ALTERNATIVES FOR CHLORIDE CONTROL - WICHITA RIVER BASIN AND TRUSCOTT BRINE LAKE, TX:

SUMMARIZED EVALUATION OF THE POTENTIAL FOR SELENIUM-RELATED IMPACTS ON WILDLIFE

Prepared By

U.S. Army Corps of Engineers
Tulsa District
Environmental Analysis and Compliance Branch
Tulsa, Oklahoma

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1. INTRODUCTION AND OBJECTIVES

The purpose of this summary is to provide an overview of methodology and findings for evaluation of potential selenium- (Se) related impacts on wildlife associated with chloride control alternatives under consideration for the Wichita River Basin, Texas. These alternatives involve a variety of options for brine collection at identified chloride source areas and ultimate disposal at Truscott Brine Lake, Texas. A complete overview of Se concerns associated with the Red River Chloride Control Project as originally formulated, a Se literature review, and a detailed description of evaluation methodology is provided in a previous Tulsa District report on this subject (USACE 1993). While much of the focus for the previous evaluation was proposed Crowell Brine Lake, Texas, similar methodology has been applied in this evaluation for Truscott Lake. The 1993 document should therefore be reviewed for an understanding of Se-related concerns associated with the project and methods used to evaluate potential Se-related impacts. The 1993 document is frequently cited for much of the information used in this evaluation.

Original Se evaluations for chloride control project features were, out of necessity, based on extremely limited field data. Given this scarcity of data, the complexity of Se behavior in the environment, and a desire for environmental protection, a very conservative modeling approach was employed for initial Se evaluations. Since that time, considerable data have been collected at brine source areas as well as at Truscott Lake, permitting a more realistic though still somewhat conservative site-specific evaluation of Se-related concerns. Additionally, important information concerning Se-related risk assessment has been added to the scientific literature since original Se evaluations for the project. The purpose of this summary is to provide an updated methodology using expanded field data and literature findings and apply it to evaluation of Truscott Lake brine disposal alternatives.

Finally, despite additional field and literature data, considerable uncertainty still exists with respect to physical, chemical, and biological processes affecting Se dynamics in aquatic systems and their implications for application to this project. It is likely that this uncertainly in the Wichita Basin can only be reduced with continued monitoring and site-specific data collection as the project progresses. Accordingly, it is also the intent of this summary to provide an identification of these areas of uncertainties for use in risk management decisions for the project.

2. ALTERNATIVES

Brine disposal alternatives for Truscott Lake for this evaluation include four potential scenarios. One alternative is the existing condition (brine collection at Area VIII employing an outlet end-of-pipeline spray field for increasing evaporation). The other three involve brine collection at additional source areas, transport via pipeline, and ultimate disposal at Truscott Brine Lake. Features of these source areas as well as Truscott Lake are described in USACE (1993).

For purposes of this evaluation, alternatives for evaluation are identified as follows:

Alternative 1: Area VIII only with 1 outlet spray field (current condition);
Alternative 2: Areas VIII, VII-2 ((-2) indicates spray fields on both ends);
Alternative 3: Areas VIII, X-2;
Alternative 4: Areas VIII, VII-2, X-2.

Design pump rates used in this evaluation for Areas VIII, VII, and X were 5.7, 8.2, and 4.2 cubic feet per second (cfs), respectively. Required Truscott Lake pool elevations, areas, and volumes for all alternatives are provided in Table 1.

TABLE 1

ELEVATION / AREA / CAPACITY TABLE FOR TRUSCOTT ALTERNATIVES
Starting Elevation: 1470 (current)

Years	Elevation, Area, Capacity	Area/# Spray Fields			
		Alt. 1	Alt. 2	Alt. 3	Alt. 4
		VIII-1	VIII, VII-2	VIII, X-2	VII, VIII, X-2
5	Elev. (ft)	1463.73	1468.69	1466.31	1472.43
	Area (m^2)	5.77E+06	6.96E+06	6.37E+06	7.67E+06
	Vol (m^3)	3.70E+07	4.67E+07	4.18E+07	5.50E+07
	Z (m)	6.41E+00	6.71E+00	6.56E+00	7.17E+00
	SSV (mm/yr)	7.91E+00	6.56E+00	7.17E+00	5.95E+00
10	Elev. (ft)	1462.6	1473.11	1466.63	1478.63
	Area (m^2)	5.52E+06	7.79E+06	6.45E+06	8.72E+06
	Vol (m^3)	3.51E+07	5.66E+07	4.24E+07	7.05E+07
	Z (m)	6.36E+00	7.27E+00	6.57E+00	8.08E+00
	SSV (mm/yr)	8.27E+00	5.86E+00	7.08E+00	5.23E+00
15	Elev. (ft)	1463.8	1475.46	1469.17	1482.64
	Area (m^2)	5.79E+06	8.19E+06	7.08E+06	9.47E+06
	Vol (m^3)	3.72E+07	6.25E+07	4.78E+07	8.16E+07
	Z (m)	6.42E+00	7.63E+00	6.75E+00	8.62E+00
	SSV (mm/yr)	7.88E+00	5.57E+00	6.45E+00	4.82E+00
20	Elev. (ft)	1462.1	1476.5	1467.86	1484.53
	Area (m^2)	5.41E+06	8.36E+06	6.76E+06	9.85E+06
	Vol (m^3)	3.43E+07	6.50E+07	4.50E+07	8.71E+07
	Z (m)	6.34E+00	7.78E+00	6.66E+00	8.84E+00
	SSV (mm/yr)	8.44E+00	5.46E+00	6.75E+00	4.63E+00
25	Elev. (ft)	1463.51	1477.75	1469.64	1486.76
	Area (m^2)	5.73E+06	8.58E+06	7.18E+06	1.03E+07
	Vol (m^3)	3.67E+07	6.84E+07	4.86E+07	9.42E+07
	Z (m)	6.40E+00	7.97E+00	6.77E+00	9.15E+00
	SSV (mm/yr)	7.97E+00	5.32E+00	6.36E+00	4.43E+00
30	Elev. (ft)	1464.68	1479.64	1470.48	1489.14
	Area (m^2)	6.00E+06	8.90E+06	7.37E+06	1.08E+07
	Vol (m^3)	3.88E+07	7.32E+07	5.06E+07	1.02E+08
	Z (m)	6.47E+00	8.22E+00	6.87E+00	9.44E+00
	SSV (mm/yr)	7.61E+00	5.13E+00	6.19E+00	4.23E+00

Table 1 (Continued)

Years	Elevation, Area, Capacity	Area/# Spray Fields			
		Alt. 1	Alt. 2	Alt. 3	Alt. 4
		VIII-1	VIII, VII-2	VIII, X-2	VII, VIII, X-2
35	Elev. (ft)	1467.7	1482.62	1473.34	1492.64
	Area (m^2)	6.71E+06	9.47E+06	7.82E+06	1.15E+07
	Vol (m^3)	4.46E+07	8.16E+07	5.71E+07	1.14E+08
	Z (m)	6.65E+00	8.62E+00	7.30E+00	9.91E+00
	SSV (mm/yr)	6.80E+00	4.82E+00	5.84E+00	3.97E+00
40	Elev. (ft)	1463.35	1479.65	1469.35	1489.97
	Area (m^2)	5.74E+06	8.91E+06	7.13E+06	1.10E+07
	Vol (m^3)	3.67E+07	7.34E+07	4.82E+07	1.05E+08
	Z (m)	6.39E+00	8.24E+00	6.76E+00	9.55E+00
	SSV (mm/yr)	7.95E+00	5.12E+00	6.40E+00	4.15E+00
45	Elev. (ft)	1464.56	1480.59	1470.63	1491.17
	Area (m^2)	5.98E+06	9.08E+06	7.38E+06	1.12E+07
	Vol (m^3)	3.86E+07	7.59E+07	5.09E+07	1.08E+08
	Z (m)	6.45E+00	8.36E+00	6.90E+00	9.64E+00
	SSV (mm/yr)	7.63E+00	5.03E+00	6.18E+00	4.08E+00
50	Elev. (ft)	1464.51	1480.63	1470.61	1491.35
	Area (m^2)	5.95E+06	9.08E+06	7.38E+06	1.12E+07
	Vol (m^3)	3.84E+07	7.59E+07	5.09E+07	1.09E+08
	Z (m)	6.45E+00	8.36E+00	6.90E+00	9.73E+00
	SSV (mm/yr)	7.67E+00	5.03E+00	6.18E+00	4.08E+00
55	Elev. (ft)	1464.61	1482.05	1471.13	1492.89
	Area (m^2)	5.98E+06	9.38E+06	7.46E+06	1.15E+07
	Vol (m^3)	3.86E+07	8.01E+07	5.20E+07	1.15E+08
	Z (m)	6.45E+00	8.54E+00	6.97E+00	1.00E+01
	SSV (mm/yr)	7.63E+00	4.87E+00	6.12E+00	3.97E+00
60	Elev. (ft)	1464.68	1481.11	1471.16	1492.16
	Area (m^2)	6.00E+06	9.18E+06	7.48E+06	1.14E+07
	Vol (m^3)	3.88E+07	7.73E+07	5.22E+07	1.12E+08
	Z (m)	6.47E+00	8.42E+00	6.98E+00	9.82E+00
	SSV (mm/yr)	7.61E+00	4.97E+00	6.10E+00	4.00E+00

Table 1 (Continued)

Years	Elevation, Area, Capacity	Area/# Spray Fields			
		Alt. 1	**Alt. 2**	**Alt. 3**	**Alt. 4**
		VIII-1	**VIII, VII-2**	**VIII, X-2**	**VII, VIII, X-2**
65	Elev. (ft)	1467.06	1484.49	1473.1	1495.21
	Area (m^2)	6.56E+06	9.85E+06	7.79E+06	1.20E+07
	Vol (m^3)	4.34E+07	8.71E+07	5.66E+07	1.23E+08
	Z (m)	6.62E+00	8.84E+00	7.27E+00	1.03E+01
	SSV (mm/yr)	6.96E+00	4.63E+00	5.86E+00	3.80E+00
70	Elev. (ft)	1469.08	1485.43	1475.19	1496.4
	Area (m^2)	7.06E+06	1.00E+07	8.14E+06	1.22E+07
	Vol (m^3)	4.76E+07	8.99E+07	6.17E+07	1.27E+08
	Z (m)	6.74E+00	8.99E+00	7.58E+00	1.04E+01
	SSV (mm/yr)	6.47E+00	4.56E+00	5.61E+00	3.74E+00
75	Elev. (ft)	1468.65	1486.83	1474.6	1497.45
	Area (m^2)	6.96E+06	1.03E+07	8.04E+06	1.24E+07
	Vol (m^3)	4.67E+07	9.42E+07	6.03E+07	1.31E+08
	Z (m)	6.71E+00	9.15E+00	7.50E+00	1.06E+01
	SSV (mm/yr)	6.56E+00	4.43E+00	5.68E+00	3.68E+00
80	Elev. (ft)	1465.09	1482.24	1471.45	1493.09
	Area (m^2)	6.09E+06	9.39E+06	7.53E+06	1.16E+07
	Vol (m^3)	3.95E+07	8.04E+07	5.29E+07	1.15E+08
	Z (m)	6.49E+00	8.56E+00	7.03E+00	9.91E+00
	SSV (mm/yr)	7.49E+00	4.86E+00	6.06E+00	3.93E+00
85	Elev. (ft)	1465.06	1483.87	1471.87	1494.47
	Area (m^2)	6.09E+06	9.73E+06	7.59E+06	1.18E+07
	Vol (m^3)	3.95E+07	8.54E+07	5.38E+07	1.20E+08
	Z (m)	6.49E+00	8.78E+00	7.09E+00	1.02E+01
	SSV (mm/yr)	7.49E+00	4.69E+00	6.01E+00	3.87E+00
90	Elev. (ft)	1467.82	1485.7	1474.54	1496.5
	Area (m^2)	6.74E+06	1.01E+07	8.02E+06	1.22E+07
	Vol (m^3)	4.48E+07	9.08E+07	6.00E+07	1.28E+08
	Z (m)	6.65E+00	8.99E+00	7.48E+00	1.05E+01
	SSV (mm/yr)	6.77E+00	4.52E+00	5.69E+00	3.74E+00

Table 1 (Continued)

Years	Elevation, Area, Capacity	Area/# Spray Fields			
		Alt. 1	**Alt. 2**	**Alt. 3**	**Alt. 4**
		VIII-1	**VIII, VII-2**	**VIII, X-2**	**VII, VIII, X-2**
95	Elev. (ft)	1467.92	1486.24	1474.39	1496.77
	Area (m^2)	6.76E+06	1.02E+07	8.00E+06	1.23E+07
	Vol (m^3)	4.50E+07	9.23E+07	5.98E+07	1.29E+08
	Z (m)	6.66E+00	9.05E+00	7.48E+00	1.05E+01
	SSV (mm/yr)	6.75E+00	4.47E+00	5.71E+00	3.71E+00
100	Elev. (ft)	1470.4	1488.23	1476.59	1498.7
	Area (m^2)	7.28E+06	1.06E+07	8.38E+06	1.27E+07
	Vol (m^3)	4.95E+07	9.87E+07	6.53E+07	1.36E+08
	Z (m)	6.80E+00	9.31E+00	7.79E+00	1.07E+01
	SSV (mm/yr)	6.27E+00	4.31E+00	5.45E+00	3.59E+00

Z = average depth
SSV = sediment settling velocity

3. <u>SUMMARY OF FIELD DATA</u>

Water quality data collected as part of the Tulsa District's Wichita River Basin monitoring program include Se data for brine source areas as well as for Truscott Brine Lake. Limited Se data were collected at brine source areas VIII and VII by the Tulsa District as part of initial evaluations for Crowell Lake in 1992. As part of a long-term monitoring effort, monthly water sample collection and Se analyses by the U.S. Geological Survey (USGS) under contract to the Tulsa District was initiated at all potential brine collection areas in the basin beginning in November 1996. This monitoring effort continues to the present. Total and dissolved Se concentrations measured at Areas VIII, VII, and X to date are included in Table 2.

TABLE 2

BRINE SOURCE AREA SELENIUM DATA

Area VIII – Bateman Pump Station South Fork Wichita (07311782)				**Area VII – Y Ranch North Fork Wichita (07311600)**				**Area X - Lowrance Middle Fork Wichita (07311630)**			
Date	**cfs**	**Total Se (ug/l)**	**Diss Se (ug/l)**	**Date**	**cfs**	**Total Se (ug/l)**	**Diss Se (ug/l)**	**Date**	**cfs**	**Total Se (ug/l)**	**Diss Se (ug/l)**
Collected by COE				Collected by COE				Collected by USGS			
7/21/1992		<20	<20	6/29/1992	176	<10	<10	11/6/1996	6.1	10	12
8/18/1992		6.6	<1	7/14/1992	24	<10	<10	11/20/1996	4.8	17	13
10/20/1992		4	3	7/29/1992	18	8	7	1/23/1997	5.8	13	15
				8/19/1992	19	5.4	6.6	3/6/1997	7.5	13	12
				9/16/1992	18	7.9	8.3	3/26/1997	5.8	11	12
				9/30/1992	21	8	8	4/23/1997	5.8	12	13
				10/21/1992	20	8	8	5/15/1997	7	16	12
				11/4/1992	23	9	8	6/5/1997	6.3	12	15
				MEAN	**40**	**8**	**8**	6/26/1997	7.5	12	12
				GEOMEAN	**27**	**8**	**8**	7/30/1997	4.8	14	12
								8/13/1997	4.9	12	14
								9/7/1997	5.1	13	16
								MEAN	**6.0**	**12.9**	**13.2**
								GEOMEAN	**5.9**	**12.8**	**13.1**
Collected by USGS				Collected by USGS				Collected by USGS			
11/5/1996	9.2	1	2	11/5/1996	19	9	12	11/5/1997	11	12	14
12/4/1996	6.3	2	2	11/19/1996	19	15	11	12/10/1997	10	13	15
1/30/1997	4.6	1	1	1/22/1997	11	14	15	1/14/1998	7.1	16	13
3/13/1997	6.8	1	1	3/6/1997	9.1	10	12	2/11/1998	5.3	13	15
4/2/1997	6.9	1	1	3/26/1997	12	9	13	3/26/1998	7.3	14	14
5/1/1997	12	1	1	4/23/1997	23	8	8	4/22/1998	4.8	15	12
5/14/1997	6.4	1	1	5/7/1997	25	9	9	5/6/1998	6.5	12	13
6/4/1997	12	2	2	5/21/1997	28	11	10	6/3/1998	5.4	15	16
6/25/1997	11	2	2	6/11/1997	22	10	10	6/17/1998	6	11	12
8/7/1997		1	2	7/29/1997	20	12	12	7/15/1998	6	14	13
9/4/1997	6.6	1	1	9/6/1997	21	<1	11	9/2/1998	5	10	12
9/8/1997	6.6	1	1	**MEAN**	**19**	**9.8**	**11.2**	**MEAN**	**6.8**	**13.2**	**13.5**
MEAN	**8.0**	**1.3**	**1.4**	**GEOMEAN**	**18**	**8.5**	**11.0**	**GEOMEAN**	**6.5**	**13.1**	**13.5**
GEOMEAN	**7.7**	**1.2**	**1.3**								

Table 2 (Continued)

Area VIII – Bateman Pump Station South Fork Wichita (07311782)				Area VII -- Y Ranch North Fork Wichita (07311600)				Area X -- Lowrance Middle Fork Wichita (07311630)			
Date	**cfs**	**Total Se (ug/l)**	**Diss Se (ug/l)**	**Date**	**cfs**	**Total Se (ug/l)**	**Diss Se (ug/l)**	**Date**	**cfs**	**Total Se (ug/l)**	**Diss Se (ug/l)**
Collected by USGS				Collected by USGS				Collected by USGS			
11/4/1997	6.7	2	2	11/4/1997	28	15	15	12/29/1998	4.8	15	14
12/9/1997	6.7	2	2	12/9/1997	27	13	14	1/20/1999	4.9	11	17
1/13/1998	6.3	2	2	1/13/1998	17	17	13	2/23/1999	5.6	11	11
2/10/1998	10	2	2	2/10/1998	15	16	15	3/16/1999	5.7	9	12
3/17/1998	6.6	3	4	3/25/1998	23	11	12	4/21/1999	4.9	6	8
4/21/1998	6.8	1	1	4/21/1998	16	15	11	5/18/1999	5.4	9	8
5/5/1998	6.8	1	1	5/5/1998	13	11	14	6/9/1999	5.3	9	6
6/2/1998	6.7	<1	<1	6/2/1998	14	14	10	6/30/1999	6.3	7	6
6/16/1998	6.6	<1	<1	6/16/1998	17	12	11	7/21/1999	7.8	4	4
7/14/1998	6.6	<1	<1	7/14/1998	12	11	10	7/28/1999	7.1	6	4
8/11/1998	6	<1	<1	8/11/1998	13	10	10	8/11/1999	5.4	5	6
9/1/1998	6.9	<1	<1	9/1/1998	16	9	10	9/15/1999	4.8	6	4
MEAN	**6.9**	**1.5**	**1.6**	**MEAN**	**18**	**12.8**	**12.1**	**MEAN**	**5.7**	**8.2**	**8.3**
GEOMEAN	**6.8**	**1.4**	**1.4**	**GEOMEAN**	**17**	**12.6**	**11.9**	**GEOMEAN**	**5.6**	**7.6**	**7.4**
Collected by USGS				Collected by USGS				Collected by USGS			
12/29/1998	10	<4	<4	12/28/1998	12	12	12	10/26/1999	5	6	3
1/21/1999	6.8	4	7	1/21/1999	10	10	14	11/26/1999	5.4	15	12
2/24/1999	5.7	4	6	2/24/1999	15	7	9	1/4/2000	7.6	14	13
3/17/1999	6.8	<2	2	3/16/1999	15	10	9	1/20/2000	6.6	8	12
4/22/1999	0.24	<4	<4	4/22/1999	14	7	7	2/29/2000	6.1	15	13
5/18/1999	6.5	6	1	5/20/1999	18	7	5	4/3/2000	6.8	16	8
6/10/1999	1.8	3	5	6/10/1999	12	6	5	4/20/2000	6.4	13	
6/24/1999	7.2	<1	4	6/24/1999	21	2	4	5/18/2000	5.9	10	6
7/22/1999	7	13	<10	7/22/1999	17	3	3	6/14/2000	6.2	7	
8/12/1999	1.7	<1	9	8/12/1999	15	3	4	7/18/2000	6.1		
9/15/1999	6.4	8	26	8/24/1999	11	6	5	**MEAN**	**6.2**	**11.6**	**9.6**
MEAN	**5.5**	**4.5**	**7.1**	9/13/1999	12	4	2	**GEOMEAN**	**6.2**	**10.9**	**8.6**
GEOMEAN	**4.0**	**3.5**	**5.1**	**MEAN**	**14**	**6.4**	**6.6**				
				GEOMEAN	**14**	**5.7**	**5.7**				

Table 2 (Continued)

Area VIII – Bateman Pump Station South Fork Wichita (07311782)				Area VII – Y Ranch North Fork Wichita (07311600)				Area X - Lowrance Middle Fork Wichita (07311630)			
Date	**cfs**	**Total Se (ug/l)**	**Diss Se (ug/l)**	**Date**	**cfs**	**Total Se (ug/l)**	**Diss Se (ug/l)**	**Date**	**cfs**	**Total Se (ug/l)**	**Diss Se (ug/l)**
Collected by USGS				Collected by USGS							
10/6/1999	6.3	<4	<4	10/19/1999	11	4	2				
11/12/1999	6.7	4	4	11/4/1999	11	6	4				
1/3/2000	2.4	3	3	12/28/1999	11	10	8				
1/19/2000	4.5	<4	<4	1/20/2000	11	8	10				
2/28/2000	2.7	<10	5	2/9/2000	9.6	12	7				
3/13/2000	4.4	14	<12	4/6/2000	15	7	6				
5/2/2000	3	<5		4/18/2000	24	10					
5/15/2000	1.2	<10	<24	5/18/2000	26	9	5				
6/27/2000	4.6	<26		7/5/2000	26	5					
MEAN	**4.0**	**5.7**	**5.4**	7/24/2000	26						
GEOMEAN	**3.6**	**4.9**	**4.7**	**MEAN**	**17**	**7.9**	**6.0**				
				GEOMEAN	**16**	**7.5**	**5.4**				
OVERALL MEAN		**3.0**	**3.5**	**OVERALL MEAN**		**9.2**	**9.1**	**OVERALL MEANS**		**11.4**	**11.3**
OVERALL GEOMEAN		**2.1**	**2.3**	**OVERALL GEOMEAN**		**8.2**	**8.3**	**OVERALL GEOMEANS**		**10.8**	**10.5**
OVERALL MEDIAN		**2.0**	**2.0**	**OVERALL MEDIAN**		**9.0**	**10.0**	**OVERALL MEDIANS**		**12**	**12**
Detection limit used in mean calculations with exception of excessively high values (<10 to <26).				Detection limit used in mean calculations							

In addition to initial 1992 data, total selenium analyses for Truscott Brine Lake waters were conducted as part of an extensive baseline Se monitoring program for a number of environmental matrices conducted by the Tulsa District during 1997 and 1998. Water sampling occurred over a range of seasons at four sampling sites ranging from Truscott Dam to the extreme upper end of the impoundment. Water samples were collected in both surface and near-bottom waters and analyzed for total Se. Primary field samples and quality control duplicates were analyzed by the USGS National Water Quality Laboratory, Arvada, Colorado. Quality assurance replicates were analyzed by an independent laboratory (Environmental Trace Substances Laboratory, Rolla, Missouri).

Selenium data for all Truscott Lake water analyses are presented in Table 3. While a total Se concentration of 2 ug/l was measured across the lake in October 1992 as the pool was filling, total Se concentrations in all field samples collected during 1997 and 1998 (once the lake reached a somewhat stable pool) were below analytical detection limits (ranging from 0.5 to 1 ug/l). The last samples collected (September 2, 1998) indicated that waterborne total Se concentrations were still less than the 0.5 ug/l detection limit after approximately 11 years of project operation. Sediment sample total Se concentrations measured during the same time period ranged from <0.4 to 0.58 mg/Kg total Se (dry weight).

Brine pumping from Area VIII to Truscott Lake began in May 1987. The impoundment slowly filled until reaching a somewhat stable pool in approximately 1996. Annual pool elevations, volumes, surface areas, and brine volumes pumped from Area VIII to Truscott Lake are presented in Table 4.

TABLE 3 TRUSCOTT LAKE SELENIUM DATA (WATER)					
Date	**Time**	**Depth**	**Total Se (ug/l)**	**Duplicate**	**QA (ETSL)**
		Site 1 (Near Dam)			
7/22/1992		S	<10		
7/22/1992		B	<10		
8/19/1992		S	<1		
8/19/1992		B	<1		
10/21/1992		S	2		
10/21/1992		B	2		
Analyses for 1992 samples conducted by Eureka Laboratories, Inc., Sacramento, CA					
2/26/1997	1000	S	<1	<1	<0.5
2/26/1997	1000	B	<1		
3/25/1997	1330	S	<1		
3/25/1997	1330	B	<1		
4/23/1997	910	S	<1		
4/23/1997	910	B	<1		
6/10/1997	1337	S	<1		
6/10/1997	1337	B	<1		
7/14/1997	1355	S	<1	<1	<0.5
7/14/1997	1355	B	<1		
8/26/1997	1313	S	<1	<1	2.2
8/26/1997	1313	B	<1		
10/22/1997	1030	S	<1		
10/22/1997	1030	B	<1		
12/15/1997	1430	S	<1		
12/15/1997	1430	B	<1		
1/26/1998	1400	S	<1		
1/26/1998	1400	B	<1		
4/30/1998	1125	S	<1		
4/30/1998	1130	B	<1		
7/7/1998	931	S	<1		
7/7/1998	931	B	<1		
9/2/1998	1315	S	<0.5 (ETSL)	0.6 (ETSL)	
9/2/1998	1315	B	<0.5 (ETSL)		
		Site 2 (Mid-Lake)			
7/22/1992		S	<10		
7/22/1992		B	<20		
8/19/1992		S	<1		
8/19/1992		B	<1		
10/21/1992		S	2		
10/21/1992		B	2		
Analyses for 1992 samples conducted by Eureka Laboratories, Inc., Sacramento, CA					

Table 3 (Continued)

Date	Time	Depth	Total Se (ug/l)	Duplicate	QA (ETSL)
2/26/1997	1035	S	<1		
2/26/1997	1035	B	<1		
3/25/1997	1410	S	<1	<1	<0.5
3/25/1997	1410	B	<1		
4/23/1997	955	S	<1		
4/23/1997	955	B	<1		
6/10/1997	1410	S	<1		
6/10/1997	1410	B	<1		
7/14/1997	1415	S	<1		
7/14/1997	1415	B	<1		
8/26/1997	1405	S	<1		
8/26/1997	1405	B	<1		
10/22/1997	1040	S	<1		
10/22/1997	1040	B	<1		
12/15/1997	1447	S	<1	<1	1
12/15/1997	1447	B	<1		
1/26/1998	1440	S	<1		
1/26/1998	1440	B	<1		
4/30/1998	1150	B	<1		
7/7/1998	959	S	<1		
7/7/1998	959	B	<1		
9/2/1998	1340	S	<0.5 (ETSL)		
9/2/1998	1340	B	<0.5 (ETSL)		
		Site 3 (Upper End)			
7/22/1992		S	<20		
8/19/1992		S	<1		
10/21/1992		S	2		
Analyses for 1992 samples conducted by Eureka Laboratories, Inc., Sacramento, CA					
2/26/1997	1055	S	<1		
3/25/1997	1440	S	<1		
4/23/1997	1020	S	<1	<1	<0.5
6/10/1997	1437	S	<1	<1	<0.5
7/14/1997	1445	S	<1		
8/26/1997	1445	S	<1		
10/22/1997	1055	S	<1	<1	<1
12/15/1997	1520	S	<1		
1/26/1998	1500	S	<1	<1	<1
4/30/1998	1205	S	<1	<1	<0.5
7/7/1998	1045	S	<1		
9/2/1998	1355	S	<0.5 (ETSL)		

Table 3 (Continued)

Date	Time	Depth	Total Se (ug/l)	Duplicate	QA (ETSL)
		Site 4 (Extreme Upper End)			
6/10/1997	1500	S	<1		
7/14/1997	1456	S	<1		
12/15/1997	1540	S	<1		
1/26/1998	1515	S	<1		
4/30/1998	1215	S	<1		
7/7/1998	1055	S	<1		
9/2/1998	1405	S	<0.5 (ETSL)		

S = surface sample (0.5 m depth)
B = bottom sample (1 m from bottom)
Duplicate = duplicate sample analyzed by primary laboratory (USGS)
QA = quality assurance sample analyzed by separate laboratory (ETSL)
ETSL = Environmental Trace Substance Laboratory, Rolla, MO.

TABLE 4

TRUSCOTT LAKE POOL AND PUMPED BRINE DATA

Date	Pool Elevation (feet)	Volume (m^3)	Area (m^2)	Annual Pumped (L)	Total Pumped (L)
10/1/1984	1423.8*	1.51E+06	8.01E+05	0	0
10/1/1985	1424.8*	1.75E+06	8.90E+05	0	0
10/1/1986	1435.50	3.18E+06	1.33E+06	0	0
10/1/1987	1445.38	1.31E+07	2.92E+06	2956985222	2956985222
10/1/1988	1448.03	1.56E+07	3.37E+06	5890531680	8847516902
10/1/1989	1452.09	2.02E+07	3.98E+06	4580428090	13427944992
10/1/1990	1457.76	2.77E+07	4.68E+06	4082045933	17509990925
10/1/1991	1460.00	3.10E+07	4.97E+06	4812348499	22322339424
10/1/1992	1466.11	4.14E+07	6.32E+06	6803409888	29125749312
10/1/1993	1468.15	4.55E+07	6.82E+06	5361309043	34487058355
10/1/1994	1468.30	4.59E+07	6.86E+06	5810346432	40297404787
10/1/1995	1471.49	5.29E+07	7.53E+06	5387215046	45684619833
10/1/1996	1470.00	4.73E+07	7.10E+06	6394155685	52078775518
10/1/1997	1471.00	4.95E+07	7.28E+06	6058138525	58136914043
10/1/1998	1471.00	4.95E+07	7.28E+06	5396800615	63533714658

* Estimated
Note: 1987 pumped volume data for May through September.

4. POST-IMPOUNDMENT MASS BALANCE ESTIMATE

An estimate of Se mass delivered to Truscott Lake since impoundment, calculation of "conservative substance" (i.e., worst case) concentration estimates, and comparison with latest measured lake water concentrations were employed as an initial means of gaining an understanding of mass balance for the system. This analysis involved mass load estimation using actual pumped brine volumes (not design averages), actual rainfall data, and Se concentration information collected to date at the Area VIII pump station. This analysis and its results are described below.

An estimate of the long-term average total Se concentration in brines collected and delivered to Truscott Lake was obtained using 1996 through 2000 monitoring data collected at the Area VIII pump station by the USGS (Table 2). This estimation was somewhat complicated by the presence of censored (below analytical reporting limit) data for a number of sampling events. In most instances, reporting limits were reasonably close to detected values for other months. Therefore, in most cases, the reporting limit was substituted for censored values in concentration calculations. In a few cases, reporting limits were extremely high (10 to 26 ug/l). In these cases (May and June 2000), these values were eliminated from calculations. For several months with no data, it was necessary to estimate concentrations based on those obtained from previous and succeeding months. All values used in calculations are shown in Table 5.

Monthly Se concentration values were averaged to obtain an estimated long-term average of 2.9 ug/l total Se for Area VIII brines (Table 5). As an alternate means of evaluation, concentration values were multiplied by actual monthly pumped volumes to obtain an estimated monthly mass of Se pumped from the collection area (Table 5). This mass was totaled (50.1 Kg) and divided by the total volume pumped during this 40-month period (1.8E10 liters) to obtain a very similar average concentration estimate of 2.8 ug/l. Owing to the use of averaged concentration data for other source areas in the modeling exercise (see below), an estimate of 2.9 ug/l total Se was used for Area VIII brines.

TABLE 5

BATEMAN (AREA VIII) LOAD CALCULATIONS FOR SE DATA PERIOD OF RECORD

Year	Month	Gallons Pumped	CFS	L Pumped	Kg/L Se*	inst. CFS*	Kg Se	Kg/d Se
1996	Nov	175377000	9.05	663801945	1.00E-09	9.2	6.64E-01	2.21E-02
	Dec	169111000	8.44	640085135	2.00E-09	6.3	1.28E+00	4.13E-02
1997	Jan	150196000	7.50	568491860	1.00E-09	4.6	5.68E-01	1.83E-02
	Feb	114156000	6.09	432080460	**1.00E-09**		4.32E-01	1.49E-02
	Mar	123173000	6.15	466209805	1.00E-09	6.8	4.66E-01	1.50E-02
	Apr	133454000	6.88	505123390	1.00E-09	6.9	5.05E-01	1.68E-02
	May	184755000	9.22	699297675	1.00E-09	**9.2**	6.99E-01	2.26E-02
	Jun	164949000	8.51	624331965	2.00E-09	12	1.25E+00	4.16E-02
	Jul							
	Aug	109290000	5.46	413662650	1.00E-09		4.14E-01	1.33E-02
	Sept	60485000	3.12	228935725	1.00E-09	6.6	2.29E-01	7.63E-03
	Oct	109930000	5.49	416085050	**1.50E-09**		6.24E-01	2.01E-02
	Nov	124644000	6.43	471777540	2.00E-09	6.7	9.44E-01	3.15E-02
	Dec	161279000	8.05	610441015	2.00E-09	6.7	1.22E+00	3.94E-02
1998	Jan	141447000	7.06	535376895	2.00E-09	6.3	1.07E+00	3.45E-02
	Feb	142733000	7.62	540244405	2.00E-09	10	1.08E+00	3.73E-02
	Mar	107979000	5.39	408700515	3.00E-09	6.6	1.23E+00	3.96E-02
	Apr	133927000	6.91	506913695	1.00E-09	6.8	5.07E-01	1.69E-02
	May	106890000	5.34	404578650	1.00E-09	6.8	4.05E-01	1.31E-02
	June	112529000	5.80	425922265	**1.00E-09**	6.6	4.26E-01	1.42E-02
	July	83279000	4.16	315211015	**1.00E-09**	6.6	3.15E-01	1.02E-02
	Aug	107817000	5.38	408087345	**1.00E-09**	6	4.08E-01	1.32E-02
	Sept	93385000	4.82	353462225	**1.00E-09**	6.9	3.53E-01	1.18E-02
	Oct	122344000	6.11	463072040	**2.00E-09**		9.26E-01	2.99E-02
	Nov	125864000	6.49	476395240	**2.00E-09**		9.53E-01	3.18E-02
	Dec	125072000	6.24	473397520	**4.00E-09**	10	1.89E+00	6.11E-02
1999	Jan	129539000	6.47	490305115	4.00E-09	6.8	1.96E+00	6.33E-02
	Feb	88762000	4.74	335964170	4.00E-09	5.7	1.34E+00	4.63E-02
	Mar	137661000	6.87	521046885	**2.00E-09**	6.8	1.04E+00	3.36E-02
	Apr	97796000	5.04	370157860	**4.00E-09**	0.24	1.48E+00	4.94E-02
	May	102496000	5.12	387947360	6.00E-09	6.5	2.33E+00	7.51E-02
	Jun	81101000	4.18	306967285	2.00E-09	**4.5**	6.14E-01	2.05E-02
	Jul	128851000	6.43	487701035	1.30E-08	7	6.34E+00	2.05E-01
	Aug	132034000	6.59	499748690	1.00E-09	1.7	5.00E-01	1.61E-02
	Sept	81004000	4.18	306600140	8.00E-09	6.4	2.45E+00	8.18E-02
	Oct	123621000	6.17	467905485	**4.00E-09**	6.3	1.87E+00	6.04E-02
	Nov	118948000	6.14	450218180	**4.00E-09**	6.7	1.80E+00	6.00E-02
	Dec	112172000	5.60	424571020	**3.00E-09**		1.27E+00	4.11E-02

Table 5 (Continued)

Year	Month	Gallons Pumped	CFS	L Pumped	Kg/L Se*	inst. CFS*	Kg Se	Kg/d Se
2000	Jan	52700000	2.63	199469500	3.00E-09	**3.5**	5.98E-01	1.93E-02
	Feb	74101000	3.95	280472285	**5.00E-09**	2.7	1.40E+00	4.84E-02
	Mar	118293000	5.90	447739005	1.40E-08	4.4	6.27E+00	2.02E-01
	Apr	91989000	4.74	348178365				
	May	74621000	3.72	282440485	*****			
	Jun	93528000	4.82	354003480	*****			
	Jul	30794000	1.54	116555290				
Sum							5.01E+01	
Averages			**6.04**		**2.89E-09**	**6.38**	**1.25E+00**	**4.10E-02**

* Data collected by USGS.
***** Data exist, but extremely high detection limits (up to 26 ug/l) preclude use.
Bold type indicates estimated values (usually detection limit used for censored data).

In addition to that resulting from pumped brines from Area VIII, a relatively minor amount of Se loading to Truscott Lake occurs via local runoff from the lake's 26.2-square-mile drainage area. Selenium loading via runoff can be estimated by assuming that 4.7% of rainfall over the entire drainage area reaches the impoundment (based on Crowell Lake estimates and similar watersheds), and that the concentration of total Se in runoff waters is approximately 0.4 ug/l. This concentration is reduced from the estimate of 1 ug/l originally used in initial Crowell Lake estimates (USACE 1993), but is more likely at the upper end of the range of "background" concentrations in freshwater environments and is the approximate median background concentration in California streams (Skorupa et al. 1996). For initial mass balance estimates, actual rainfall data (Table 6) were used to estimate runoff loads since Truscott Lake impoundment.

TABLE 6 ESTIMATED RUNOFF SE LOADS: 1984 TO 1998				
Year	**Rain (inches.)**	**Inflow (L)** [1]	**Kg Se** [2]	**Kg/d Se**
1984	22.24	1801933283	0.721	0.002
1985	24.45	1980992301	0.792	0.002
1986	30.07	2436336953	0.975	0.003
1987	32.03	2595140425	1.038	0.003
1988	21.54	1745217757	0.698	0.002
1989	24.87	2015021617	0.806	0.002
1990	30.78	2493862700	0.998	0.003
1991	30.83	2497913809	0.999	0.003
1992	35.04	2839017187	1.136	0.003
1993	32.22	2610534640	1.044	0.003
1994	19.40	1571830292	0.629	0.002
1995	38.34	3106390381	1.243	0.003
1996	17.34	1404924601	0.562	0.002
1997	33.69	2729637244	1.092	0.003
1998	20.14	1631786705	0.653	0.002
Sum	412.98	33460539896	13.38	
Average	27.532	2230702660	0.892	0.002
		(6.11E6 L/d)		
(1) Based on 26.2 square-mile drainage, assuming 4.7% rainfall reaches lake. (2) Assumes Se concentration of 0.4 ug/l in runoff.				

For purposes of both initial mass balance estimates and modeling exercises, atmospheric deposition of Se to Truscott Lake was assumed to be insignificant. It is unlikely that wind-blown surface soils in the area would contain significant concentrations of Se, and industrial facilities with a potential for Se discharge are absent from the area. Total mass delivered to Truscott Lake from impoundment (1984) through initiation of pumping (May 1987) to the latest Truscott lake water Se analyses (September 1998) was therefore estimated as follows:

Runoff: (33,460,539,896 liters)(4E-10 Kg/l Se) = 13.38 Kg Se (Table 6)
Pumped: (63,533,714,658 liters)(2.89E-9 Kg/l Se) = 183.61 Kg Se (Table 4)
Total: 13.38 Kg + 183.61 Kg = **197 Kg**

In September 1998, Truscott Lake possessed a pool volume of approximately 4.95E10 liters (Table 4). Therefore, if Se were to be considered as totally conserved (no mass loss from water column), lake water total Se concentration in September 1998 could be estimated as:

197 Kg Se / 4.95E10 liters = **4 ug/l**

On September 2, 1998 (latest Truscott Lake water analysis), total Se concentrations across Truscott Lake (end-to-end, surface, and bottom waters) were reported as <0.5 ug/l. Values similarly below detection limits (0.5 to 1 ug/l) were consistently measured across sampling dates (spanning a range of seasons) and sites throughout 1997 and 1998 (Table 3). It can therefore be demonstrated that somewhere in excess of 87% of Se mass estimated to have been delivered to Truscott Lake during the 14-year period between impoundment and September 1998 could not be accounted for in total waterborne Se analyses.

5. SELENIUM LOAD ESTIMATION FOR ALTERNATIVES

For this evaluation, it was necessary to estimate Se mass loads for each of the alternatives under consideration. These loads were then used in modeling exercises for estimation of long-term water and sediment Se concentrations for all alternatives.

Loads resulting from local inflow (runoff) were estimated using the 30-year average annual rainfall (24 inches), a 26.2-square-mile watershed for Truscott Lake, the assumption that 4.7% of rainfall reaches the lake as runoff, and an assumed Se concentration in runoff waters of 0.4 ug/l. The resulting load is 0.002 Kg/day and was used as an estimate for local inflow load for evaluation of all alternatives.

Selenium load for brine inputs from Area VIII was estimated using an average total Se concentration of 2.9 ug/l (derived as described above) and the average design pumping rate of 5.7 cfs (13,947,034 l/day). The resulting estimated load is 0.040 Kg/day and was used for evaluation of all alternatives.

Loads for other brine collection areas were similarly derived using average total Se concentrations (Table 2) and design pump rates. Selenium concentrations at these areas are somewhat higher than those at Area VIII, and censored concentration data were largely absent for these areas. For Area VII, a design pump rate of 8.2 cfs (20,064,154 l/day) and average Se concentration of 9.2 ug/l (Table 2) yielded an average daily load of 0.185 Kg/day. For Area X, a design pump rate of 4.2 cfs (10,276,762 l/day) and an average total Se concentration of 11.4 ug/l (Table 2) yielded an average daily load of 0.117 Kg/day. These estimated loads were used in evaluations involving these areas.

Total Se loads for alternatives analyses were obtained by summing loads for local runoff and appropriate source areas. Using this approach, the following average daily Se loads (Kg/day) were obtained and used as model input in alternative evaluation:

Alternative 1:	0.042
Alternative 2:	0.227
Alternative 3:	0.159
Alternative 4:	0.344

If alternative 1 (existing condition) is used as a reference, alternatives 2, 3, and 4 would result in estimated 440, 279, and 719% increases, respectively, in Se load over current conditions. It is also of interest to note the estimated average inflow total Se concentrations of these alternatives. If total mixing of all Se inputs as described above is assumed, resulting average inflow concentrations for alternatives 1 through 4 would be 2.2, 5.8, 5.4, and 6.9 ug/l total Se, respectively.

6. PREDICTIVE MODELING EVALUATION OF ALTERNATIVES

Water quality modeling was employed as a means of obtaining reasonable estimates of temporal changes in Se concentration in water and sediments in Truscott Lake for project alternatives listed above. The modeling approach was very similar to that employed in initial Se evaluations for project features (USACE 1993) using the Simplified Lake and Stream Analysis (SLSA) model (Hydroqual, Inc. 1981, 1982). Detailed description of model characteristics, assumptions, input parameters, and uncertainties are provided in USACE (1993) and should be thoroughly reviewed for an understanding of this approach. As noted in the 1993 document, considerable uncertainties regarding Se dynamics in brine disposal lakes for the project necessitated a very conservative initial modeling approach to Se prediction. While many uncertainties remain, additional field data collected at Truscott Lake permit a reevaluation of model input parameter values to more closely match observed field data. Details for this reanalysis and their impacts on alternatives evaluation are provided in this section.

When applied to Se simulation for the approximate 10-year period from initiation of brine input (May 1987) to September 1998 (most recent Truscott lake data), input parameters used for initial Se predictions significantly overestimate total waterborne Se concentrations and underestimate sediment Se levels. Predicted values using original input values for this time period are 2.8 ug/l and 0.06 mg/Kg (dry wt) total Se for water and sediments, respectively. These compare to measured values of <0.5 ug/l for water (Table 3) and sediment concentrations ranging from 0.1 to 0.49 mg/Kg total Se (1998 data). The conservative nature of this approach for estimation of waterborne Se concentrations, which was recognized and discussed in USACE (1993), is apparent in these comparisons. It is also apparent that the original model substantially underestimated Se concentrations in sediments.

In an effort to more closely simulate observed conditions at Truscott Lake for alternative comparisons, SLSA model input was varied until predicted values for both water and sediment were reasonably close to 1998 reported Se concentration for these matrices. For this exercise, the actual volume of pumped brine (not design average) from project initiation to September 1998 was used in load estimation (Table 4). The resulting estimated Se load over this period was 0.049 Kg/day. For the sake of continued conservatism, it was then determined that the model should be adjusted to predict an approximate waterborne total Se concentration of 0.6 ug/l for the "calibration" time period – a concentration slightly higher than the latest reported detection limit of 0.5 ug/l (Table 3). The degree of conservatism would be dependent upon how close actual concentrations are to this detection limit. Finally, a related goal of model adjustment was to more closely simulate observed sediment concentrations as sediments have been noted to be a major sink for Se in lakes (Bowie et al. 1996).

Processes reflected by SLSA model input data originally employed in Se predictive analysis (Table 2 of USACE 1993) were evaluated for potential explanation of Se mass loss in Truscott Lake as described in Section 4 above. Two processes attributed to significant Se mass loss from the water column in other systems include volatilization and sediment adsorption (see detailed discussion and citations in USACE, 1993). These two processes therefore became the focus for model input adjustment. While relative contribution of these processes is currently unknown, an attempt was made to adjust input values to provide reasonable agreement with field findings while maintaining consistency with reports from the Se literature.

Volatilization of methylated Se compounds has been demonstrated to be a significant source of Se mass loss in a number of systems (see discussion in USACE 1993). Cooke and Bruland (1987) reported that outgassing of Se may have been substantial in Kesterson Reservoir and estimated that roughly 30% of Se introduced to the system was volatilized to the atmosphere. Similarly, Thompson-Eagle and Frankenberger (1990) reported a 35% loss of the total Se inventory of pond water from Kesterson reservoir after 43 days of incubation. Biomethylation and volatilization of Se have been shown to vary considerably with Se species, concentrations, and overall aquatic productivity. From a mass removal standpoint, volatilization may be a more significant process in wetlands (Zhang and Moore 1997) relative to lakes (Bowie et al. 1996).

Owing to considerable uncertainty regarding the importance of this process and a desire for initial conservatism, original 1993 water column and sediment volatilization rate coefficients (day^{-1}) used in brine lake Se simulations were set extremely low (2E-6 day^{-1}). These values were three to four orders of magnitude lower than the few that could be found reported in the literature (0.003 to 0.053 day^{-1}; Calderone et al. 1990). For Truscott Lake simulations for this analysis, volatilization rate constants were varied to more realistically reflect both recent literature findings for lakes and to account for a fraction of observed Se mass loss. In one of the few modeling exercises described in the literature, Bowie et al. (1996) estimated net volatilization losses of less than 5% of Se loading to Hyco Reservoir, North Carolina. They reported that similar minor losses probably occur in most lakes. Accordingly, both (water and sediment) volatilization rate constants were varied to approximate 5% or less (depending on alternative) mass loss from the system over a 100-year period. The resulting rates (2E-5 day^{-1}) were still two to three orders of magnitude lower than those found in the literature but were thought to reasonably account for some Se mass loss from the system while still providing a measure of conservatism. These values were therefore used in all SLSA modeling exercises for this evaluation.

Changes in water column and sediment partition coefficients (l/Kg) were next evaluated for providing model simulations more closely matching observed field conditions. Through iterative simulation, water column and sediment partition coefficients of 500 and 350 l/Kg, respectively, resulted in a predicted waterborne total Se concentration of approximately 0.6 ug/l in Truscott Lake for a simulation period from impoundment to September 1998. This was very close to the prediction goal as described above. Predicted total Se in Truscott Lake sediments was 0.19 mg/Kg dry weight - a value very much within the range of 0.1 to 0.49 mg/Kg reported for 1998 sediment sampling and a much closer estimate of sediment Se predictions than that obtained using previous partition coefficients. Based on this evaluation, water column and sediment partition coefficients of 500 and 350 l/Kg were retained for use in Truscott Lake alternatives evaluation. Use of these values improved simulation accuracy of the model by increasing predicted flux of Se to sediments – a process reported to be of major importance in lakes (Bowie et al. 1986).

With the exception of coefficients described above and alternative-specific parameters, all input parameters used in original Se simulations (Table 2, USACE 1993) were used in SLSA model analysis of alternatives for this evaluation. Simulations were conducted for separate 5-year intervals over a total time span of 100 years. Discrete simulations were conducted to mitigate the influence of significantly changing pool volumes and surface areas during initial years of project operation for some alternatives. Input parameters dependent upon pool morphometry, including water volume, sedimentation rates, and water depth (Table 1), were varied to match anticipated conditions for each alternative.

7.0 MODELING RESULTS

Predicted total Se concentrations in Truscott Lake water and sediments for all alternatives for this evaluation are provided in Table 7, Figure 1, and Table 8, Figure 2, respectively.

For water, maximum concentrations (ug/l) and operational time to occurrence are as follows:

Alternative 1: 0.9 (40 years)
Alternative 2: 4.5 (65 years)
Alternative 3: 3.2 (50 years)
Alternative 4: 6.4 (80 years)

Similarly, estimated maximum total Se concentrations in sediments (mg/Kg dry wt) and operational time to occurrence are:

Alternative 1: 0.30 (90 years)
Alternative 2: 1.57 (65 years)
Alternative 3: 1.11 (55 years)
Alternative 4: 2.23 (85 years)

These values were used in alternatives evaluation relative to Se concerns.

TABLE 7

ESTIMATED LAKEWATER TOTAL SE CONCENTRATIONS (ug/l) FOR WICHITA BASIN ALTERNATIVES*

ALT 1: Area VIII - 1 spray field
ALT 2: Areas VIII-1, VII-2
ALT 3: Areas VIII-1, X-2
ALT 4: Areas VIII-1, VII-2,X-2

Years	Alternative 1	Alternative 2	Alternative 3	Alternative 4
5	0.3	1.4	1.1	2.0
10	0.5	2.2	1.9	3.0
15	0.7	3.3	2.2	3.8
20	0.8	3.2	2.6	4.3
25	0.8	3.5	2.7	4.8
30	0.8	3.7	2.9	5.0
35	0.8	3.8	2.9	5.2
40	**0.9**	4.1	3.1	5.8
45	0.9	4.2	3.1	5.8
50	0.9	4.3	**3.2**	5.9
55	0.9	4.3	3.2	6.0
60	0.9	4.4	3.2	6.2
65	0.9	**4.5**	3.2	6.2
70	0.9	4.3	3.2	6.2
75	0.9	4.3	3.2	6.2
80	0.9	4.4	3.2	**6.4**
85	0.9	4.4	3.2	6.4
90	0.9	4.4	3.0	6.4
95	0.9	4.4	3.2	6.4
100	0.9	4.3	3.2	6.3
MAX	**0.9**	**4.5**	**3.2**	**6.4**

* SLSA Model Output

Figure 1. Estimated Lakewater Total Se Concentrations

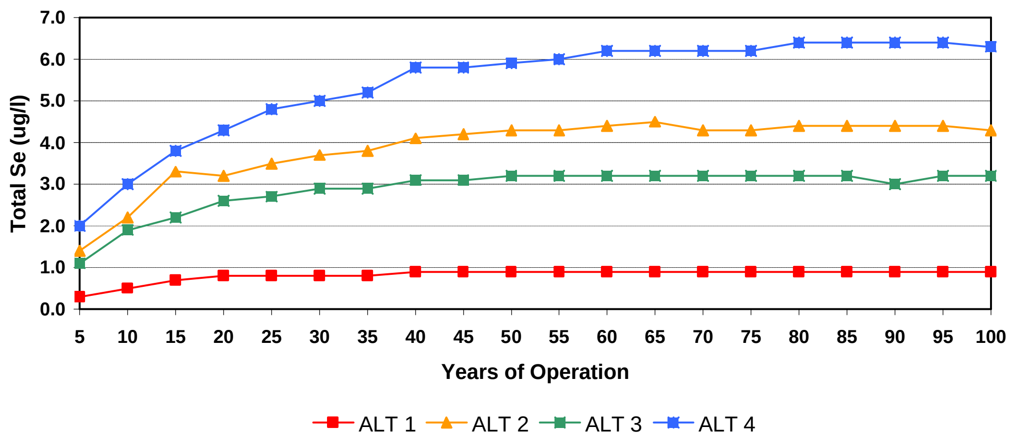


TABLE 8

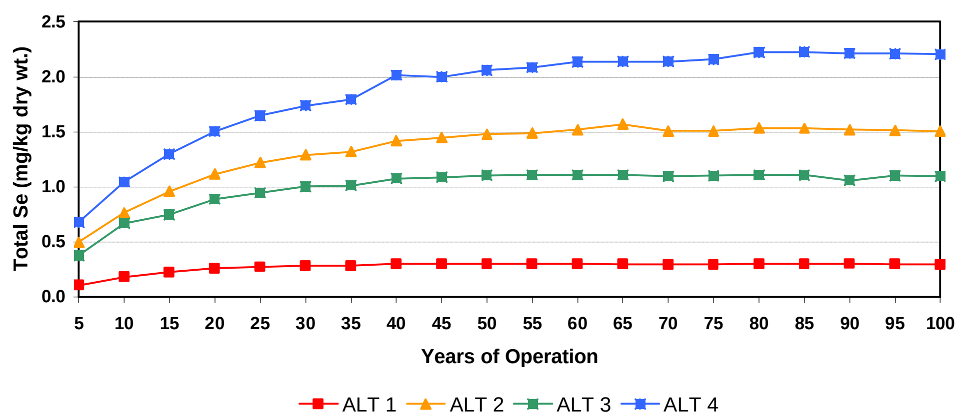
ESTIMATED SEDIMENT TOTAL SE CONCENTRATIONS (MG/KG DRY WT) FOR WICHITA BASIN ALTERNATIVES*

ALT 1: Area VIII - 1 spray field
ALT 2: Areas VIII-1, VII-2
ALT 3: Areas VIII-1, X-2
ALT 4: Areas VIII-1, VII-2,X-2

Years	Alternative 1	Alternative 2	Alternative 3	Alternative 4
5	0.108	0.497	0.376	0.680
10	0.184	0.765	0.668	1.046
15	0.224	0.960	0.749	1.298
20	0.261	1.117	0.889	1.505
25	0.274	1.222	0.946	1.648
30	0.283	1.290	1.005	1.739
35	0.283	1.322	1.012	1.794
40	0.300	1.418	1.077	2.015
45	0.300	1.448	1.088	1.997
50	0.301	1.479	1.105	2.060
55	0.301	1.488	**1.110**	2.084
60	0.301	1.518	1.110	2.136
65	0.298	**1.570**	1.109	2.137
70	0.296	1.509	1.097	2.138
75	0.296	1.508	1.100	2.158
80	0.301	1.536	1.109	2.222
85	0.301	1.533	1.107	**2.226**
90	**0.303**	1.518	1.060	2.212
95	0.298	1.515	1.102	2.210
100	0.295	1.506	1.097	2.203
MAX	**0.303**	**1.570**	**1.110**	**2.226**

* SLSA Model Output

Figure 2. Estimated Sediment Total Se Concentrations



8.0 THRESHOLD LEVELS OF CONCERN

Considerable discussion regarding Se levels of concern related to brine disposal lakes for the original Red River Chloride Control Project is provided in USACE (1993). As noted in this document, project impoundments are designed solely for disposal of collected brines. As such, primary environmental concerns center around potential impacts on semi-aquatic organisms tied to these systems via food chain dynamics, and not maintenance of diverse communities of exclusively aquatic species (e.g., fish). Owing to a demonstrated sensitivity of aquatic birds to waterborne Se, their potential use of brine disposal lakes, and substantial information regarding impacts on these species, birds were (and continue to be) the focus for Se-related impact evaluation for the project. This focus should be carefully considered in threshold evaluation.

Owing to two distinct categories of Se-related impacts on aquatic birds, it was necessary to distinguish between Se criteria for: (1) potential reproductive impairment of birds nesting at the project area, and (2) potential detrimental impacts on adult and juvenile birds nesting at sites removed from the project (e.g., wintering waterfowl). In the 1993 evaluation for Crowell Lake, a total waterborne Se concentration of 10 ug/l was used as a threshold value protective of avian embryotoxicity. For impacts on adult and juvenile birds in the absence of reproductive concerns, a threshold value of 34 ug/l was proposed. Finally, a sediment concern threshold level of 4 mg/Kg (dry weight) was used in this evaluation. Literature citations supporting these criteria are provided in USACE (1993) and should be reviewed for an understanding of issues related to threshold estimation for this study.

Subsequent to the USACE (1993) report, a significant amount of literature has provided additional information on threshold levels for Se in the environment and their application to risk evaluation. Principal among these are Lemly (1993, 1995, 1996), Skorupa et al. (1996), and Heinz (1996). In addition, Se concentrations in a number of environmental matrices from field case studies where Se toxicity has been observed have been reported by Skorupa et al. (1996) and Skorupa (1998). Collectively, these publications have provided additional information for establishment of Se toxicity thresholds in the aquatic environment and have generally resulted in a gradual lowering of concentrations reported to be toxic to fish and wildlife.

One area of apparent consensus among Se researchers is that waterborne Se concentration in and of itself is a poor predictor of impact on fish and wildlife and that water (as well as sediment) data should be evaluated along with Se concentrations in food chain organisms and fish and wildlife tissues for conclusions regarding Se impacts (Lemly 1996). For ultimate assessment of bird-related impacts, avian eggs are believed to be the best biotic matrix for risk/impact assessment though considerable between-species variability in embryo sensitivity exists (Lemly 1993, Skorupa et al. 1996). Complexities involved with using water-based criteria for impact prediction have even resulted in proposed methods for deriving site-specific water quality criteria for Se (e.g., Van Derveer and Canton 1997, Lemly 1998). Important considerations in deriving site-specific crieria appear to be Se speciation, sediment organic content, and application to lotic versus lentic systems (Van Derveer and Canton 1997). The current USEPA chronic criteria for Se (as well as the State of Texas chronic water quality standard) is 5 ug/l.

Despite the complexities and uncertainties involved, it was still necessary to derive water and sediment criteria for use in pre-construction evaluation of brine disposal alternatives and projected impacts on birds. While site-specific monitoring of both biotic and abiotic environmental matrices would undoubtedly reduce this uncertainty upon project implementation, pre-construction evaluation of alternatives made this assessment necessary. Given the complexities and uncertainties involved, a range of threshold values appearing in the literature was chosen for comparison to predicted values in alternatives analysis.

Though not confined exclusively to impacts on birds, Lemly (1995) assigned a "low hazard" (defined as ". . . periodic or ephemeral toxic threat that could marginally affect the reproductive success of some sensitive species, but most species will be unaffected.") rating to dissolved (0.45 um filtered) Se concentrations of 2 to 3 ug/l based on an extensive literature review. Later, Lemly (1996) recommended that waterborne Se concentrations of 2 ug/l or greater (total recoverable basis in 0.45-um filtered samples) be considered "highly hazardous" to the health and long-term survival of fish and wildlife. Though originally based on dissolved concentrations (totals might be slightly higher) and not confined exclusively to birds, a total Se concentration of 2 ug/l was used as the lower value for the threshold range for this evaluation.

Given conservatism associated with both predicted Se values for this assessment as well as the 2 ug/l threshold, this lower end might be considered as “ultraconservative” for purposes of this evaluation. In studies relating Se concentrations in water to bioaccumulation of Se in bird eggs, Skorupa and Ohlendorf (1991) proposed 10 ug/l waterborne Se as protective of avian embryotoxicity under most conditions. This was the concentration used in the 1993 evaluation and was retained as the upper limit of the threshold range for this evaluation. Consequently, a range of 2 to 10 ug/l was used as a minimum threshold total waterborne Se value range for impacts on breeding birds associated with alternatives evaluation.

The threshold concentration of 34 ug/l total Se for impacts on non-breeding birds was originally based on recommended dietary exposure for non-breeding birds and empirically-derived regression equations for prey accumulation of Se (see USACE 1993). Nothing could be found in the recent literature to justify modification of this threshold and it was therefore retained for use in alternatives evaluation.

Currently, there is no well developed empirical basis for assessing fish and wildlife risk as a function of sediment Se concentration (Skorupa et al. 1996, Van Derveer and Canton 1997). Sediment concentrations are particularly important in systems where the benthic detrital food web may influence Se transfer (Van Derveer and Canton 1997). Lemly (1995) characterized sediment Se concentrations of 2-3 mg/Kg dry weight as “low hazard” (an assessment again not entirely based on bird data). Skorupa et al. (1996) cited unpublished data, which suggested egg Se concentrations exceeded embryotoxicity thresholds for sensitive bird species in black-necked stilt eggs at ponds averaging greater than or equal to 1.8 ppm Se in sediments. They also cited studies reporting an approximate background Se concentration of <1.9 mg/Kg in Texas freshwater environments. Based on a review of field data from throughout the United States, Van Derveer and Canton (1997) derived a “predicted effect level” of sediment Se concentrations in the range of 2.5 mg/Kg and an “observed effect level” in the range of 4.0 mg/Kg. They also cited sediment total organic carbon (TOC) concentrations as important considerations in these evaluations. Finally, a 4 mg/Kg concern threshold was proposed by Lemly and Smith (1987) and was the value used in the original Crowell Lake evaluation (USACE 1993). Accordingly, an approximate minimum threshold range of 2 to 4 mg/Kg dry weight Se in sediments was used in this assessment of alternatives. Again, the lower end of the range (around 2 mg/Kg) might be considered "ultraconservative" for purposes of this evaluation.

9. COMPARISON OF ALTERNATIVES

Predicted values for total Se in Truscott Lake water (Table 7) and sediments (Table 8) for the four brine disposal alternatives were compared to threshold ranges described above for estimation of potential impacts on birds. This analysis permitted both impact estimation and a comparison of alternatives relative to selenium concerns.

Predicted waterborne Se concentrations for Alternative 1 (current operational condition) are extremely low, near analytical detection limits, and below threshold values for Se-related impacts on birds. Under this scenario, the maximum estimated concentration, 0.9 ug/l, would be predicted to occur after approximately 40 years of project operation (Table 7). A maximum sediment concentration of 0.303 mg/Kg was predicted after approximately 90 years of project operation (Table 8) – a value that is likewise well below the threshold range for protection of fish and wildlife. Based on the methodology and assumptions used for this assessment, Se-related concerns would not be expected to occur with this alternative.

Alternatives 2 and 3 have similar predicted maximum Se concentrations in water of 4.5 and 3.2 ug/l, respectively (Table 7). For alternative 2, the maximum concentration would be predicted after approximately 65 years of project operation. Estimated time to maximum concentration for alternative 3 is approximately 50 years. Predicted waterborne Se concentrations for both alternatives are within, but near the lower end of the threshold range for impacts on breeding birds (2 – 10 ug/l), indicating that reproductive impacts on some avian species (particularly sensitive species) breeding at Truscott lake might be possible. Estimated water concentrations for both alternatives are well below the threshold range for impacts on young and adult birds in the absence of reproductive concerns. Likewise, estimated maximum sediment Se concentrations for both alternatives are in the 1 to 1.6 mg/Kg range (Table 8) and therefore below the impacts threshold range for sediments.

Predicted maximum total Se concentration for Truscott Lake water is highest for Alternative 4. This concentration, 6.4 ug/l, was estimated to occur after approximately 80 years of project operation (Table 7). This concentration is within the threshold range for avian reproductive impairment (2 – 10 ug/l), but closer to the upper end of this range relative to other alternatives. Accordingly, the potential for impacts on breeding birds might still be relatively low for this alternative and limited to sensitive to moderately-sensitive avian species, but the risk of occurrence of these effects is the highest of all evaluated alternatives. As with other alternatives, maximum estimated waterborne concentrations are well below the 34 ug/l threshold for non-reproductive impacts on young and adult birds. Predicted sediment concentrations are highest for this alternative (maximum of 2.23 mg/Kg) and slightly exceed the conservative lower end of the sediment threshold range used for this evaluation.

10. SUMMARY AND CONCLUSIONS

Based on methodology and assumptions used for this evaluation of Se-related concerns associated with brine disposal alternatives, it appears reasonable to assume that all alternatives could be implemented without Se-induced impacts on non-breeding birds (e.g., wintering waterfowl) or significant Se-related sediment concerns for these species at Truscott Brine Lake, Texas. Modeled estimates for Se concentrations for all alternatives are below estimated threshold values for non-reproductive impacts.

Estimated concentrations of total Se in Truscott Lake waters for all alternatives involving increased brine flows to the impoundment from additional collection areas are within a range of threshold values which indicate at least a potential for reproductive impacts on sensitive species of semi-aquatic bird species nesting at Truscott Lake. Alternatives involving collection and disposal of additional brines from either Area VII or X result in predicted waterborne Se concentrations near the conservative end of a range of threshold values indicating the potential for avian reproductive impacts. Addition of brines from both areas (Alternative 4) results in an estimated total Se concentration in water closer to the upper end of a threshold range indicative of the potential for these effects. In addition, this alternative results in estimated sediment Se concentrations near the lower end of a threshold range for potential impacts. Given the assumed conservative nature of the approach used, it would seem that the potential for Se-related impacts predicted by this evaluation is not excessive and is low enough that any of the alternatives could reasonably be implemented, provided that an adequate Se monitoring program accompanies project implementation. This monitoring program should include a number of environmental matrices, including water, sediment, vegetation, avian food items (e.g., fish, invertebrates), and eggs of appropriate (i.e., sedentary, semi-aquatic) bird species.

It must be noted that considerable uncertainty exists regarding environmental dynamics of Se and associated impacts on wildlife. These areas of uncertainty and their impacts on Se evaluations for this project are addressed in original Se evaluations (USACE 1993) and should be reviewed for an understanding of these issues. Given the site-specific nature of many of these issues, it is likely that these uncertainties can only be significantly reduced by continued monitoring in the Wichita River Basin as the project progresses. A monitoring program designed to reduce these uncertainties is recommended for implementation of any alternative.

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