Mine Waste Technology Program
Activity III, Project 39

Long-Term Monitoring of a Permeable Treatment Wall

Project Management

Norma Lewis - EPA

Lynn McCloskey - MSE

Apatite Treatment Technology Deployment

Description:

- System designed to provide temporary treatment of a slipstream of the mine discharge (approximately 20 gpm)
- System designed to saturate the apatite media to help control odor issues

Purpose:

- Technology deployment for DOE of an apatite treatment technology
- Reduction of dissolved zinc (Zn) concentrations in treated water

Barrier design and installation were funded through DOE/WETO, TTP#FT10WE31, Task B

Project Site Location

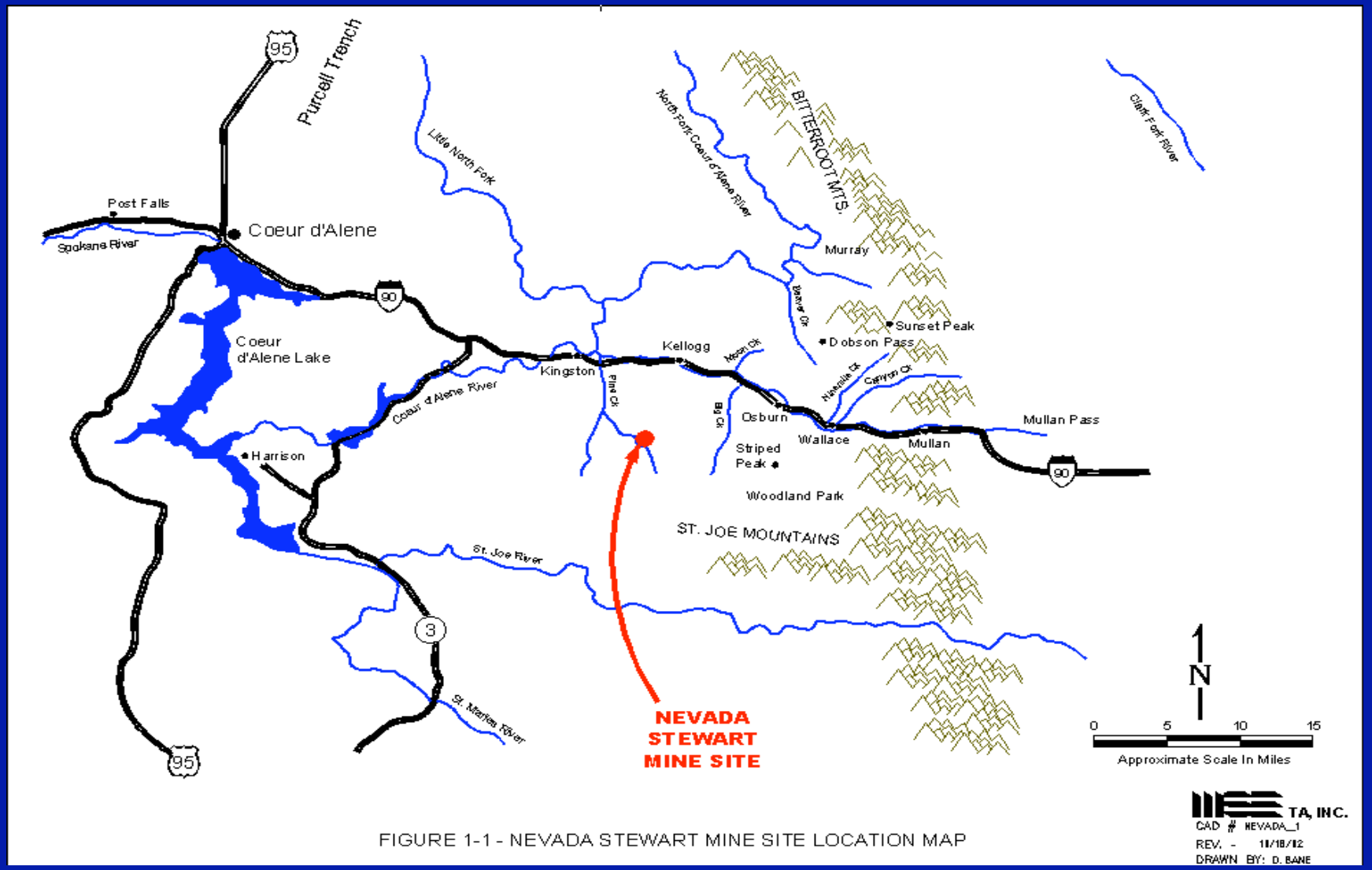


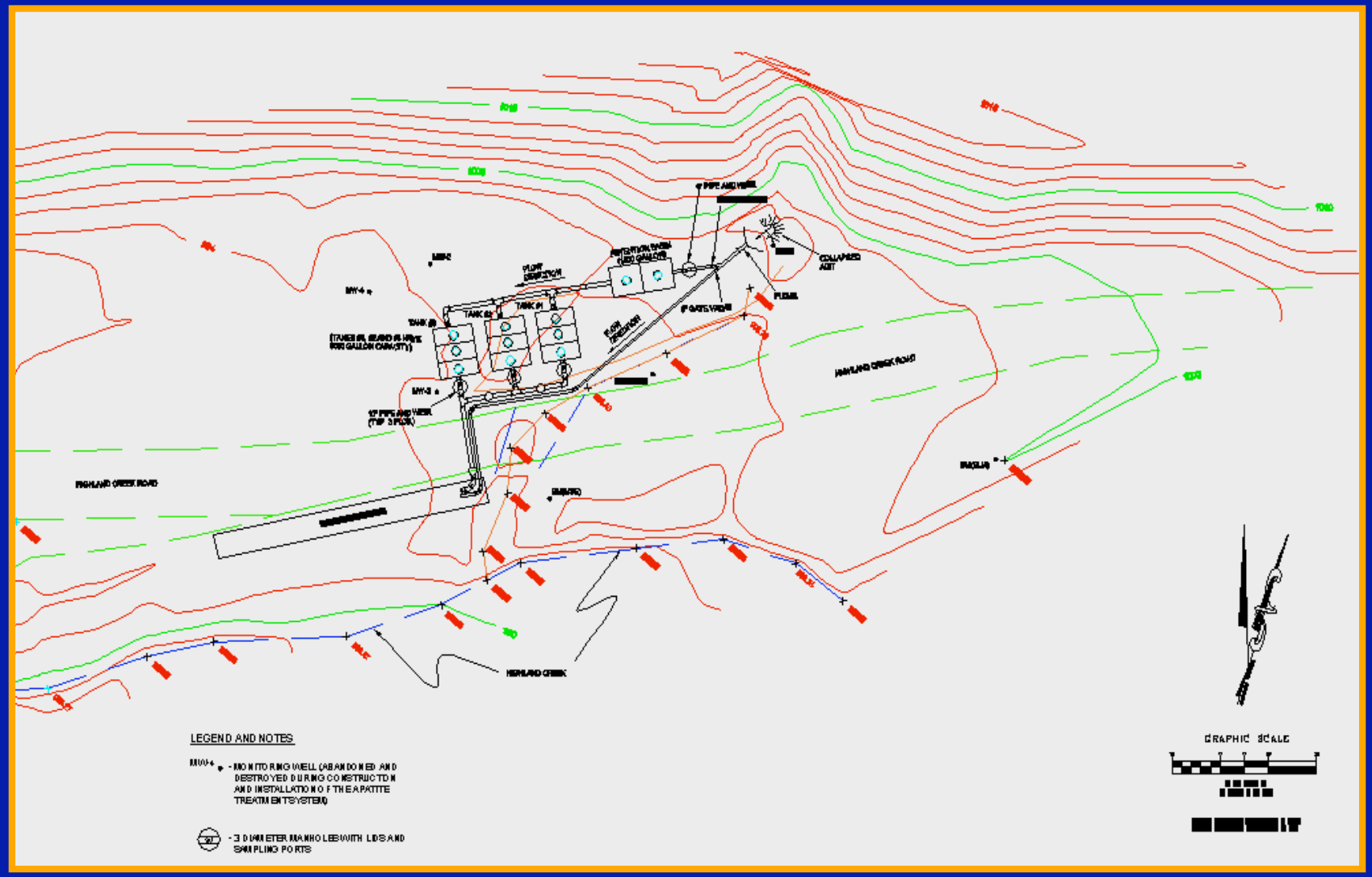
FIGURE 1-1 - NEVADA STEWART MINE SITE LOCATION MAP

TA, INC.
CAD # NEVADA_1
REV. - 11/18/12
DRAWN BY: D. BANE

Apatite Treatment Technology Deployment

Site prior to project start

Plan View Design Map of the Apatite Treatment System



Apatite Treatment Technology Deployment

System installation

Apatite Treatment Technology Deployment

Post system installation – October 6, 2002

Post Installation Activities

- November 2002 – baseline sampling performed
- December 2002 – partially plugged, with flow at 6 gpm
- February 2003 – cleaned out effluent/influent lines to maintain flow
- November 2002–August 2004 – performance sampling period
- May 2003, October 2003, February 2004, and April 2004 – initial permeability enhancement of material (SP3 partially plugged and flowed over top of the apatite media)

Monitoring Activities

- Water quality sampling for metals loading and concentrations
- Geochemical modeling analysis – Golder Associates, Inc.
- Solids/media and microscopic analysis – Montana Tech – SEM, XRD, and literature search
- Acute aquatic toxicity testing for treatment evaluation
  - Jim Lazorchak, EPA, NRMRL, Cincinnati, Ohio

Average Flow Through System

Total Flow through System through March 2004
= 10.6 Million Gallons

Sample Port	Average Monthly Flow (gpm)
Sample Port 1 - Influent	17.73
Sample Port 2 - Effluent	5.47
Sample Port 3 - Effluent	8.61
Sample Port 4 - Effluent	3.65

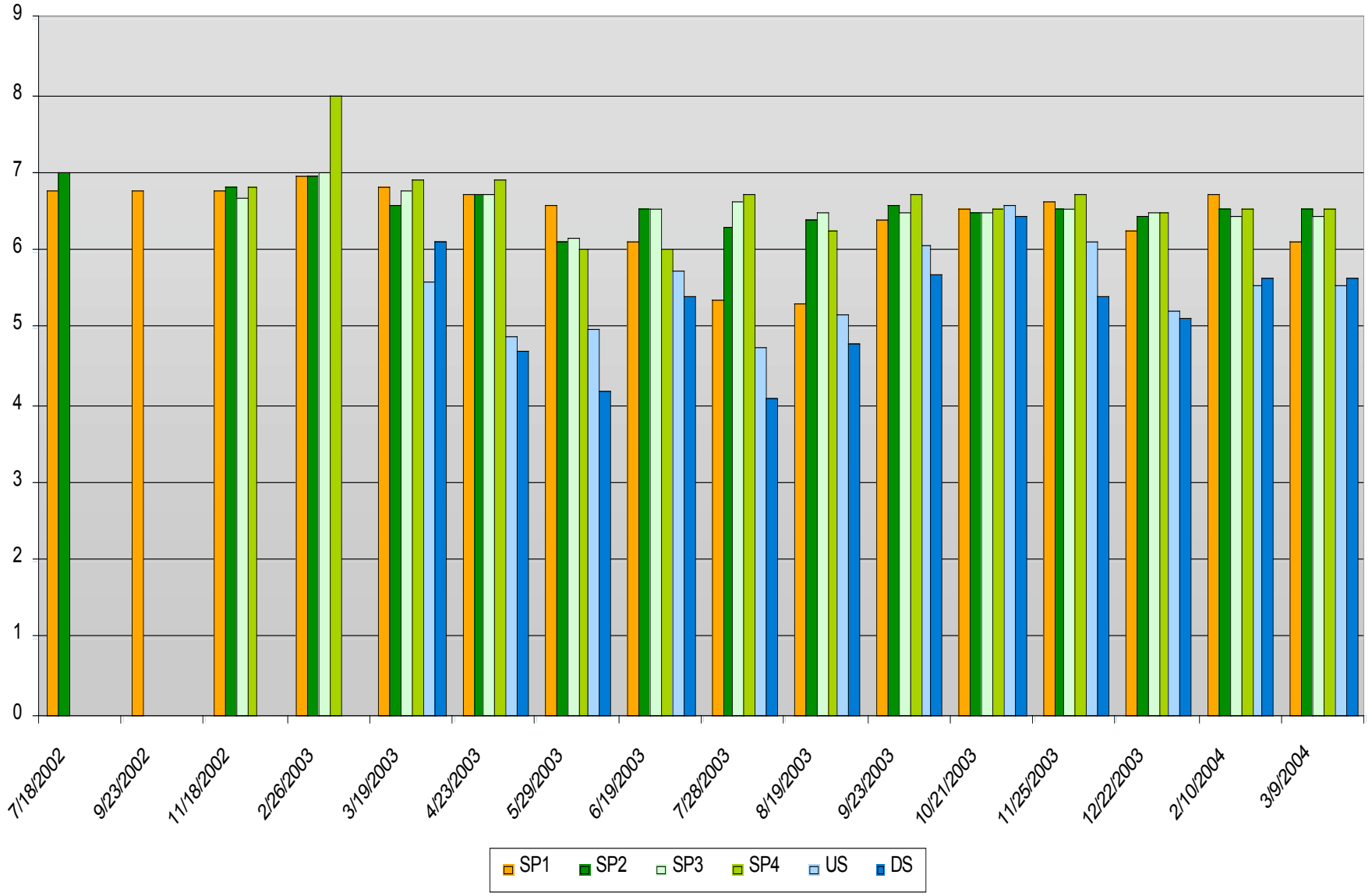
Water Quality and Metals Loading Observations

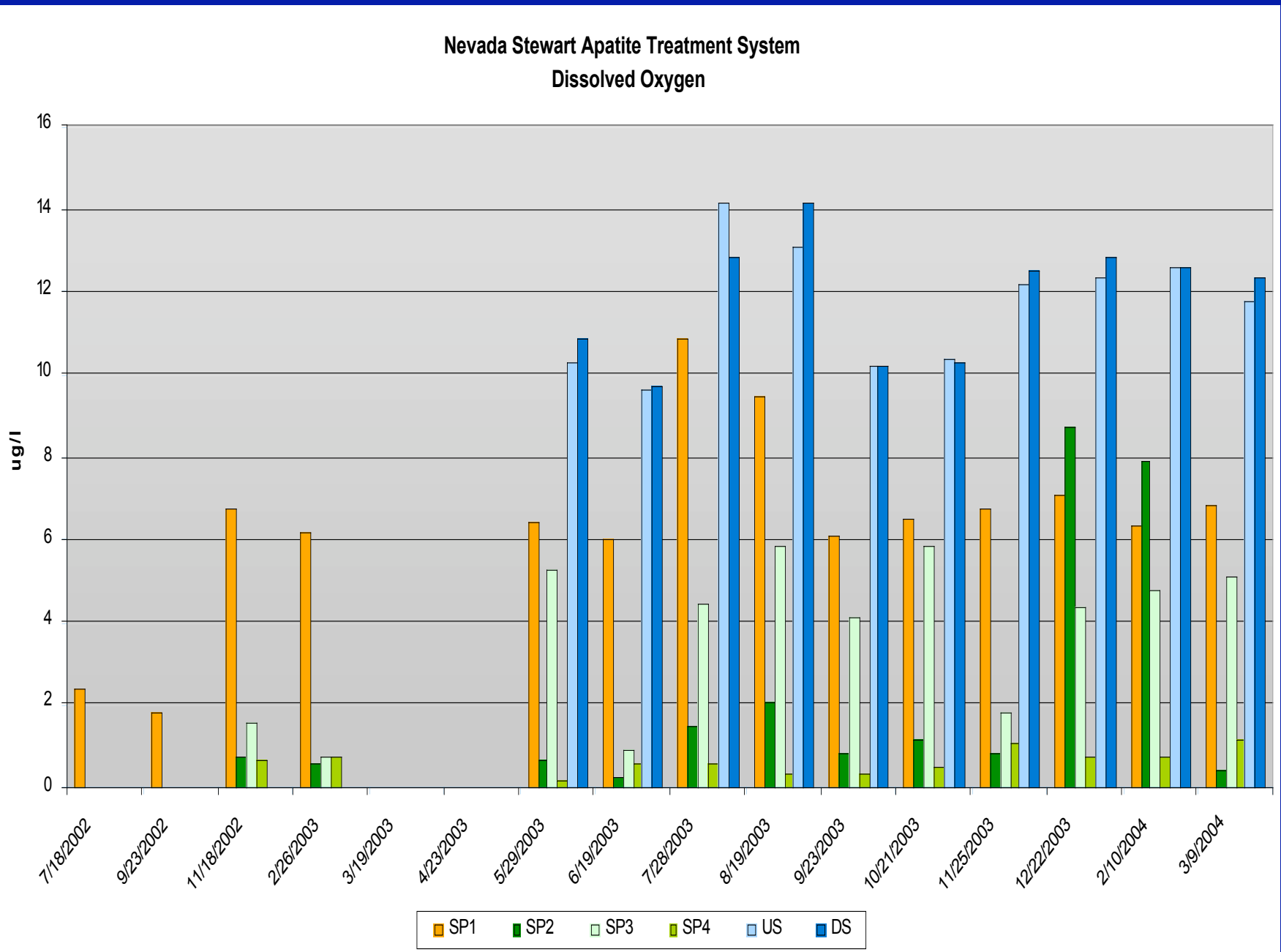
Key for the following 10 Graph:

SP1 – Inflow from adit to treatment system - orange

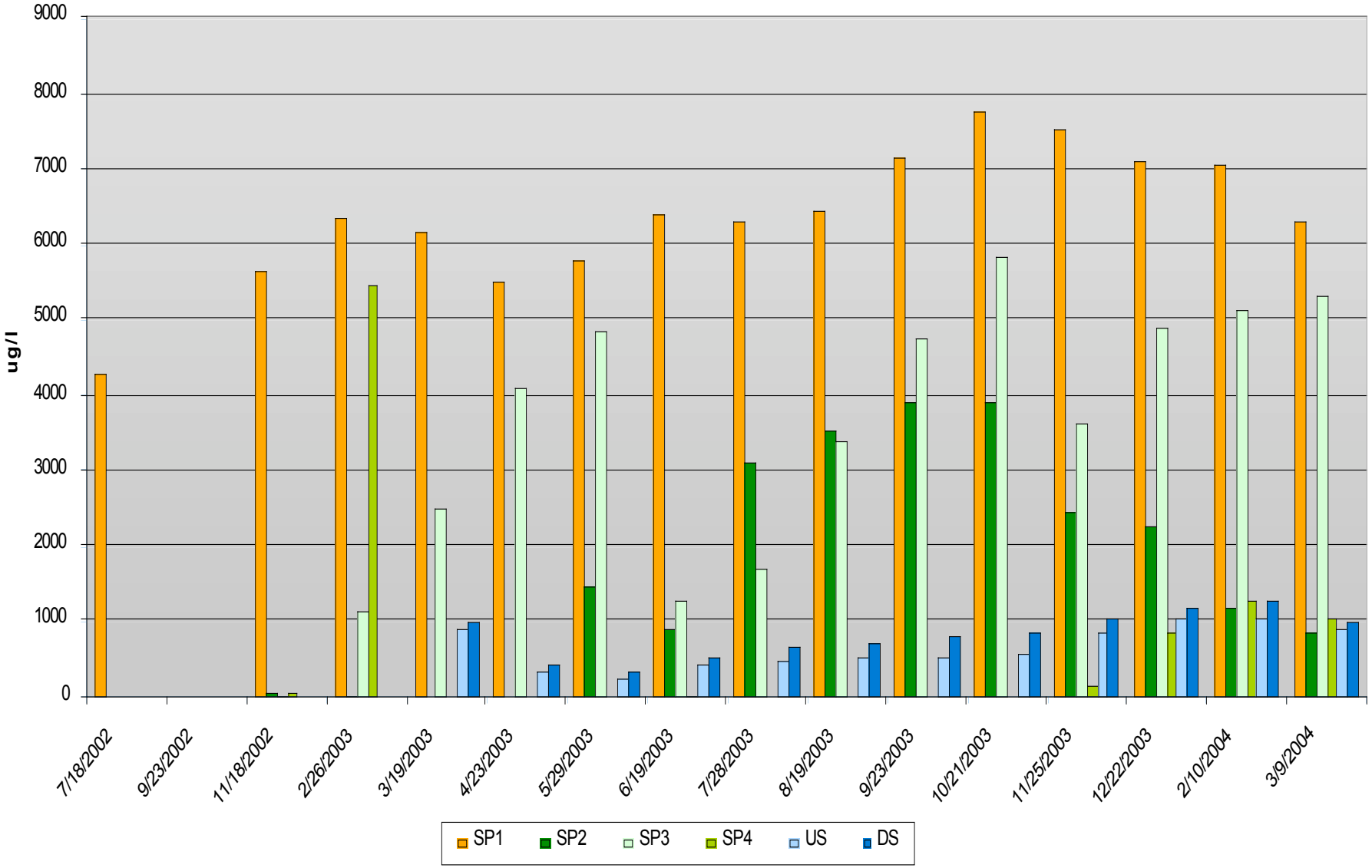
SP2, SP3, SP4 – Outflow from apatite treatment system - green

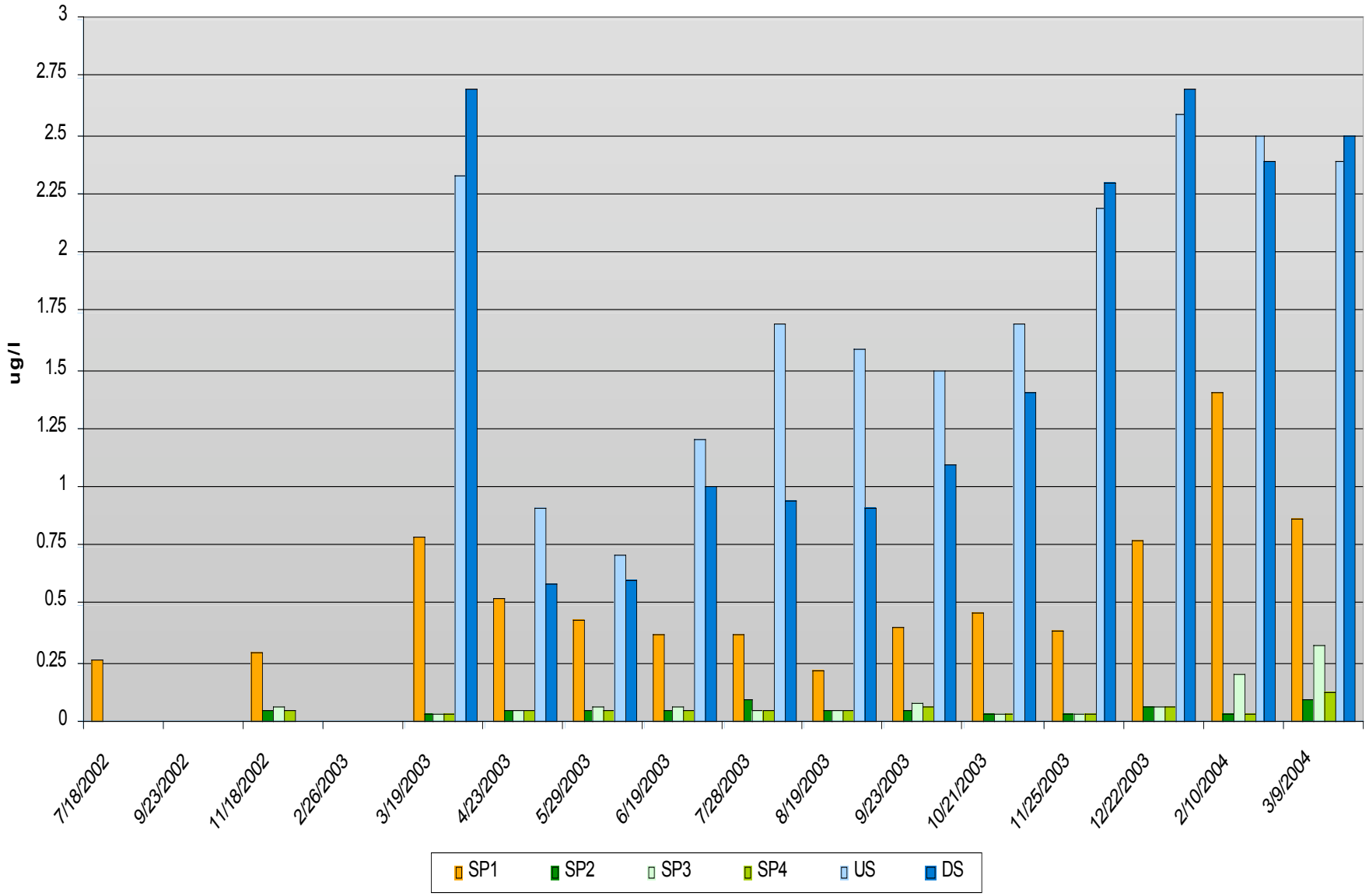
US and DS – Up stream and down stream samples of Highland Creek - blue

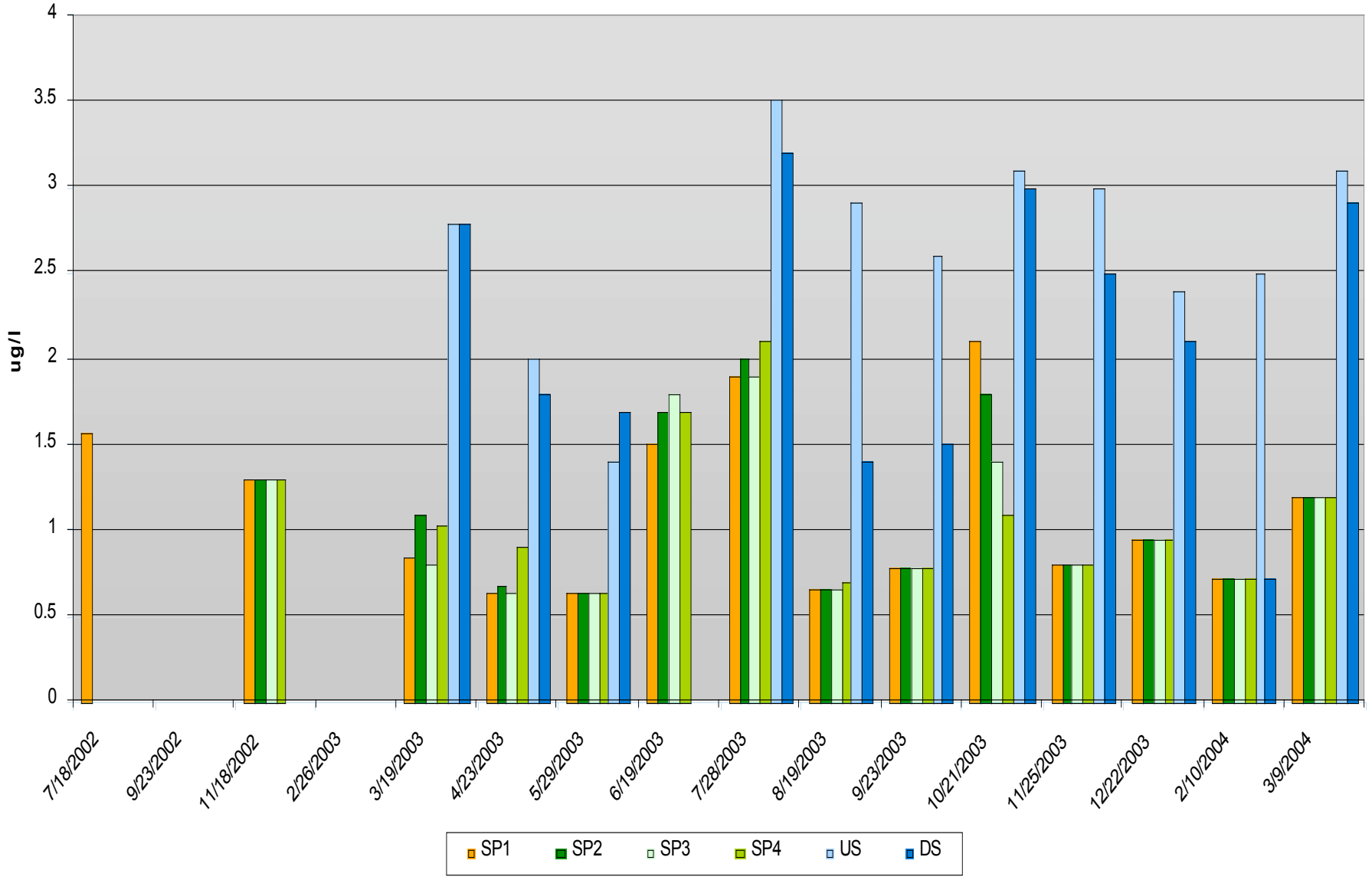

Nevada Stewart Apatite Treatment System
pH
9
8
7
6
5
4
3
2
1
0
7/18/2002
9/23/2002
11/18/2002
2/26/2003
3/19/2003
4/23/2003
5/29/2003
6/19/2003
7/28/2003
8/19/2003
9/23/2003
10/21/2003
11/25/2003
12/22/2003
2/10/2004
3/9/2004
SP1
SP2
SP3
SP4
US
DS


Nevada Stewart Apatite Treatment System
Dissolved Oxygen
ug/l
16
14
12
10
8
6
4
2
0
7/18/2002
9/23/2002
11/18/2002
2/26/2003
3/19/2003
4/23/2003
5/29/2003
6/19/2003
7/28/2003
8/19/2003
9/23/2003
10/21/2003
11/25/2003
12/22/2003
2/10/2004
3/9/2004
SP1
SP2
SP3
SP4
US
DS

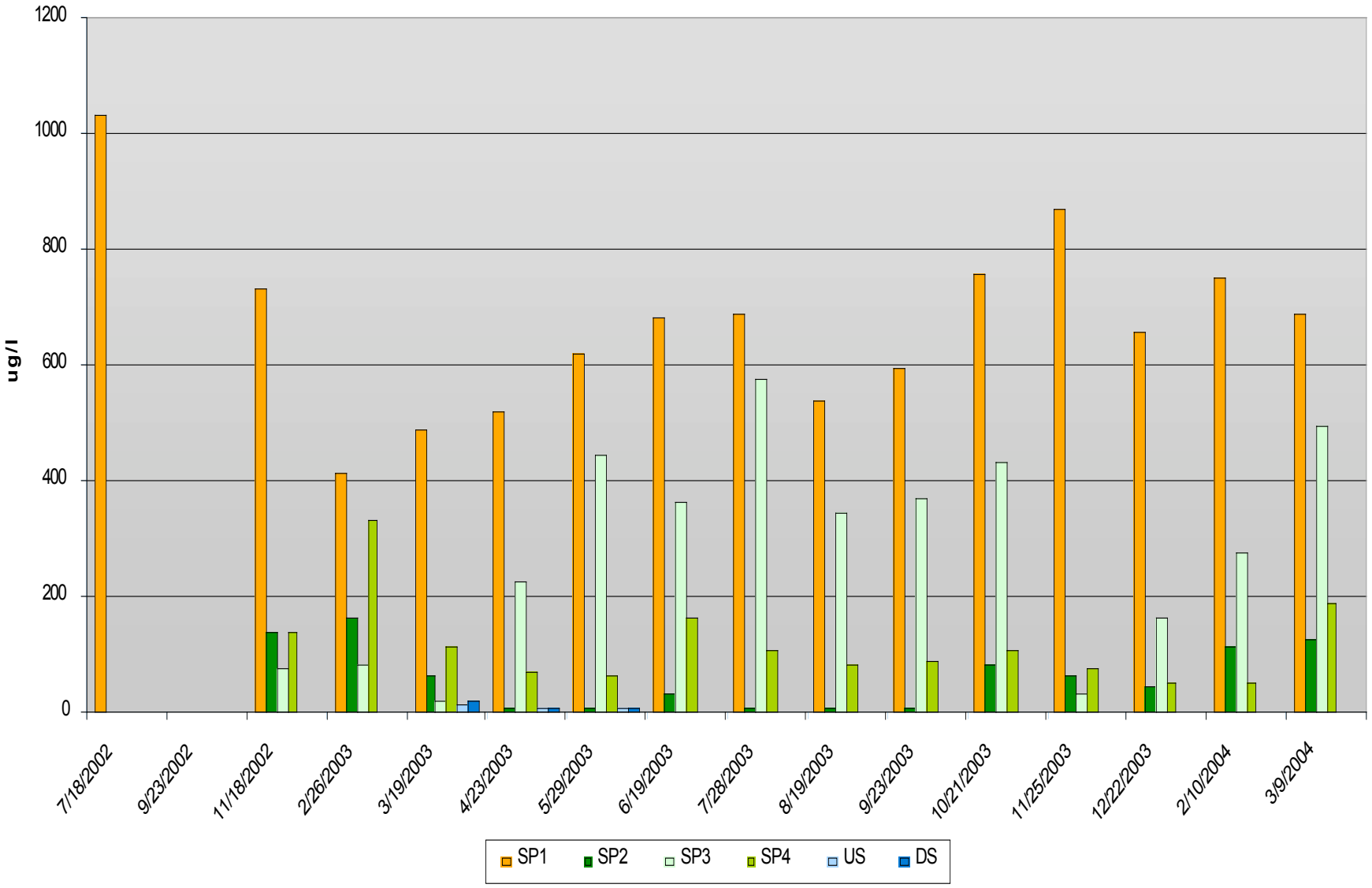
Nevada Stewart Apatite Treatment System
Dissolved Zinc



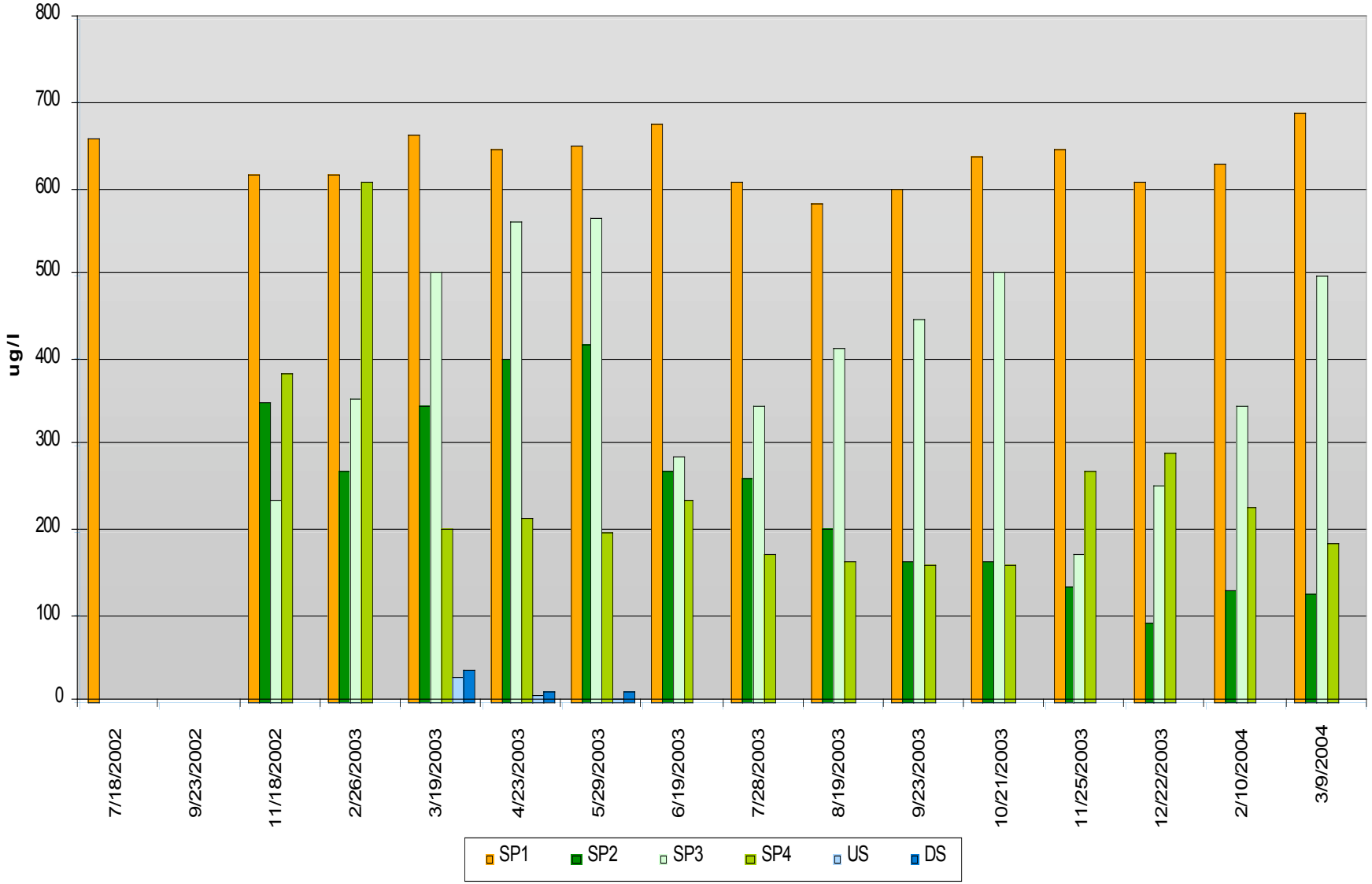

Nevada Stewart Apatite Treatment System
Dissolved Cadmium
ug/l
3
2.75
2.5
2.25
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
7/18/2002
9/23/2002
11/18/2002
2/26/2003
3/19/2003
4/23/2003
5/29/2003
6/19/2003
7/28/2003
8/19/2003
9/23/2003
10/21/2003
11/25/2003
12/22/2003
2/10/2004
3/9/2004
SP1
SP2
SP3
SP4
US
DS

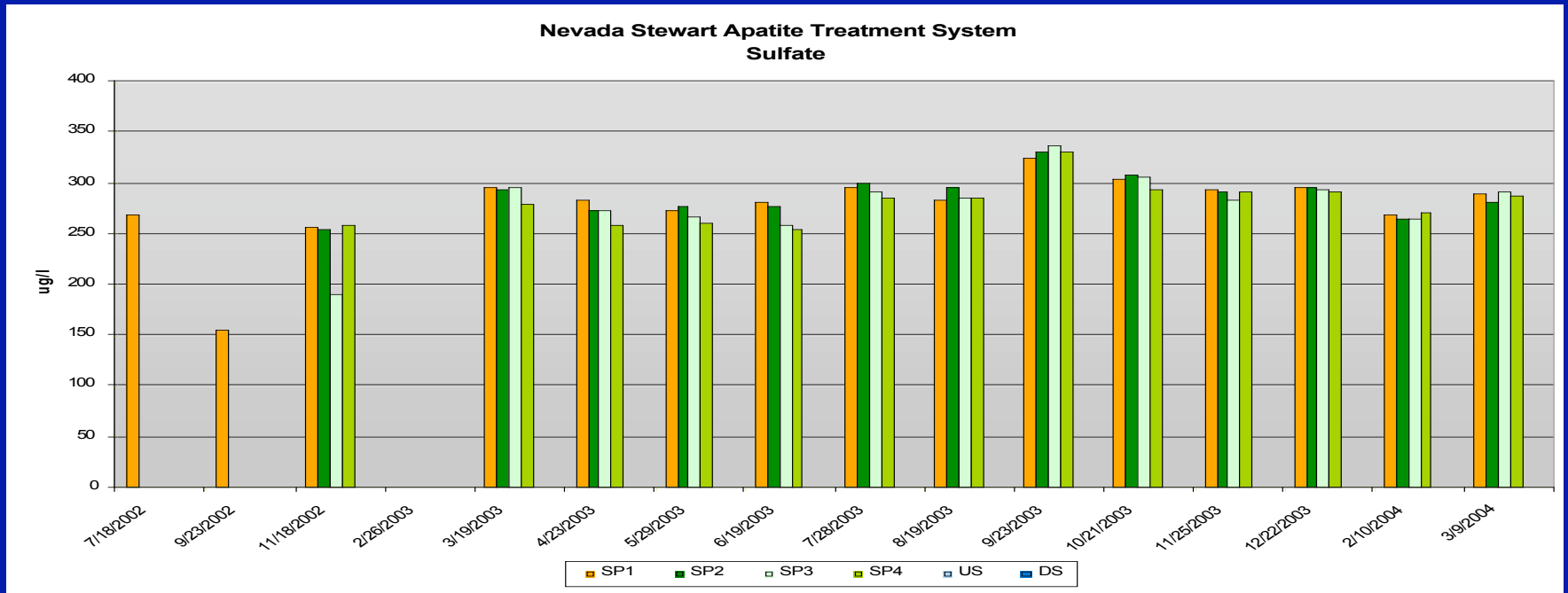

Nevada Stewart Apatite Treatment System
Dissolved Lead
ug/l
4
3.5
3
2.5
2
1.5
1
0.5
0
7/18/2002
9/23/2002
11/18/2002
2/26/2003
3/19/2003
4/23/2003
5/29/2003
6/19/2003
7/28/2003
8/19/2003
9/23/2003
10/21/2003
11/25/2003
12/22/2003
2/10/2004
3/9/2004
SP1
SP2
SP3
SP4
US
DS

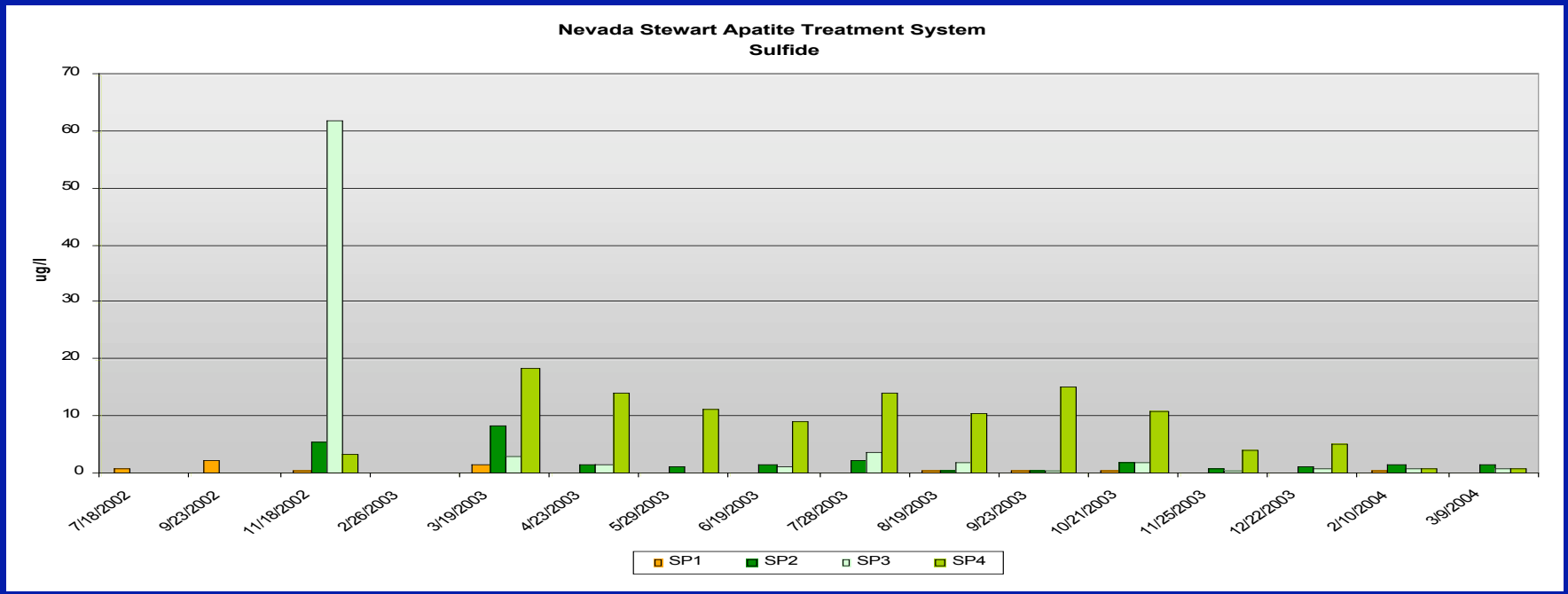
Nevada Stewart Apatite Treatment System
Dissolved Iron



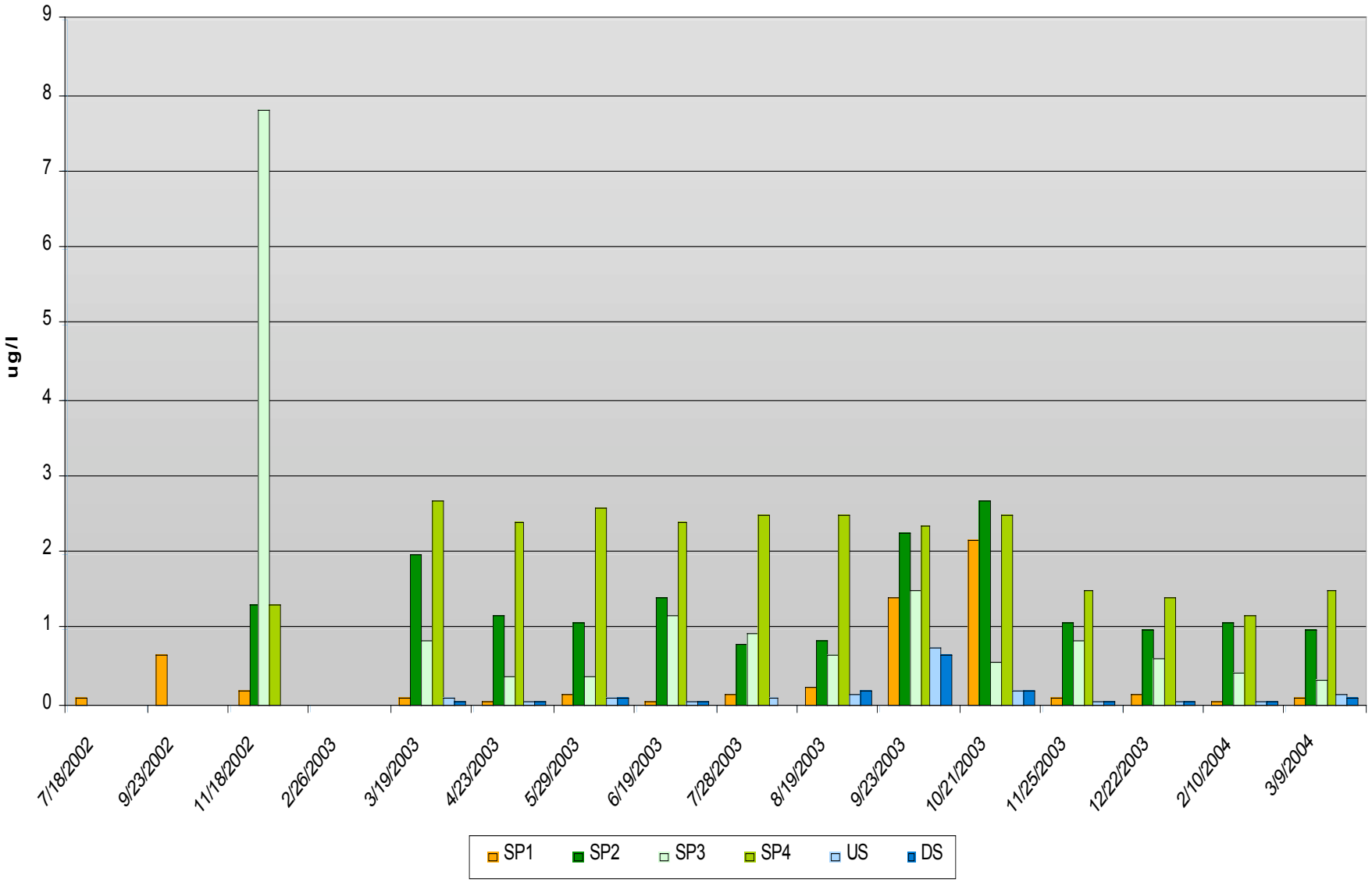
Nevada Stewart Apatite Treatment System
Dissolved Manganese




Nevada Stewart Apatite Treatment System
Sulfate
ug/l
400
350
300
250
200
150
100
50
0
7/18/2002
9/23/2002
11/18/2002
2/26/2003
3/19/2003
4/23/2003
5/29/2003
6/19/2003
7/28/2003
8/19/2003
9/23/2003
10/21/2003
11/25/2003
12/22/2003
2/10/2004
3/9/2004
SP1
SP2
SP3
SP4
US
DS


Nevada Stewart Apatite Treatment System
Sulfide
ug/l
70
60
50
40
30
20
10
0
7/18/2002
9/23/2002
11/18/2002
2/26/2003
3/19/2003
4/23/2003
5/29/2003
6/19/2003
7/28/2003
8/19/2003
9/23/2003
10/21/2003
11/25/2003
12/22/2003
2/10/2004
3/9/2004
SP1
SP2
SP3
SP4

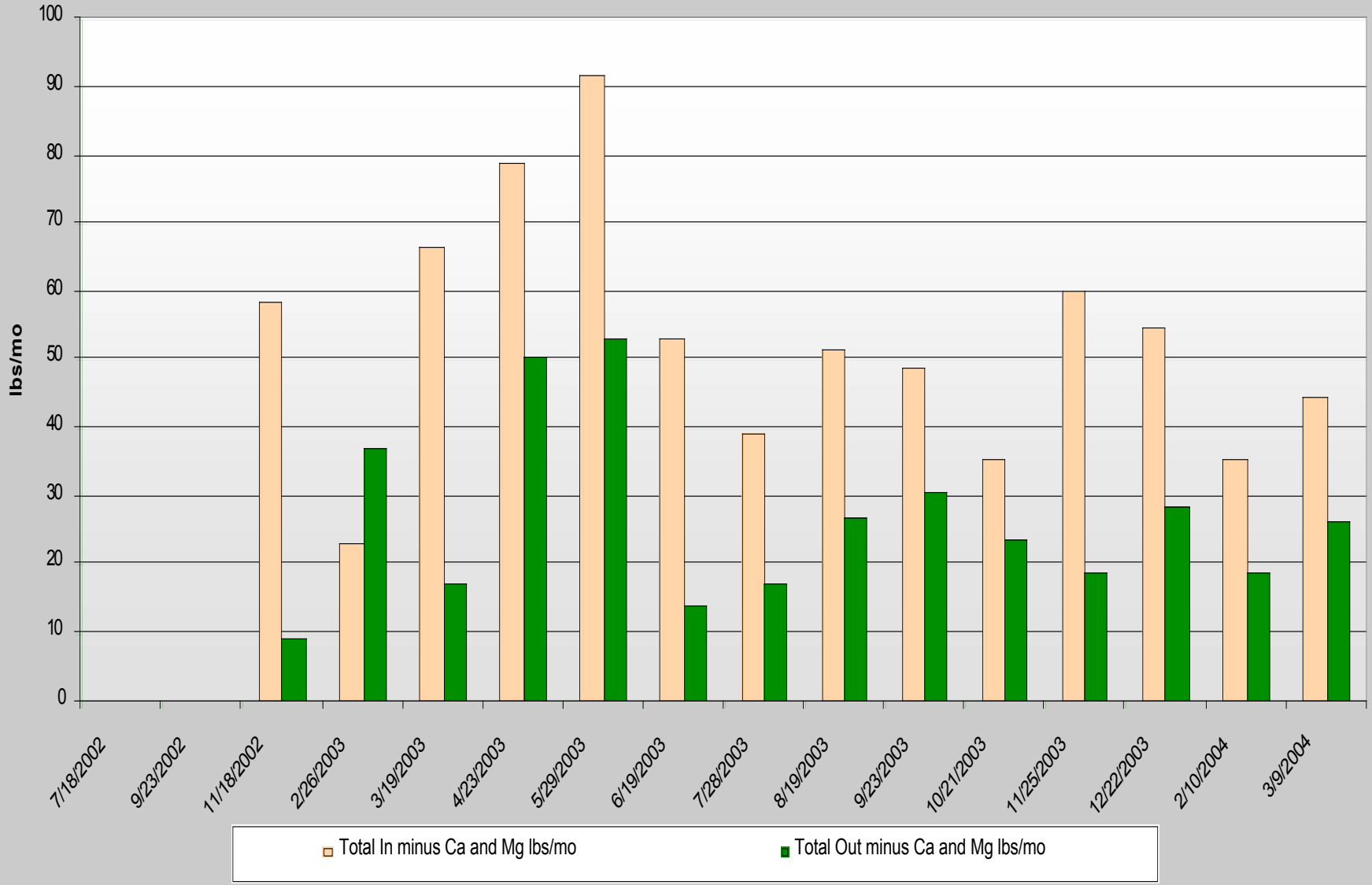
Nevada Stewart Apatite Treatment System
Phosphorus

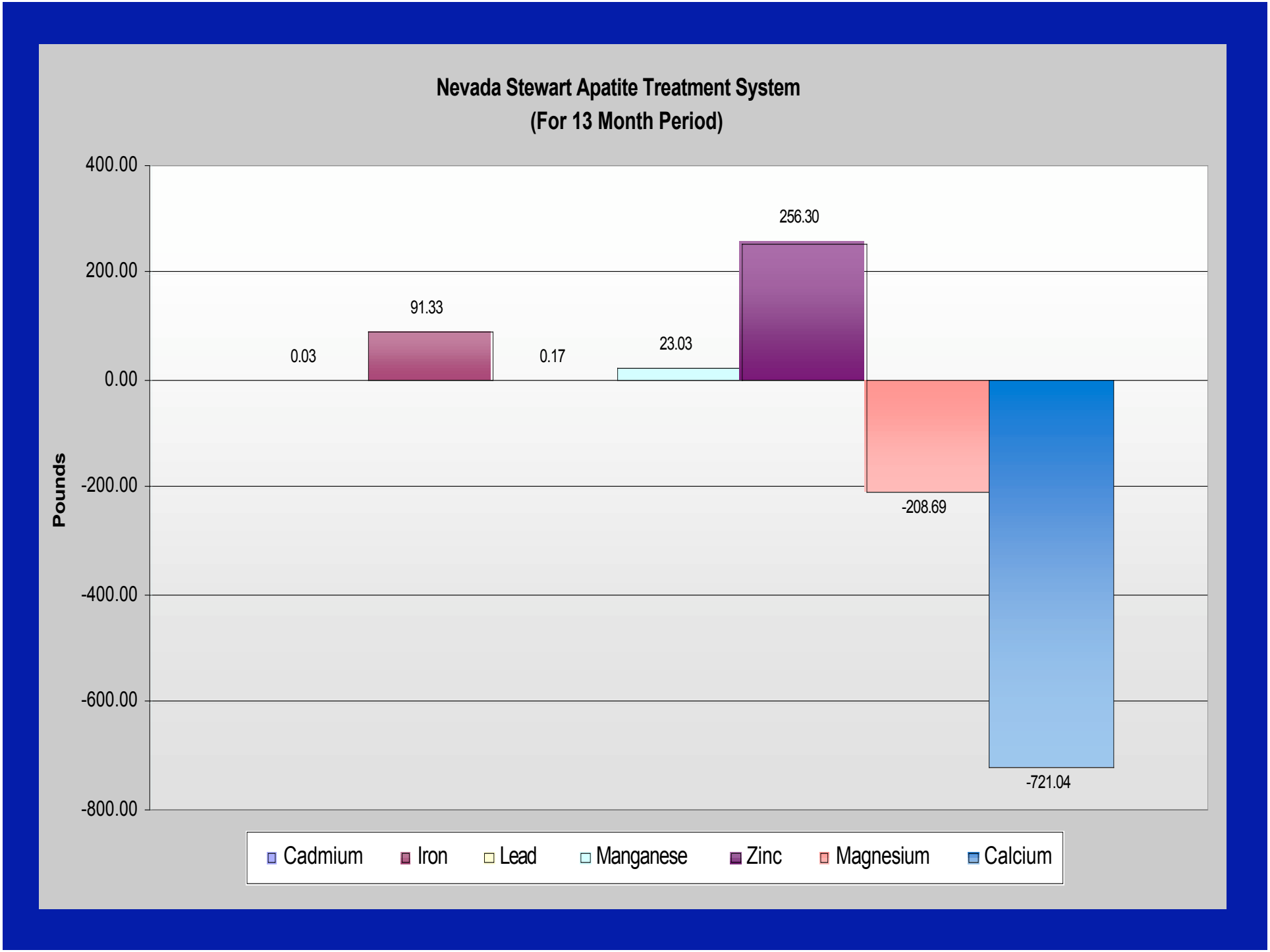


Nevada Stewart Mine

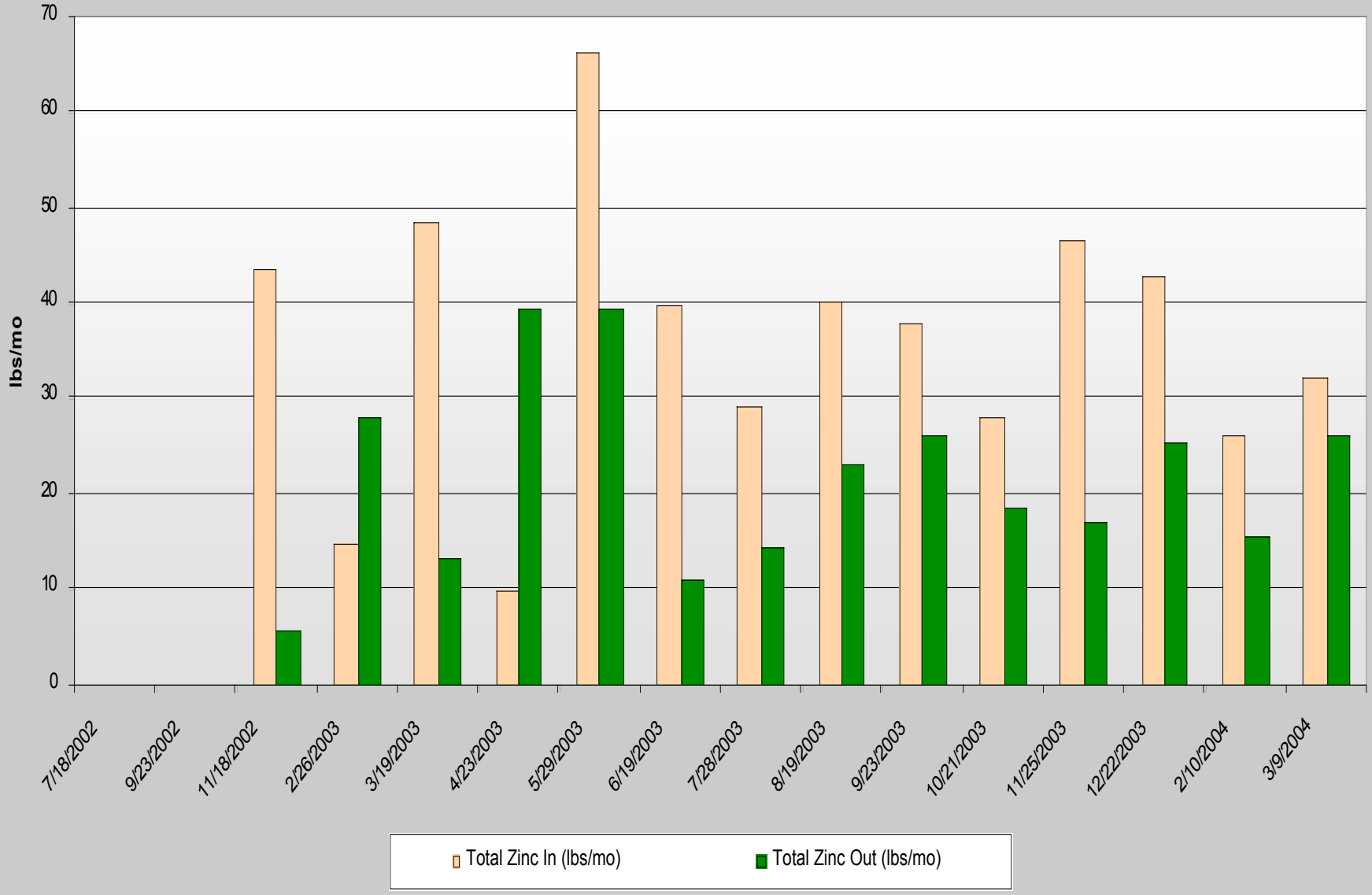
Metals Loading for Treatment System and for Zinc

Nevada Stewart Apatite Treatment System
Total Metals In vs Out




Nevada Stewart Apatite Treatment System
(For 13 Month Period)
Pounds
400.00
200.00
0.00
-200.00
-400.00
-600.00
-800.00
0.03
91.33
0.17
23.03
256.30
-208.69
-721.04
Cadmium
Iron
Lead
Manganese
Zinc
Magnesium
Calcium

Nevada Stewart Apatite Treatment System
Total Zinc In vs Out



Geochemical Modeling

- Performed during November 2002, March 2003, April 2003, and December 2003
- Manganese (Mn) phosphate may control Mn concentration
- Zn and Fe attenuation may be due to precipitation of metal sulfides
- Need solid phase characterization of treatment media to determine nature of removal reactions

Montana Tech – Solids Analysis

- Solid reactor fishbone samples taken July 28, 2003
  - Samples collected from each treatment tank
  - Varying depths
  - 8”, 16”, 24”, and 32”
  - Digested according to EPA Method 3050B
- Background Apatite – Unreacted samples taken September 2002 during installation
- Literature search

Montana Tech – Solids Analysis (cont.)

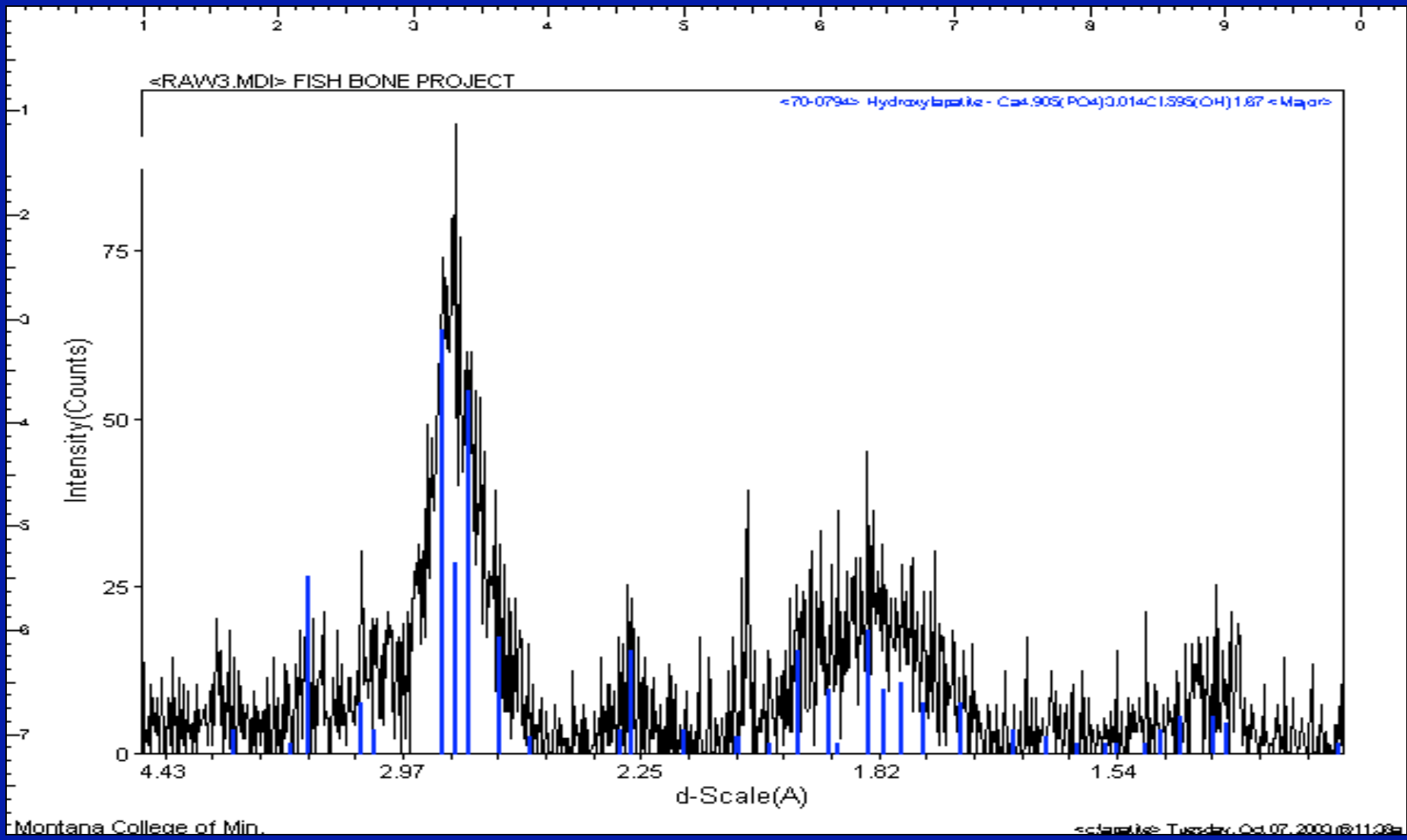
- Wet chemistry on treated and untreated media – solid sample digestion and analysis (ICP)
- X-ray diffraction (XRD)
- Scanning electron microscopy (SEM/EDX)
- Hydrogen Sulfide Experiment
- Final report and graduate thesis Fishbone Digest

Selected Fishbone Digest-Results

Sample	Ca	Cd	Fe	Mg	Mn	Pb	Zn
Raw/Background Sample 1	201107.01	0.23	219.56	3173.43	17.25	0.46	167.90
Tank 2 Sample 1 (SP2)	214092.14	1.19	3224.93	2755.19	591.69	4.61	14092.14
Tank 3 Sample 1 (SP3)	205544.93	1.76	5248.57	2275.33	1414.91	7.02	18355.64
Tank 4 Sample 1 (SP4)	219178.08	0.85	3268.10	2612.52	675.15	10.08	13698.63

All data is in mg/kg

XRD-Results


<RAW3.MDI> FISH BONE PROJECT
<70-0794> Hydroxylapatite - Ca4.905(PO4)3.014Cl.595(OH)1.87 <Major>
Intensity(Counts)
75
50
25
0
4.43
2.97
2.25
1.82
1.54
d-Scale(A)
Montana College of Min.

SEM-EDX Uncontaminated Fishbone

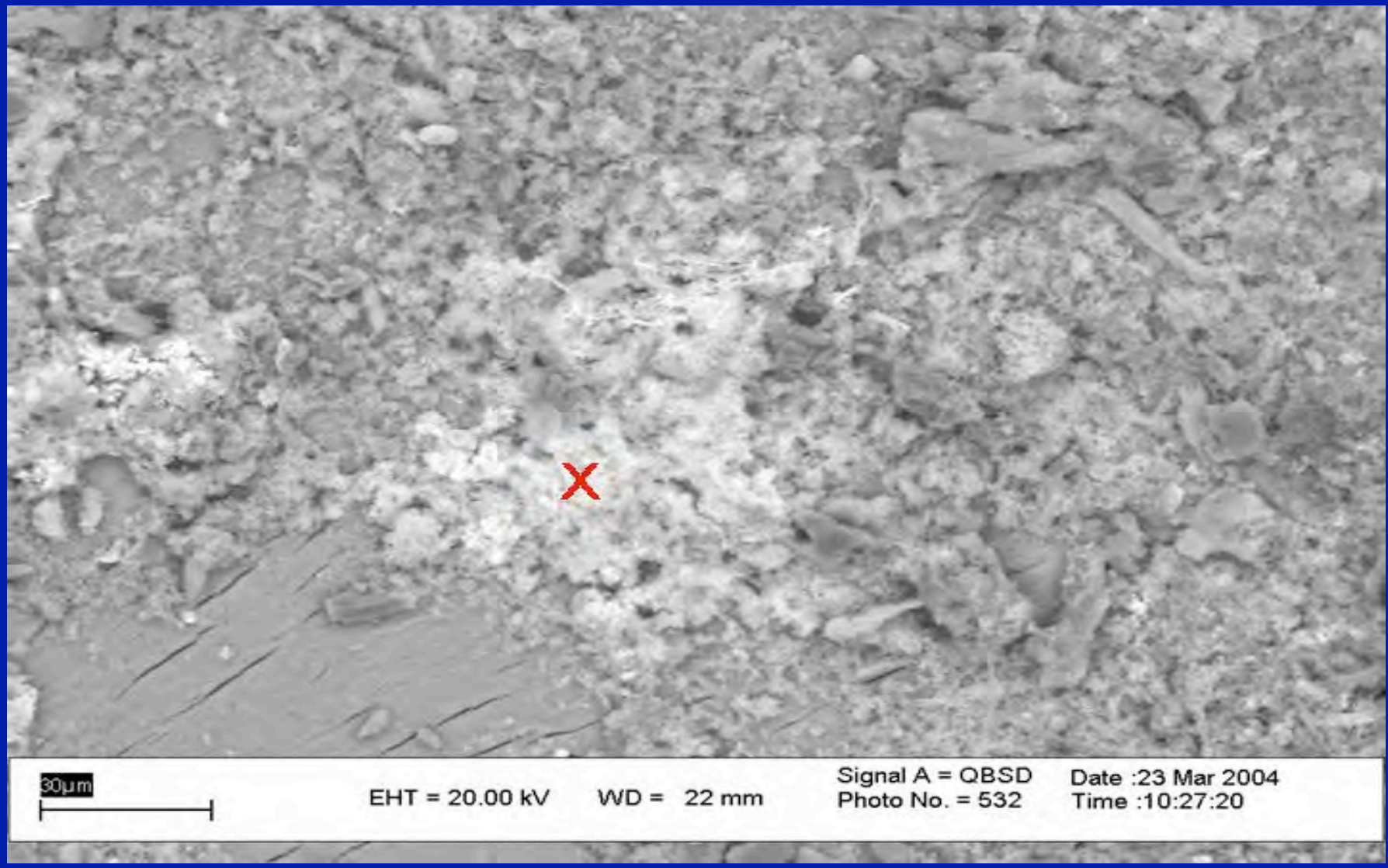
Element	Wt%	At%
Ca	2.69	0.94
P	2.09	0.95
Cl	0.13	0.05
O	43.70	38.41
C	50.57	59.21
Si	0.16	0.08
Al	0.12	0.06
Mg	0.18	0.11
Na	0.22	0.13
K	0.10	0.04
S	0.04	0.02
Total	100.00	100.00

SEM-EDX Uncontaminated Fishbone

SEM-EDX General Treatment Tank Trend

Element	Wt%	At%
Ca	14.48	7.70
P	9.56	6.58
O	56.18	74.84
Si	2.98	2.26
Al	3.96	3.13
Mg	0.29	0.25
K	0.41	0.22
S	2.56	1.70
Fe	3.37	1.29
Zn	6.09	1.99
Mn	0.07	0.03
Cu	0.06	0.02
Total	100.00	100.00

SEM-EDX Close-up of Contaminated Bone



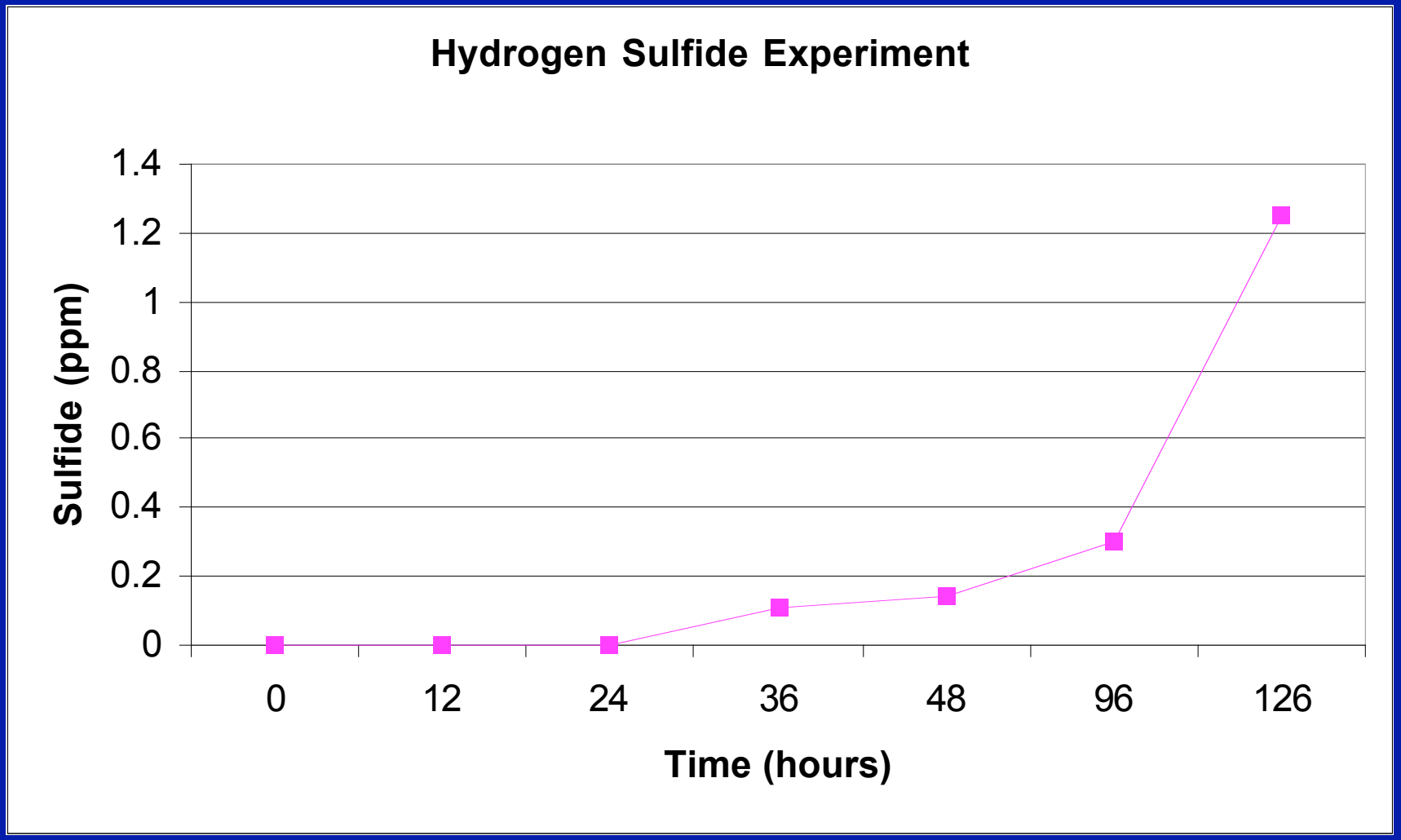
SEM-EDX Close-up of Contaminated Bone

Element	Wt%	At%
Ca	8.43	5.01
P	6.27	4.82
O	46.42	69.02
Si	3.27	2.77
Al	2.44	2.15
Mg	0.05	0.05
K	0.42	0.26
S	9.53	7.07
Fe	6.72	2.86
Zn	16.25	5.91
Mn	0.18	0.08
Cu	0.02	0.01
Total	100.00	100.00

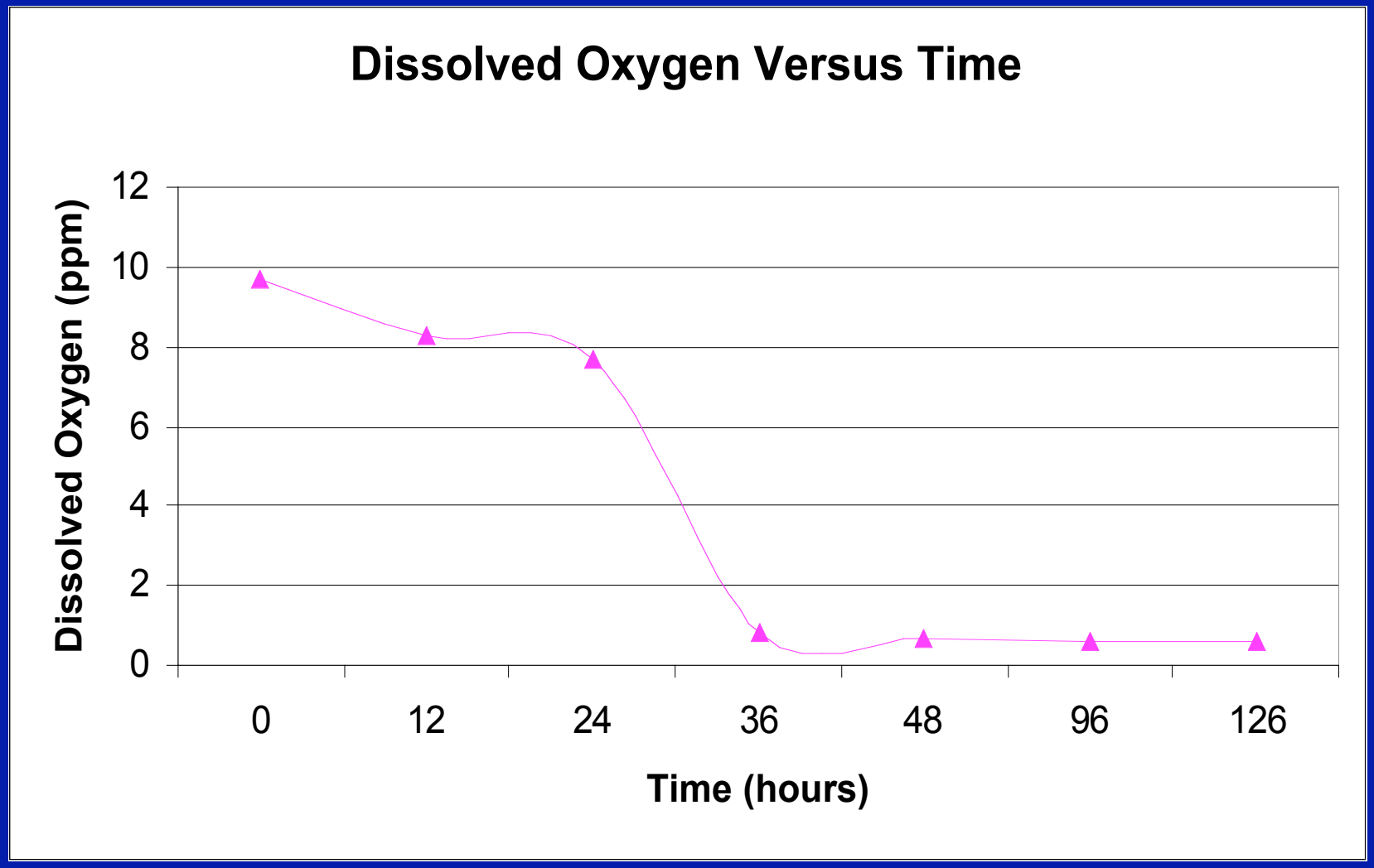
Hydrogen Sulfide Experiment

- Raw fishbone samples were allowed to react with contaminated adit water from the Nevada-Stewart Mine
- Tested for Eh, pH, SC, DO, Temperature, and H_2S

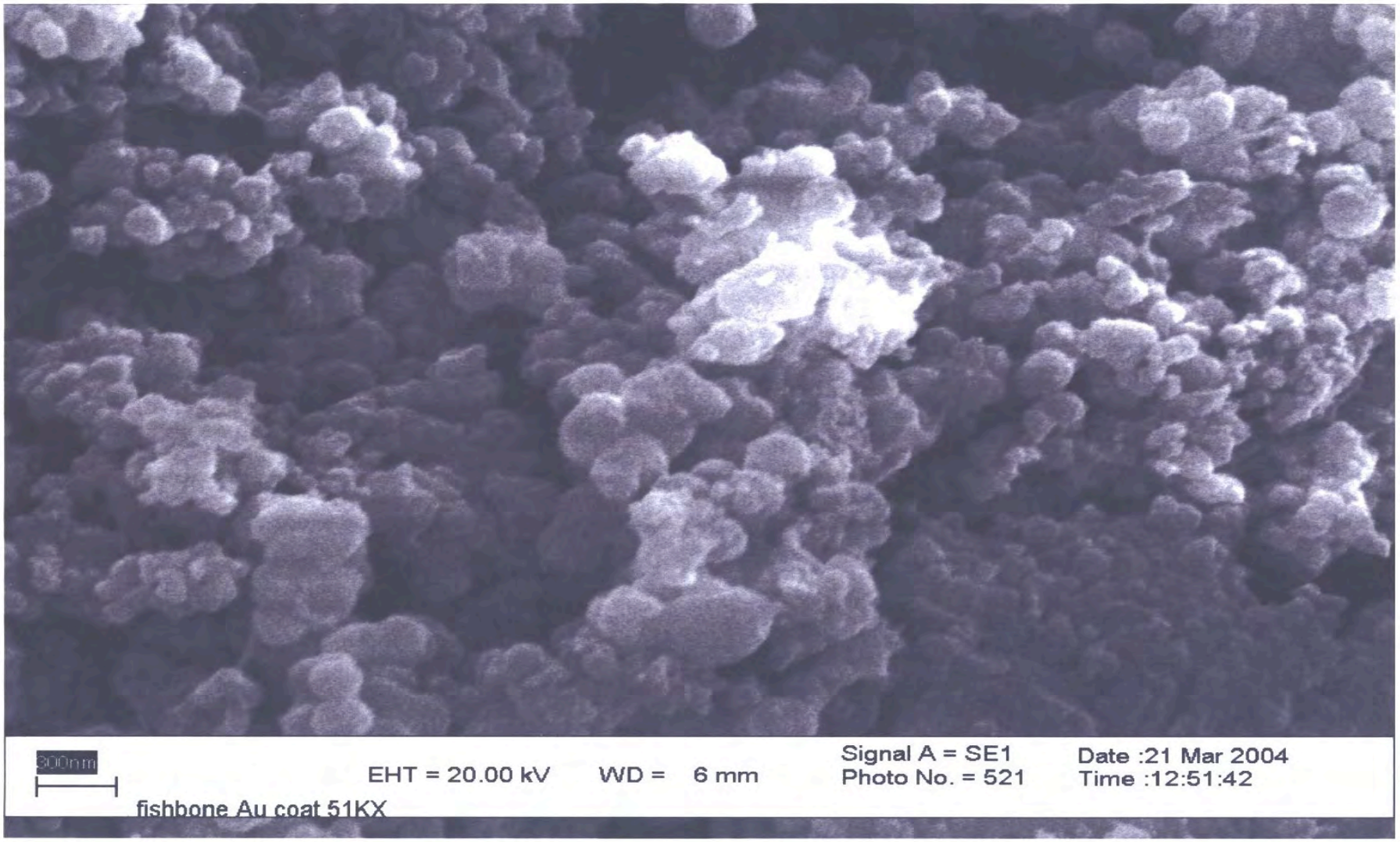
Hydrogen Sulfide Experiment



Hydrogen Sulfide Experiment



Zinc Sulfide Crystals



Montana Tech Conclusions

- Zn is being removed as a metal sulfate – sphalerite. Quick Reaction.
- Pb is being removed as a lead phosphate and this is slower reaction
- Cd and Fe being removed as a sulfide
- Reduced environment provides highest metal removal rates

Current Status

- The system is presently flowing at 17 gpm
- Geochemical modeling is being performed on data through August 2003
- September sampling event was performed and audited by EPA
- Montana Tech has completed the analysis of the solid material to determine the fundamental removal mechanisms working in the system