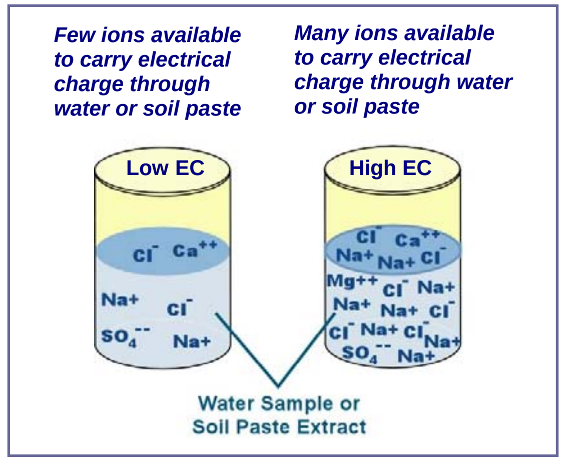
DEFINITION OF KEY PARAMETERS

EC: Electrical Conductivity

Description: EC represents the ability of a solution to carry an electrical current through ions in the water. In practice, EC is proportional to the amount of inorganic ions (primarily sodium, chloride, sulfate, calcium, potassium, magnesium, and bicarbonate) dissolved in the water. EC is the opposite of resistivity and may also be called specific conductance.

Units: EC is measured in milli-mhos per centimeter (mmhos/cm), or deciSiemens per meter (dS/m). Note that 1 mmhos/cm = 1 dS/m.

Method: For Liquid: Use Method 120.1 (Black, 1965). For Soil: Use the Paste Extract Method 62-2.2 (Black, 1965).



TDS: Total Dissolved Solids

Description: TDS is the total sum of all dissolved constituents in the water. This test is performed by: 1) filtering the water to remove suspended solids, 2) heating the sample to drive off all the water, and 3) weighing the residue.

Units: TDS is reported in milligrams per liter (mg/L). For most applications, mg/L can be assumed to be equivalent to parts-per-million (ppm).

Method: 160.1 (U.S. EPA, 1983) or estimated from liquid EC.

DATA TIP 1:

Some meters and laboratories report specific conductance in units of *micro-mhos per centimeter* (µmhos/cm), particularly for water samples.

Make sure to convert micro-uhos/cm (µmhos/cm) to *milli-mhos per centimeter (mmhos/cm)* by dividing micro-mhos/cm by 1000 to use some of the rules in this guide!

DATA TIP 2:

EC and TDS are two different measurements for the same water quality characteristic. EC is an indirect measurement that can be performed in the field with a meter, while TDS is a direct measurement performed in the lab. You can convert between them with:

IF EC < 5 mmhos/cm: EC (mmhos/cm) x 613 = TDS (mg/L or ppm)

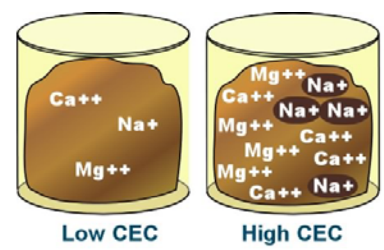
IF EC > 5 mmhos/cm: EC (mmhos/cm) x 800 = TDS (mg/L or ppm)

CEC: CATION EXCHANGE CAPACITY OF SOIL

Description: A cation is a positively charged ion. For evaluation of soil sodicity, the key cations are calcium, potassium, magnesium, and sodium. CEC is the total amount of exchangeable cations that can be held in the soil (i.e., cations that can be removed and exchanged for other cations in waters infiltrating through the soil).

Units: Milliequivalents per 100 grams soil.

Method: 57-3 (Black, 1965)



ESP: EXCHANGEABLE SODIUM PERCENTAGE OF SOIL

Description: The percentage of CEC of a soil sample that is comprised of sodium. Similar to **SAR** (sodium adsorption ratio).

Units: Percent (%)

Calculation:
$$ESP = \frac{\textit{Exchangeable Sodium (meq/100 grams soil)}}{\textit{CEC (meq/100 grams soil)}} \times 100$$

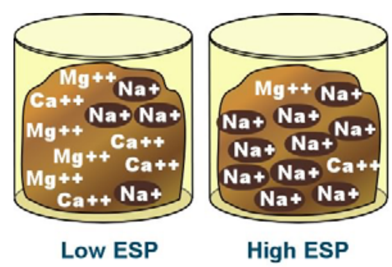
SAR: SODIUM ADSORPTION RATIO OF SOIL

Description: An indication of the sodium hazard to a soil. Similar to **ESP**.

Units: unitless (-)

Calculation:
$$SAR = \frac{[Sodium(meq/l)]}{\sqrt{\left(\frac{[Calcium(meq/l) + Magnesium(meq/l)]}{2}\right)}}$$

(in concentrations of meq/L), or use **DATA TIP 3**.



Importance of CEC, ESP, and SAR

Clays and organic soils have a large number of negatively-charged sites that can hold cations such as sodium. During a salt spill, the calcium, potassium, and magnesium can be replaced by sodium, which changes the structure of the clays.

DATA TIP 3:

ESP and SAR are two expressions for the fraction of the soil's cations that are comprised of sodium. You can convert between ESP and SAR using the following approximation:

$$ESP(\text{in } \%) = 100 \times \frac{-0.0126 + 0.01475 \times SAR}{1 + (-0.0126 + 0.01475 \times SAR)}$$

DATA TIP 4:

The chloride concentration and sodium concentration of produced water can be estimated by assuming all of the TDS is comprised of salt, and using the following equations:

Sodium concentration (mg/L)	= TDS (mg/L) x 0.2 (low end estimate) = TDS (mg/L) x 0.35 (high end estimate)
Chloride Concentration (mg/L)	= TDS (mg/L) x 0.3 (low end estimate) = TDS (mg/L) x 0.6 (high end estimate)

How Salt Can Affect Plants

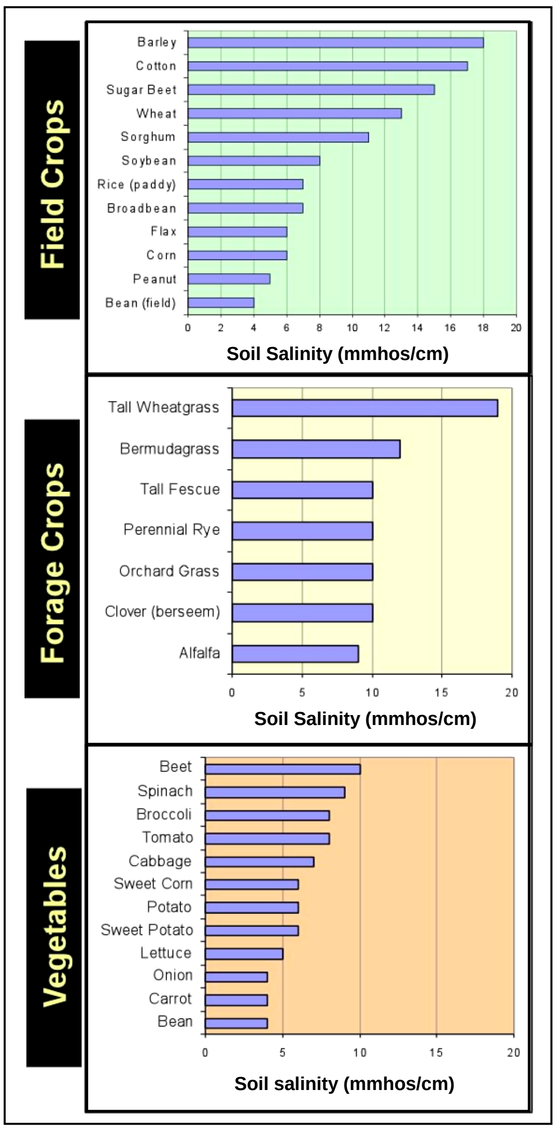
Water present within the soil pores is subject to several forces related to: i) the soil solid phase; ii) the dissolved salts; and iii) the gravitational field. Plants work against the capillary tension of water within the soil pores in order to draw in water. An increase in the TDS of the soil pore water increases the osmotic effect, thereby increasing the force a plant must exert to extract water from the soil. This can cause plants to go into drought stress even though a substantial amount of water may still be present in the soil.

Plants are more sensitive to salinity during germination than in later stages of growth. Sprigging, sodding, or transplanting of plant materials is a way to avoid the sensitivity of the seedling stage.

Symptoms of Plant Stress Caused by Salt

Excessive soil salinity can result in barren spots, stunted vegetative growth with considerable variety in size, and a deep blue-green foliage (USDA, 1954). Plants that are stunted due to low fertility are usually yellow-green, while those stunted due to elevated salinity are characteristically blue green. The bluish appearance is the result of an unusually heavy waxy coating on the surface of the leaves, and the darker color is due to increased chlorophyll content. Some plants may develop dead areas or tipburn or exhibit cupping or rolling of the leaves.

Soil Salinity Levels at Which 50% Decrease in Plant Yield is Expected. Data Compiled by Ayers and Westcot (1977).



Effects of Salt-Impacted Soil on Plant Growth
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Tolerance of Specific Plant to Sodicity (excess sodium) of Soil (adapted from Keech, 1995)

SENSITIVE	MODERATELY TOLERANT	TOLERANT	VERY TOLERANT
SOIL ESP = 2-20%	SOIL ESP = 20-40%	SOIL ESP = 40-60%	SOIL ESP > 60%
Deciduous Fruit	Clover	Wheat	Crested Wheatgrass
Nuts	Oat	Cotton	Tall Wheatgrass
Citrus Fruit	Tall Fescue	Alfalfa	Rhodegrass
Avocado	Rice	Barley	
Bean	Dallisgrass	Tomato	
		Beet	

KEY POINTS: *OSMOTIC STRESS*

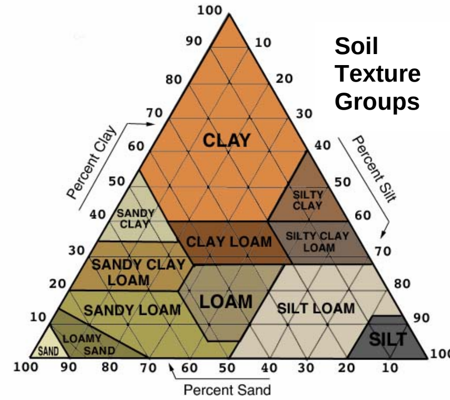
Cause: High Soil EC/Salinity Values

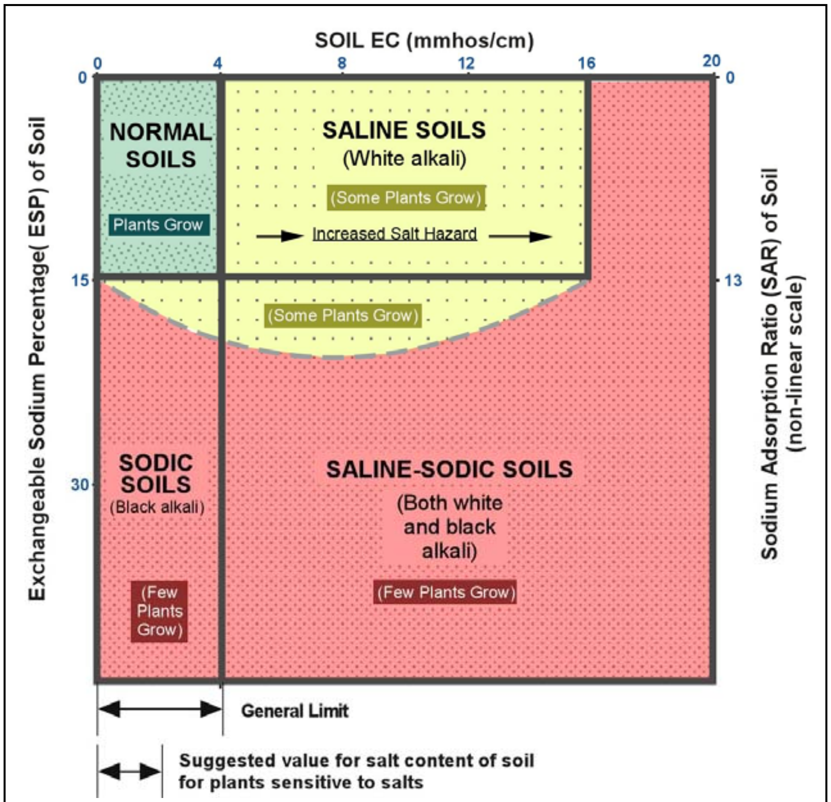
Mechanism: As salinity increases, osmotic forces hinder transport of water from soil pores to plant roots.

Potential Impacts:
Plants can be stressed or killed.

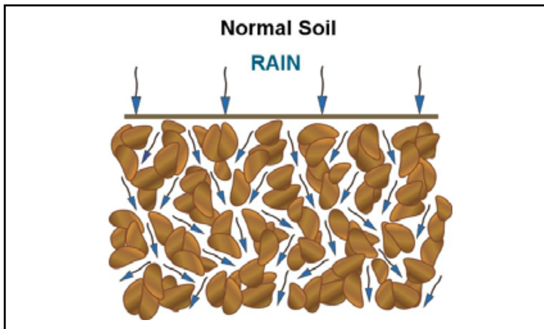
The Impact of Salt on Clay in Soils

When salt migrates through soils containing clay minerals (see soil texture triangle to the right), the non-sodium ions present in the clays (e.g., potassium, calcium, and magnesium) can be removed and replaced (exchanged) by the sodium in the salt water. This results in *dispersion,* an electro-chemically induced process which causes soil clay particles to repel each other, physically move apart, and clog soil macropores (i.e., clog the large openings in the soil). Dispersed soils have lower permeability to water than non-dispersed soils. In addition, the repulsive forces acting among the soil particles reduce the soil cohesion and make the dispersed soil more susceptible to erosion.

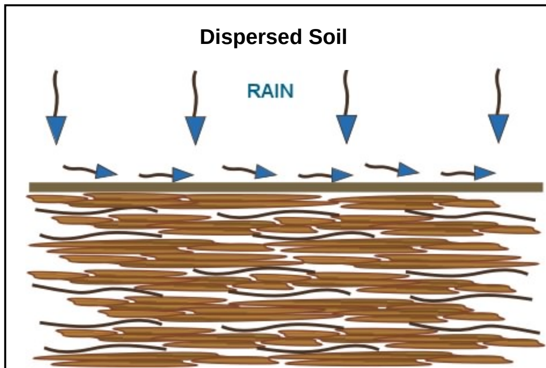




Soil Classification Based on ESP (%) (Y-Axis) and EC (mmhos/cm) (X-Axis) (API Publication 4663); adapted from Donahue et al., 1983).



Soil particles attract one another and clump together, forming macropores through which water can penetrate soil.



Soil particles repel one another and disperse, closing soil macropores. Water cannot penetrate soil, runoff is high, and soil is very erodible.

Soil Descriptions:

Normal Soils:	(EC< 4, ESP < 15) No adverse effect due to salinity
Saline Soils:	(EC>4, ESP < 15) Plants can experience osmotic stress. No dispersion and no damage to soil structure.
Sodic Soils:	(EC<4, ESP > 15) Plants will not experience osmotic stress. Soil is dispersed, damaging soil structure.
Saline-Sodic Soils:	(EC>4, ESP > 15) Plants will likely experience osmotic stress. Soil is dispersed, damaging soil structure.

Note: Soil dispersion is only a factor for clayey soils.

KEY POINTS: **SOIL DISPERSION**

Indicator:	High ESP (> 15%)
Mechanism:	Increased proportion of sodium in clays disperses clay particles, damaging soil structure.
Potential Impacts:	Soil structure is affected, drainage through soil is reduced, and soils are easier to erode.

RELATIVE IMPORTANCE OF FACTORS – GROUNDWATER IMPACTS

Groundwater Sensitivity Analysis

In a modeling study of potential impacts to groundwater (API Publication 4734), nine technical factors were evaluated as part of a sensitivity analysis. The objective of this study was to determine which of the nine factors were the most important and which were the least important in terms of predicting whether a produced water release could impact shallow groundwater (i.e., the uppermost water-bearing unit, not deeper regional aquifers). The nine factors evaluated and the range of values used in the sensitivity analysis are show below.

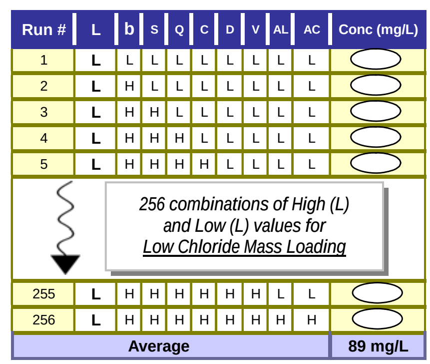
		Nine Factors Evaluated								
		1	2	3	4	5	6	7	8	9
Range of Values		Chloride Mass Loading "L" (grams/ft²)	Thickness of Aquifer "b" (ft)	Soil "S" (-)	Aquifer Flux "Q" (ft/day)	Climate "C" (-)	Ground-Water Depth "D" (ft)	Volume of Brine Release "V" (ft^3)	Dispersion Length "AL" (ft)	Ambient Cl Concentration in Groundwater "AC" (mg/L)
Level	Low	76.20	9.84	Sand	0.003	Humid (Shreveport, LA)	9.843	421.094	0.328	0
	High	18,288	98.43	Clay	0.164	Arid (Hobbs, NM)	98.425	42,109	6.562	100

Sensitivity Analysis Approach

The sensitivity analysis used a "2^k factorial" approach, where a total of 512 model simulations (2^9 = 512) were performed, one for each combination of "High" and "Low" values for the nine factors. This procedure is described below, and shown in the figure to the right.

1) To assess the importance of *Chloride Mass Loading*, 256 simulations were run with the *Chloride Mass Loading* set at "Low", and all High/Low combinations of the other eight factors. The average increase in chloride concentration to shallow ground-water was calculated to be 89 mg/L (see diagram to the right).
2) An additional 256 simulations were run where the "High" *Chloride Mass Loading* was used, resulting in an average chloride concentration increase in the shallow groundwater of 8357 mg/L.
3) Subtracting out the average of the "Low" runs from the average of the "High" runs gave a difference of (8357-89) = 8268 mg/L.

When this same approach was used for the *Groundwater Depth* factor, the difference between the "Low" and "High" runs was only 1827 mg/L, compared to 8268 mg/L for *Chloride Mass Loading*. Therefore *Chloride Mass Loading* is likely to have a greater effect than *Groundwater Depth* on chloride concentration in shallow groundwater.

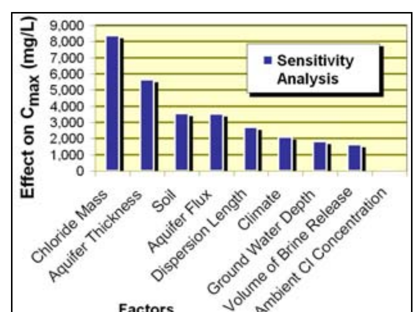


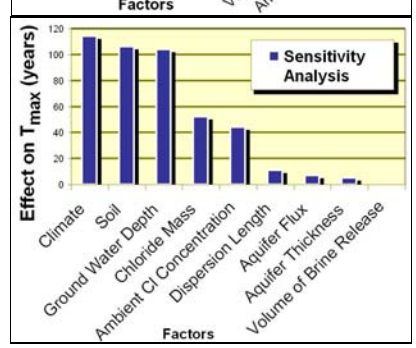
Schematic: 2^k Factorial Method Used in API Publication 4734.

This type of sensitivity analysis was performed to evaluate key factors for:

- C_{max}, the increase in chloride concentration in shallow groundwater; and
- T_{max}, the time to reach the maximum increase in chloride concentration in shallow groundwater.

Results of the sensitivity analysis are shown in the bar charts to the right. Note the values shown on the Y axis (C_{max}, or increase in chloride concentration in shallow groundwater, and T_{max}, average time to reach C_{max} concentration in groundwater) are only meaningful in a relative sense (to compare factors). The absolute value (such as 8268 mg/L for *Chloride Mass Loading*) does not correspond to an expected value for actual site conditions.





A summary of the relative importance of the nine factors is shown below:

C_{max}		T_{max}
Chloride Mass Loading	MORE IMPORTANT	Climate
Aquifer Thickness		Soil
Soil Type		Groundwater Depth
Aquifer Flux		Chloride Mass Loading
Dispersion Length		Ambient Cl Conc.
Climate		Dispersion Length
Groundwater Depth		Aquifer Flux
Volume Released		Aquifer Thickness
Ambient Cl Conc.	LESS IMPORTANT	Volume Released

KEY DATA INPUTS FOR IMPACT ASSESSMENT AND REMEDY SELECTION

Background - DATA

PARAMETER	USED ON PAGE(S)	USED FOR	HOW TO GET THIS DATA
SOIL CHEMICAL DATA			
EC of impacted soil (saturated paste method)	2, 4, 5	Rule of thumb for soil impact Soil response decision charts	Method 62-2.2 (Black, 1965) See pages 18, 23
Chloride concentration of impacted soils	9, 10	Rule of thumb for groundwater impact Groundwater planning model	Method 325.2 (U.S. EPA, 1983) See page 18
ESP (or SAR) of impacted soils	2, 7	Rule of thumb for soil impact Design of chemical amendment project	Calculated. See page 18
CEC of impacted soils	7	Design of chemical amendment project	Method 57- 3 (Black, 1965) See page 18
EC goal for soils (saturated paste method)	8	Design of mechanical remediation project	(See page 24 for related information)
SOIL PHYSICAL DATA			
Depth to impermeable layer in unsaturated zone	4	Soil response decision charts	Site-specific knowledge, site characterization data, County Soil Surveys **
Hydraulic conductivity of unsaturated zone	4	Soil response decision charts	
Shrink-swell potential of soil	4	Soil response decision charts	
Slope of land	5	Soil response decision charts	
Depth to groundwater	3	Rule of thumb for groundwater impact	
Type of soil (first 36 inches)	5, 6	Soil response decision charts Natural remediation design	
Type of unsaturated zone (36 inches deep to water table)	3	Rule of thumb for groundwater impact	
PRODUCED WATER RELEASE DATA			
Volume of produced water release	3, 7, 10	Rule of thumb for groundwater impact Design of chemical amendment project Groundwater planning model	Site-specific knowledge
Sodium concentration of produced water release	7	Design of chemical amendment project	Method 200.7 (U.S. EPA, 1983) See page 18
TDS concentration of produced water release	2	Rule of thumb for soil impact	Method 160.1 (U.S. EPA, 1983) See page 18
Chloride concentration of produced water release	3	Rule of thumb for groundwater impact Groundwater planning model	Method 325.2 (U.S. EPA, 1983) See page 18
Area of produced water release (area of affected soil)	3	Rule of thumb for groundwater impact Groundwater planning model	Site-specific knowledge
GENERAL DATA			
Release area wetland?	4	Soil response decision charts	API Publication 4663
Annual precipitation	5, 6	Soil response decision charts Natural remediation design Groundwater planning model	Web page* or API Publication 4663
Annual evaporation	5	Soil response decision charts	Web page* or API Publication 4663
GROUNDWATER DATA			
Effective width of source	12	Groundwater planning model	Sketch of site (see pages 12 and 22)
Groundwater (Darcy) velocity	13	Groundwater planning model	Site-specific knowledge, site characterization data, or approximation method (see page 13)
Thickness of water-bearing unit	13	Groundwater planning model	Site-specific knowledge, site characterization data, or approximation method (see page 13)
Distance to point of interest	14	Groundwater planning model	Site-specific knowledge and/or site characterization data
Transverse dispersivity	14	Groundwater planning model	Estimated
Groundwater concentration goal for chloride	15	Groundwater planning model	Site-specific knowledge (see page 24 for related information)

* Get precipitation and evaporation maps over the web.
One source:
http://jan.ucc.nau.edu/~doetqp-p/courses/env302/lec3/LEC3.html

**Order soil survey reports for your county at:
http://soils.usda.gov/survey/
OR
Call the USDA National Resources Conservation Service

EXAMPLE OF DATA COLLECTION EFFORT – SITE SKETCH

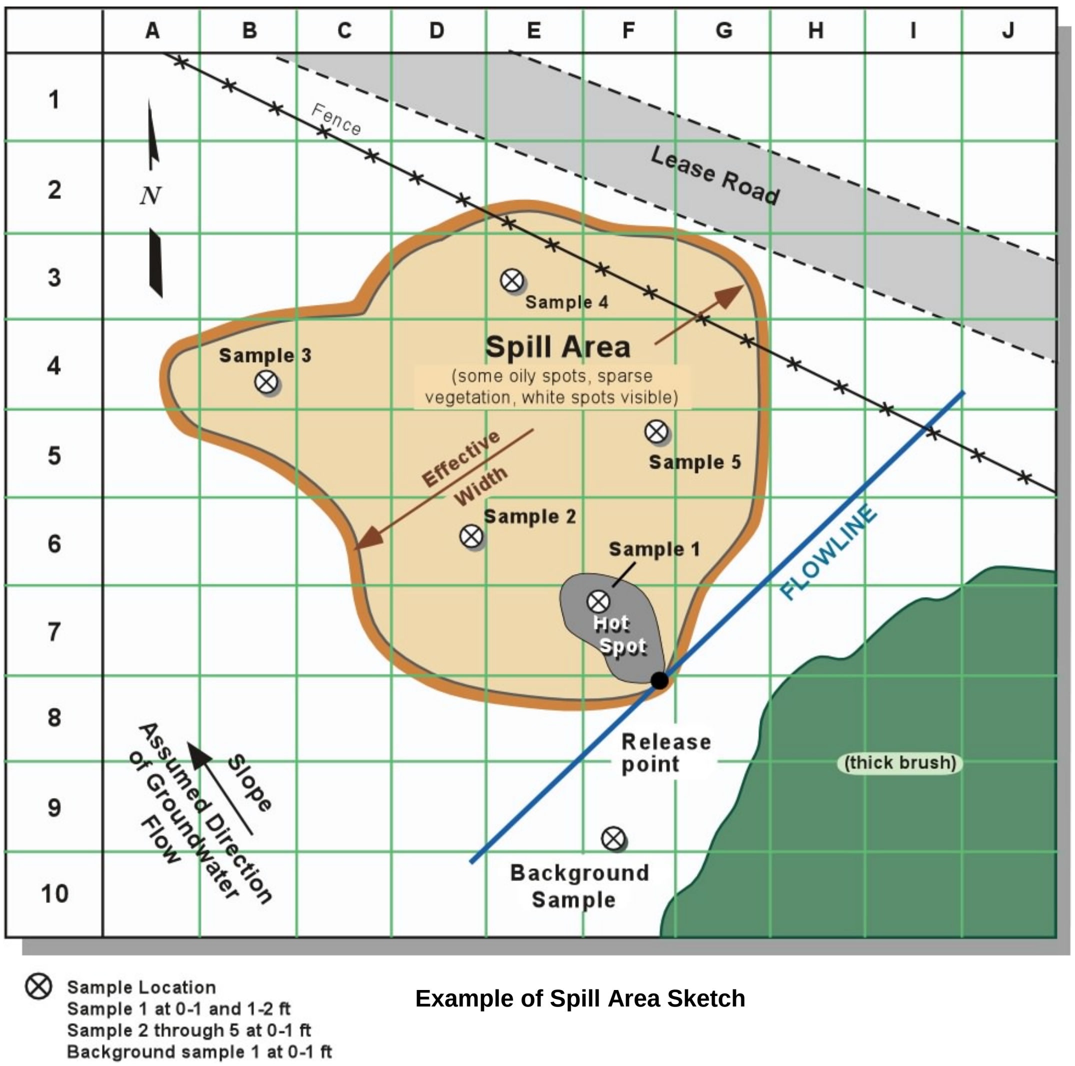
DRAW A SKETCH OF THE SITE:

Typically, the sketch should show:

Natural Features
- Different soil types
- Different plant types
- Slope
- Rocky features
- Extent of stressed vegetation

Release Data
- Sampling locations
- Approximate area of spill
- Release location

Use of Electromagnetic Conductivity Tool (EM-31)
to Delineate Areas of Salt-Impacted Soil
Photo courtesy of David Carty



Example of Spill Area Sketch

Lab Data That May Be Needed for Remediation

- _Screening studies_ or _quick field assessments_ need fewer of these lab tests.
- _Detailed remediation designs_ need more of these tests.
- _Site-specific conditions_ may determine actual data needs. At some sites, very limited data are needed to evaluate impacts and determine appropriate response. At other sites, more complicated tests (e.g., soil column studies) can be helpful.

DATA NEEDS:

Basic:
These tests are used for screening and to select between natural, chemical, and mechanical remediation.

Design:
These tests are used to design chemical amendment remediation projects (such as adding gypsum).

Compare:
These tests are used to determine if background conditions will limit plant growth.

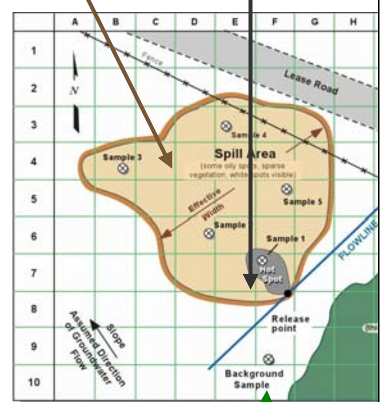
TECH TIP 1: COMPOSITING SAMPLES

The objective of the sampling exercise is to determine the _average_ condition of the soil. Compositing samples from 3 to 5 locations together can be an effective method to reduce analytical costs and define average soil conditions.

Rules of thumb: These general rules are typically applicable:

- Sample only when the soil is relatively dry. Clumps should be broken and the soil easy to mix.
- Collect samples from the surface to the depth where the EC is no longer elevated, to a maximum depth of 4 feet.

Data Need	Soil Lab Test	Hot Spot	Full Spill Area	Background Samples
Basic	**EC (saturated paste; see Tech Tip 2 below)**	✓	✓	✓
Basic	**As-Received Moisture %**	✓	✓	
Basic	**Saturated paste moisture %**	✓	✓	
Basic	**pH**	✓	✓	
Design	**SAR**	✓		
Design	**CEC**	✓	✓	✓
Design	**ESP**	✓		
Design	**Chloride**	✓	✓	
Compare	**Basic soil fertility (N, P, K, Ca, Mg, Na, S, EC)**	✓	✓	✓



TECH TIP 2: MEASURING SOIL EC

To measure the EC of a soil sample, you must add water to convert the dry soil to a saturated paste as described below:

1) Place an amount of soil in a wide-mouth container.

2) If you want to calculate the % moisture, weigh the container with soil.

3) Slowly add distilled water to the soil while gently tapping the container on a hard surface and gently stirring the soil. The water should be added until all the soil pores are filled, without any standing water on the surface. When the soil is saturated, the top of the saturated soil mass should glisten, the paste should fill the hole left by the stirring rod, and the paste should slide off the stirring rod. There should be no free water on the surface.

4) Cover with aluminum foil and let stand for one hour so the salts and water can reach equilibrium.

5) If free water has appeared after an hour, add more soil and stir. If the paste has stiffened, add more water and stir. Repeat Step 4.

6) Extract water from the paste using positive pressure (such as a filter and syringe, or under a vacuum (such as with a Buchner funnel)).

7) Use a conductivity meter to measure the EC of the extract. This value is used as the EC of the soil.

ALTERNATIVE METHOD 1: 1:1 SOIL EXTRACT METHOD. Mix 100 grams of dried soil with 100 grams of pure water. Let sit for minimum of 16 hours. Vacuum filter water through qualitative filter paper, recover extract, and measure EC of extract.

NOTE: Alternative Method 1 is easier but may not be as comparable to salt tolerance values that were determined using the saturated paste method.

ALTERNATIVE METHOD 2: IPEC SOIL SALT ANALYSIS KIT. (See www.ipec.utulsa.edu.)

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U.S. EPA, 2006. National Recommended Water Quality Criteria, EPA Office of Water (43047), 2006. http://www.epa.gov/waterscience/criteria/wqcriteria.html

NOTES

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QUESTIONS

Action 452990

QUESTIONS

Operator: CHEVRON U S A INC 6301 Deauville Blvd Midland, TX 79706	OGRID: 4323
	Action Number: 452990
	Action Type: [C-141] Site Char./Remediation Plan C-141 (C-141-v-Plan)

QUESTIONS

Prerequisites

Incident ID (n#)	**nAB1803756772**
Incident Name	**NAB1803756772 DONALDSON COM A #001 @ 30-015-22404**
Incident Type	**Produced Water Release**
Incident Status	**Remediation Plan Received**
Incident Well	**[30-015-22404] DONALDSON COM A #001**

Location of Release Source

Please answer all the questions in this group.

Site Name	DONALDSON COM A #001
Date Release Discovered	01/22/2018
Surface Owner	Private

Incident Details

Please answer all the questions in this group.

Incident Type	Produced Water Release
Did this release result in a fire or is the result of a fire	No
Did this release result in any injuries	No
Has this release reached or does it have a reasonable probability of reaching a watercourse	No
Has this release endangered or does it have a reasonable probability of endangering public health	No
Has this release substantially damaged or will it substantially damage property or the environment	No
Is this release of a volume that is or may with reasonable probability be detrimental to fresh water	No

Nature and Volume of Release

Material(s) released, please answer all that apply below. Any calculations or specific justifications for the volumes provided should be attached to the follow-up C-141 submission.

Crude Oil Released (bbls) Details	*Not answered.*
Produced Water Released (bbls) Details	Cause: Overflow - Tank, Pit, Etc. | Tank (Any) | Produced Water | Released: 110 BBL | Recovered: 109 BBL | Lost: 1 BBL.
Is the concentration of chloride in the produced water >10,000 mg/l	Yes
Condensate Released (bbls) Details	*Not answered.*
Natural Gas Vented (Mcf) Details	*Not answered.*
Natural Gas Flared (Mcf) Details	*Not answered.*
Other Released Details	*Not answered.*
Are there additional details for the questions above (i.e. any answer containing Other, Specify, Unknown, and/or Fire, or any negative lost amounts)	*Not answered.*

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QUESTIONS (continued)

Operator:	
CHEVRON U S A INC 6301 Deauville Blvd Midland, TX 79706	OGRID: 4323
	Action Number: 452990
	Action Type: [C-141] Site Char./Remediation Plan C-141 (C-141-v-Plan)

QUESTIONS

Nature and Volume of Release (continued)	
Is this a gas only submission (i.e. only significant Mcf values reported)	**No, according to supplied volumes this does not appear to be a "gas only" report.**
Was this a major release as defined by Subsection A of 19.15.29.7 NMAC	**Yes**
Reasons why this would be considered a submission for a notification of a major release	**From paragraph A. "Major release" determine using:** **(1) an unauthorized release of a volume, excluding gases, of 25 barrels or more.**
With the implementation of the 19.15.27 NMAC (05/25/2021), venting and/or flaring of natural gas (i.e. gas only) are to be submitted on the C-129 form.	

Initial Response *The responsible party must undertake the following actions immediately unless they could create a safety hazard that would result in injury.*	
The source of the release has been stopped	True
The impacted area has been secured to protect human health and the environment	True
Released materials have been contained via the use of berms or dikes, absorbent pads, or other containment devices	True
All free liquids and recoverable materials have been removed and managed appropriately	True
If all the actions described above have not been undertaken, explain why	*Not answered.*
Per Paragraph (4) of Subsection B of 19.15.29.8 NMAC the responsible party may commence remediation immediately after discovery of a release. If remediation has begun, please prepare and attach a narrative of actions to date in the follow-up C-141 submission. If remedial efforts have been successfully completed or if the release occurred within a lined containment area (see Subparagraph (a) of Paragraph (5) of Subsection A of 19.15.29.11 NMAC), please prepare and attach all information needed for closure evaluation in the follow-up C-141 submission.	

I hereby certify that the information given above is true and complete to the best of my knowledge and understand that pursuant to OCD rules and regulations all operators are required to report and/or file certain release notifications and perform corrective actions for releases which may endanger public health or the environment. The acceptance of a C-141 report by the OCD does not relieve the operator of liability should their operations have failed to adequately investigate and remediate contamination that pose a threat to groundwater, surface water, human health or the environment. In addition, OCD acceptance of a C-141 report does not relieve the operator of responsibility for compliance with any other federal, state, or local laws and/or regulations.	
I hereby agree and sign off to the above statement	Name: Amy Barnhill Title: Waste & Water Specialist Email: ABarnhill@chevron.com Date: 04/17/2025

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QUESTIONS

Site Characterization

Please answer all the questions in this group (only required when seeking remediation plan approval and beyond). This information must be provided to the appropriate district office no later than 90 days after the release discovery date.

What is the shallowest depth to groundwater beneath the area affected by the release in feet below ground surface (ft bgs)	Between 26 and 50 (ft.)
What method was used to determine the depth to ground water	Direct Measurement
Did this release impact groundwater or surface water	No
What is the minimum distance, between the closest lateral extents of the release and the following surface areas:	
A continuously flowing watercourse or any other significant watercourse	Between ½ and 1 (mi.)
Any lakebed, sinkhole, or playa lake (measured from the ordinary high-water mark)	Between 1 and 5 (mi.)
An occupied permanent residence, school, hospital, institution, or church	Between 500 and 1000 (ft.)
A spring or a private domestic fresh water well used by less than five households for domestic or stock watering purposes	Between 500 and 1000 (ft.)
Any other fresh water well or spring	Between 500 and 1000 (ft.)
Incorporated municipal boundaries or a defined municipal fresh water well field	Greater than 5 (mi.)
A wetland	Between ½ and 1 (mi.)
A subsurface mine	Greater than 5 (mi.)
An (non-karst) unstable area	Greater than 5 (mi.)
Categorize the risk of this well / site being in a karst geology	Medium
A 100-year floodplain	Between ½ and 1 (mi.)
Did the release impact areas not on an exploration, development, production, or storage site	Yes

Remediation Plan

Please answer all the questions that apply or are indicated. This information must be provided to the appropriate district office no later than 90 days after the release discovery date.

Requesting a remediation plan approval with this submission	Yes
Attach a comprehensive report demonstrating the lateral and vertical extents of soil contamination associated with the release have been determined, pursuant to 19.15.29.11 NMAC and 19.15.29.13 NMAC.	
Have the lateral and vertical extents of contamination been fully delineated	Yes
Was this release entirely contained within a lined containment area	No
Soil Contamination Sampling: (Provide the highest observable value for each, in milligrams per kilograms.)	
Chloride (EPA 300.0 or SM4500 Cl B)	10600
TPH (GRO+DRO+MRO) (EPA SW-846 Method 8015M)	2227
GRO+DRO (EPA SW-846 Method 8015M)	886
BTEX (EPA SW-846 Method 8021B or 8260B)	0
Benzene (EPA SW-846 Method 8021B or 8260B)	0
Per Subsection B of 19.15.29.11 NMAC unless the site characterization report includes completed efforts at remediation, the report must include a proposed remediation plan in accordance with 19.15.29.12 NMAC, which includes the anticipated timelines for beginning and completing the remediation.	
On what estimated date will the remediation commence	06/09/2025
On what date will (or did) the final sampling or liner inspection occur	06/23/2025
On what date will (or was) the remediation complete(d)	06/26/2025
What is the estimated surface area (in square feet) that will be reclaimed	26694
What is the estimated volume (in cubic yards) that will be reclaimed	6065
What is the estimated surface area (in square feet) that will be remediated	26694
What is the estimated volume (in cubic yards) that will be remediated	6065
These estimated dates and measurements are recognized to be the best guess or calculation at the time of submission and may (be) change(d) over time as more remediation efforts are completed.	
The OCD recognizes that proposed remediation measures may have to be minimally adjusted in accordance with the physical realities encountered during remediation. If the responsible party has any need to significantly deviate from the remediation plan proposed, then it should consult with the division to determine if another remediation plan submission is required.	

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	Action Number: 452990
	Action Type: [C-141] Site Char./Remediation Plan C-141 (C-141-v-Plan)

QUESTIONS

Remediation Plan (continued)

Please answer all the questions that apply or are indicated. This information must be provided to the appropriate district office no later than 90 days after the release discovery date.

This remediation will (or is expected to) utilize the following processes to remediate / reduce contaminants:

(Select all answers below that apply.)

(Ex Situ) Excavation and **off-site** disposal (i.e. dig and haul, hydrovac, etc.)	Yes
Which OCD approved facility will be used for **off-site** disposal	R360 ARTESIA LLC LANDFARM [fEEM0112340644]
OR which OCD approved well (API) will be used for **off-site** disposal	*Not answered.*
OR is the **off-site** disposal site, to be used, out-of-state	*Not answered.*
OR is the **off-site** disposal site, to be used, an NMED facility	*Not answered.*
(Ex Situ) Excavation and **on-site** remediation (i.e. On-Site Land Farms)	*Not answered.*
(In Situ) Soil Vapor Extraction	*Not answered.*
(In Situ) Chemical processing (i.e. Soil Shredding, Potassium Permanganate, etc.)	*Not answered.*
(In Situ) Biological processing (i.e. Microbes / Fertilizer, etc.)	*Not answered.*
(In Situ) Physical processing (i.e. Soil Washing, Gypsum, Disking, etc.)	*Not answered.*
Ground Water Abatement pursuant to 19.15.30 NMAC	*Not answered.*
OTHER (Non-listed remedial process)	*Not answered.*

Per Subsection B of 19.15.29.11 NMAC unless the site characterization report includes completed efforts at remediation, the report must include a proposed remediation plan in accordance with 19.15.29.12 NMAC, which includes the anticipated timelines for beginning and completing the remediation.

I hereby certify that the information given above is true and complete to the best of my knowledge and understand that pursuant to OCD rules and regulations all operators are required to report and/or file certain release notifications and perform corrective actions for releases which may endanger public health or the environment. The acceptance of a C-141 report by the OCD does not relieve the operator of liability should their operations have failed to adequately investigate and remediate contamination that pose a threat to groundwater, surface water, human health or the environment. In addition, OCD acceptance of a C-141 report does not relieve the operator of responsibility for compliance with any other federal, state, or local laws and/or regulations.

I hereby agree and sign off to the above statement	Name: Amy Barnhill Title: Waste & Water Specialist Email: ABarnhill@chevron.com Date: 04/17/2025

The OCD recognizes that proposed remediation measures may have to be minimally adjusted in accordance with the physical realities encountered during remediation. If the responsible party has any need to significantly deviate from the remediation plan proposed, then it should consult with the division to determine if another remediation plan submission is required.

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QUESTIONS

Deferral Requests Only	
Only answer the questions in this group if seeking a deferral upon approval this submission. Each of the following items must be confirmed as part of any request for deferral of remediation.	
Requesting a deferral of the remediation closure due date with the approval of this submission	No

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	Action Number: 452990
	Action Type: [C-141] Site Char./Remediation Plan C-141 (C-141-v-Plan)

QUESTIONS

Sampling Event Information	
Last sampling notification (C-141N) recorded	***{Unavailable.}***

Remediation Closure Request	
Only answer the questions in this group if seeking remediation closure for this release because all remediation steps have been completed.	
Requesting a remediation closure approval with this submission	No

Sante Fe Main Office
Phone: (505) 476-3441

General Information
Phone: (505) 629-6116

Online Phone Directory
https://www.emnrd.nm.gov/ocd/contact-us

State of New Mexico
Energy, Minerals and Natural Resources
Oil Conservation Division
1220 S. St Francis Dr.
Santa Fe, NM 87505

CONDITIONS

Action 452990

CONDITIONS

Operator:	
CHEVRON U S A INC 6301 Deauville Blvd Midland, TX 79706	OGRID: 4323
	Action Number: 452990
	Action Type: [C-141] Site Char./Remediation Plan C-141 (C-141-v-Plan)

CONDITIONS

Created By	Condition	Condition Date
rhamlet	The Remediation Plan is conditionally approved. The Variance Request to install a geosynthetic bentonite liner below surface is denied. Due to the sensitive nature of the site (shallow groundwater <50 feet), the site will need to be remediated to the strictest closure criteria standards from Table 1 of the OCD Spill Rule. The OCD won't consider a variance for the liner install until as much of the contaminated material has been excavated as possible. At that time, we can possibly take another look at the request. Once you feel like you have safely excavated as much as possible, submit a remediation plan addendum and we will take a look at it. Please include pictures of the excavation in the amended report.	5/9/2025
rhamlet	Due to the shallow groundwater and sensitive nature of the release area, the variance for 400 ft2 confirmation sample size is denied. Collect 5-point confirmation samples every 200 ft2 throughout the entire release area. Samples must be analyzed for all constituents listed in Table I of 19.15.29.12 NMAC. Floor confirmation samples should be delineated/excavated to meet closure criteria standards from Table 1 of the OCD Spill Rule for site assessment/characterization/depth to water determination. Sidewall samples should be delineated/excavated to 600 mg/kg for chlorides and 100 mg/kg for TPH to define the edge of the release. Please make sure that the edge of the release extent is accurately defined. The groundwater analytical results collected during assessment activities show groundwater at the site has not been impacted. At this time, no additional action regarding groundwater is requested at the site.	5/9/2025