Wetland Treatment of Abandoned Mine Drainage

Use of Biosolids in the Passive Treatment of Abandoned Mine Drainage at the Jennings Environmental Education Center

Brady Twp. Butler County, Pennsylvania

Slippery Rock Watershed Coalition
c/o Stream Restoration Incorporated
A PA Non-Profit Organization 501(c)(3)
338 Glen Eden Road, Rochester, PA 15074

The Slippery Rock Creek Headwaters Area (State Water Plan 20-C) Comprised of
The Seaton Creek Watershed (high priority; stream # 34751 segment # 4571)
and Slippery Rock Creek Watershed (high priority; stream # 34032 segment # 5900)

FINAL REPORT

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Pennsylvania Department of Conservation and Natural Resources
Bureau of State Parks
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Submitted To: Pennsylvania Department of Environmental Protection
Bureau of Watershed Conservation
Division of Watershed Support
Lynn Langer, Chief, Watershed Management Section
Kevin R. Kelly, Aquatic Biologist

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Introduction

Purpose

The widespread application of vertical flow type passive treatment systems which utilize spent mushroom compost in conjunction with limestone to abate aluminum-bearing acid mine drainage will increase the need for an alternative organic media which is both more economical and readily available. This study, performed at the Jennings Environmental Education Center, Brady Township, Butler County, Pennsylvania evaluated the use of composted biosolids in both aerobic surface-flow and anaerobic vertical-flow type wetland systems. Vegetative establishment and water quality were monitored in a constructed aerobic wetland which utilized biosolids as an organic component in a fabricated substrate. The results of this monitoring indicate that the use of composted biosolids is both a safe and an effective method to establish vegetation in a constructed wetland. Installation and monitoring of a pilot-scale vertical flow system using composted biosolids mixed with limestone demonstrated this organic material to be as effective as the current industry standard, spent mushroom compost. Composted biosolids have been found to be a safe and effective alternative organic media for the passive treatment of acid mine drainage.

Public Outreach

The results of this project have been shared with the general and scientific communities on a regional, national and international basis through the development of a poster and paper presented at the American Society for Surface Mining and Reclamation 1999 conference in Scottsdale, AZ(abstract published in conference proceedings p. 715) and the National Association of Abandoned Mine Lands Programs 1999 conference in Champion, PA, respectively and reporting related activities in the Slippery Rock Watershed Coalition's monthly newsletter, "The Catalyst". (See attached paper, photo. 2, and newsletter.)

Work Completed

Channel Wetland

A channel wetland utilizing composted biosolids mixed with quarry fines was constructed as part of the full-scale passive treatment system at Jennings installed in August of 1997. The channel is approximately 190' long by 10' wide with four check dams installed at equal amounts of fall dividing the wetland into four cells of varying lengths. A fabricated substrate was added to the wetland which consisted of a 1 : 1, by volume mixture of quarry fines(inorganic silt) and composted biosolids(Table 1). The substrate was saturated and seeded with a mixture of 22 different wetland plants.

The vegetation within the channel wetland was surveyed three times. These surveys were completed: Fall 1998, Winter 1999, and Summer 1999. The results of these surveys are presented in Table 2. Water samples were taken at the influent and effluent of the channel wetland to monitor the effects of the wetland on the water quality for both standard mining parameters (Figures 2 through 11) and a suite of metals associated with the use of biosolids (Figures 1 & 2). A more in depth discussion of the methods and results of these studies is included in the attached paper, "Establishment of Vegetation in Constructed Wetlands Using Biosolids and Quarry Fines".

Table 1. Representative Analysis - Composted Biosolids

BUTLER AREA SEWER AUTHORITY COMPOST ANALYSES

Sample Date / Sample ID Components (reported on dry weight basis)		9/9/93 Cell 8 Compost	3/10/94 Finished Compost	6/2/94 Compost Cell 17	8/24/94 Finished Compost Cell	12/22/94 Finished Compost	2/23/95 Finished Compost Cell 8	3/28/95 Finished Compost	Maximum and Minimum Range of Values	Average Values	EPA Part 503 Conc. Limits for EQ biosolids (mg/kg)	PA DER Maximum Class I biosolids concentrations allowed for land application (mg/kg)
NH_4-N	%	0.008	0.003	0.010	0.006	0.010	0.010	0.01	0.003 - 0.01	0.008	---	---
TKN	%	0.461	1.100	1.000	1.000	1.000	1.200	0.99	0.461 - 1.20	0.960	---	---
Plant Available Nitrogen	%	0.140	0.330	0.300	0.300	0.300	0.360	---	0.140 - 0.36	0.290	---	---
Phosphorous	mg/kg	45.500	8420.000	106.000	2400.000	36.000	140.000	14200.00	36 - 14200	3621.000	---	---
Potassium	mg/kg	720.000	1040.000	996.000	984.000	889.000	1190.000	1000.00	720 - 1190	974.000	---	---
Total Solids	%	68.200	59.400	76.600	83.300	77.100	73.200	69.20	59.4 - 83.3	72.400	---	---
Volatile Solids	%	37.200	44.300	47.200	43.100	51.300	50.800	50.63	37.2 - 51.3	46.400	---	---
Total Organic Carbon	%	20.700	24.600	26.200	23.900	28.500	28.200	28.13	20.7 - 28.5	25.700	---	---
C:N Ratio		44.800	22.400	26.200	23.900	28.500	23.500	28.40	22.4 - 44.8	28.200	---	---
pH		7.800	8.200	9.000	8.800	8.000	7.800	6.90	6.9 - 9.0	8.100	---	---
Arsenic (As)	mg/kg	4.000	2.900	2.300	<6.000	28.000	9.000	2.50	2.3 - 28.0	7.800	41.0	41.0
Barium (Ba)	mg/kg	396.000	NA	NA	NA	NA	NA	NA	396	396.000	---	---
Cadmium (Cd)	mg/kg	3.000	<2.000	2.000	1.000	1.000	<1.000	0.80	0.8 - 3.0	1.500	39.0	25.0
Chromium (Cr)	mg/kg	10.000	20.000	30.000	13.000	13.000	10.000	12.10	10.0 - 30.0	15.400	1200.0	1200.0
Lead (Pb)	mg/kg	40.000	30.000	<12.000	17.000	34.000	21.000	33.60	<12.0 - 40.0	26.800	300.0	300.0
Nickel (Ni)	mg/kg	40.000	34.000	32.000	20.000	21.000	14.000	16.50	14.0 - 40.0	25.400	420.0	420.0
Silver (Ag)	mg/kg	25.000	13.000	16.000	30.000	26.000	29.000	NA	13.0 - 30.0	23.200	---	---
Copper (Cu)	mg/kg	130.000	397.000	145.000	182.000	178.000	252.000	167.50	130.0 - 397.0	207.000	1500.0	1500.0
Zinc (Zn)	mg/kg	378.000	862.000	280.000	435.000	497.000	865.000	529.30	280.0 - 865.0	549.000	2800.0	2800.0
Molybdenum (Mo)	mg/kg	10.000	<20.000	10.000	<10.000	<10.000	<10.000	2.10	2.1 - <20.0	10.300	---	18.0
Sodium (Na)	mg/kg	368.000	611.000	519.000	465.000	514.000	661.000	NA	368.0-661.0	523.000	---	---
Selenium (Se)	mg/kg	1.100	<0.800	0.200	<6.000	<6.000	<7.000	<0.38	0.2 - <7.0	3.100	36.0	36.0
Mercury (Hg)	mg/kg	1.000	0.840	0.930	1.100	1.200	1.200	1.12	0.84 - 1.2	1.050	17.0	17.0
PCB's	mg/kg	<0.100	<0.200	<0.400	<0.100	<0.300	<0.100	NA	<0.1 - <0.4	<0.200	---	2.0

--- = Not Applicable
NA = Not Analyzed

Pilot Scale System

A pilot scale vertical flow system based on the full-scale and other pilot scale systems at Jennings was installed to compare the effectiveness of using composted biosolids as an alternative to spent mushroom compost. Physical properties of the treatment media mixture were measured at the beginning, middle and end of the project.

The pilot scale tank utilized a compost : limestone mixture, 1.25 : 1 by weight. This ratio was chosen based on a similar pilot scale system at Jennings which utilized spent mushroom compost as the organic component. A 1500 gal tank 8' in diameter was utilized. 0.5' of #57 river gravel was placed in the bottom of the tank. An underdrain constructed of approximately 30' of 3/4" sch. 40 PVC with 1/4" holes on 0.5' centers facing downward was installed. The PVC underdrain consisted of a lattice work of a six laterals(3 on each side) feeding a single header with an outlet near the bottom of the tank. A staff gauge was installed with 0 being set at the invert of the underdrain(the compost/river gravel contact).

Composted biosolids from the Butler Area Sewer Authority were mixed with #9 Vanport limestone from the Quality Aggregates quarry in Boyers, PA. A total of 2764 lbs of compost were mixed with 2108 lbs of limestone. This was done by adding 15 gal. of compost for every 5 gal. of limestone and mixing them with a shovel within the tank. The thickness of the compost/limestone mixture as installed was 1.8'. An overdrain constructed in a similar manner to the underdrain was installed on the top of the treatment media with the perforations facing downward. The influent enters the tank through a port near the bottom of the tank and conveyed via 1" PE pipe to the center of the over drain. (See Photo 4.) The tank was plumbed into an existing flow control box which delivered an average of 0.4 gpm throughout the project.

Results/Discussion

Channel Wetland - Vegetation

The three surveys completed in conjunction with this project indicate that the addition of biosolids to a constructed wetland soil is a very effective means to establish diverse and dense vegetative cover. The results are summarized in Table 2. Of particular interest is the fact that the wetland plants were observed to be growing even during winter months(See Photo 2). The second survey was completed during mid March(Winter 1999) at which time 47% coverage was observed. This is mainly attributed to the relatively warm water influent from the full-scale vertical flow system, which receives acid drainage from a subsurface drain near the abandoned mine entry and piped to an overdrain system at the top of the treatment media below a water cap. The relatively warm temperature in the channel wetland may also be maintained by shallow water depths and relatively high water velocities.

Channel Wetland - Water Quality

Due to the small surface area of the channel wetland(1900SF) only a very small improvement in water quality relating to standard mining parameters was expected. The pH was consistently higher at the effluent of the channel compared to the influent. This is assumed to be caused by the release of carbon dioxide and subsequent reduction in carbonic acid concentrations in the water. (See Figure 3.)

Table 2. Establishment of Vegetation

Percent coverage of wetland observed on three occasions.
Visual estimation technique used for 10/26/98 survey.
Portable 1 m^2 grid used to estimate coverages during 3/16/99 & 6/20/99 surveys.

	Seeding Rate lb/ac	Common Name	Family	Genus	Species	% COVERAGE OBSERVED 10-26-98	3-16-99	6-20-99
1		Maple Trees	Aceraceae	Acer	rubrum	0.02%		
2		Yarrow	Asteraceae	Achillea	millefolium	0.09%		
3		Grey Goldenrod	Asteraceae	Solidago	nemoralis	0.03%		
4		Flat-topped Goldenrod	Asteraceae	Euthamia	graminifolia	0.07%		
5	2.2	Nodding Bur Marigold	Asteraceae	Bidens	ceruna	2.52%		
6	4.8	Green Bulrush	Cyperaceae	Scripus	atrovirens		observed	4.41%
7	1.4	Soft-Stemmed Bulrush	Cyperaceae	Scripus	validus			3.96%
8		Marsh Straw Sedge	Cyperaceae	Carex	hormathodes			
9	1.2	Cosmos Sedge	Cyperaceae	Carex	comosa	0.34%	observed	2.50%
10	1	Lake Bank Sedge	Cyperaceae	Carex	lacustris			
11		Flatsedge	Cyperaceae	Cyperus	sp.	1.69%		
12		Three way sedge	Cyperaceae	Dulichium	arundinaceum	0.19%	1.00%	0.00%
13		Soft Rush	Juncaceae	Juncus	effuses	3.31%	2.00%	5.39%
14		Lesser Duckweed	Lemnaceae	Lemna	minor	26.55%		
15		Wild Onion	Lileaceae	Allium	sp.	0.19%		
16		Purple-leaved Willow herb	Pimulaceae	Epilobium	coloratum	1.90%		
17	7.6	Virginia Wild Rye	Poaceae	Elymus	virginicus	11.66%		
18	2.5	Rice Cut Grass	Poaceae	Leersia	oryzoides			
19		Crown Vetch	Poaceae	Coronilla	varia	0.03%		
20		Reed Grass	Poaceae	Phragmites	maximus		37.00%	45.87%
21		Kentucky Bluegrass	Poaceae	Poa	pratensis			
22		Bentgrass	Poaceae	Agrostis	sp.			
23		Cord Grass	Poaceae	Spartina	pectinata			
24	7.6	Meadow Foxtail	Poaceae	Alopecurus	pratensis	53.31%		
25		Docks	Polygonaceae	Rumex	sp.	0.17%		
26		Smartweed	Polygonaceae	Polygonum	sp.	6.66%		
27		Meadowsweet	Rosaceae	Spiraea	sp.	0.03%		
28		Aspen Trees	Salicaceae	Poplus	sp.			observed
29	0.8	Monkey Flower	Scrophlariaceae	Mimulus	ringens	0.09%		
30		Cattails	Typhaceae	Typha	sp.	3.52%	7.00%	12.82%
31	0.6	Blue Vervain	Verbanaceae	Verbena	hastata	1.43%		
32	0.2	Turtlehead	Scrophlariaceae	Chelone	glabra			
33	0.1	Virgins Bower	Ranuncluaceae	Clematis	virginiana			
34	0.9	Hard-Stem Bulrush	Cyperaceae	Scirpus	acutus			
35	2.3	Button Bush	Rubiaceae	Cephalanthus	occidentalis			
36	0.3	Wool Grass	Cyperaceae	Scirpus	cyperinus			
37	0.3	Small Seeded Bulrush	Cyperaceae	Scirpus	microcarpus			
38	1.2	Pickerel Weed	Ponteriaceae	Pontederia	cordata			
39	1.4	Soft-Stem Bulrush	Cyperaceae	Scirpus	validus			
40	0.2	Rough Leaved Goldenrod	Asteraceae	Solidago	patula			
41	1.2	Lesser Bur-reed	Sparganiaceae	Sparganium	americanum			
42	4.6	Giant Bur-reed	Sparganiaceae	Sparganium	eurycarpum			
43	4.6	Arrow Arum	Araceae	Peltandra	virginica			

Total Percent Coverage Observed: 113.80% 47.00% 74.94%

Planted and Established (Observed)
Not Planted and Established (Observed)
Planted and Not Established (Not Observed)

Number of Planted Species Observed: 10
Number of Non-Planted Species Observed: 21
Number of Planted Species Not Observed: 12

Wetland surveys performed by the following groups and inviduals:
10-26-98 by Slippery Rock University students under the direction of Dr. Jerry Chmielewski Dept. of Biology.
3-16-99 by Micheal Enringht, Grove City College under the direction of Dr. Fred Brenner, Dept. of Biology.
6-20-99 by Charlene J. Wick, Biologist, with assistance from Dr. Fred Brenner, Dept. of Biology, Grove City College.

Some information from the above table was revised according to USDA NRCS on-line database *http://plants.usda.gov/plants/fr_scilist.cgi*

The water entering the wetland from the vertical flow system was net alkaline and there was only a slight change in alkalinity from influent concentrations to effluent concentrations. During the colder months the effluent had a lower alkalinity relative to the influent which is probably due to mineral acidity being generated as iron and aluminum precipitate in the wetland. An increase in effluent alkalinity was observed during periods of higher ambient temperatures. This is probably due to increased microbial activity during the warmer months which increased the amount of bicarbonate alkalinity generated within the wetland. (See Figure 4.)

As expected there was generally a slight decrease in iron and aluminum concentrations from the influent to the effluent of the wetland(Figures 6 & 7). Manganese also appeared to be removed by the channel wetland to a small degree(Figure 8). Sulfate and conductivity both increased and decreased slightly from influent to effluent(Figures 9 & 10). Total suspended solids on average were decreased as the water flowed through the channel(Figure 11).

A suite of metals associated with the use of biosolids was monitored during this project. These metals include: As, Cd, Cr, Ca, Cu, Hg, Mo, Ni, Pb, Se, & Zn. These samples were filtered in the field using a 0.45 micron filter and fixed with nitric acid. Overall there was a slight decrease in all concentrations for these metals, with two exceptions, cadmium and lead. On one out of three occasions, the cadmium concentration increased from 0.001 ppm influent to 0.002 ppm effluent. The highest cadmium concentration observed, 0.002 ppm, is 2.5X below the EPA drinking water standard. Two of the three samples showed an increase in lead of 0.001 ppm and 0.005 ppm. The maximum concentration measured at the effluent of the wetland was 0.0019 ppm Pb which is 8X below the EPA drinking water standard. Due to the very small variations in concentrations observed during this project and the small sample set reviewed, it is difficult to determine if these two observed increases are caused by dissolution from the biosolids or minor analytical errors. (See Figures 1 & 2.)

Pilot Scale System - Physical Properties

In order to determine the actual bulk density of the treatment media both as separate components and as a mixture the volume and weight of each material was measured as they were added to the tank. Composted biosolids were added using a fifteen gallon container and weighed. Limestone was added using a five gallon container and weighed.

Table 3 shows the amounts of each material added to the tank. The bulk density was determined for both materials by weighing a known volume of each. From this information the total volume of the treatment media mixture was calculated. Once all the material was mixed and placed in the tank the volume of the mixture was measured by multiplying the depth by the surface area of the eight foot diameter tank. This number was used to calculate the actual(measured) bulk density of the material.

Table 3. Volume, Weight and Bulk Density of Treatment Media.

Material	lbs/gal	# of gallons	Total Weight used (lbs)	Total Volume used (CY)	Bulk Density (T/CY)
Composted Biosolids	5.4	515	2781	2.96	0.47
#9 Limestone	12.4	170	2108	0.96	1.10
Combined - Calculated	7.2	685	4889	3.92	0.62
Combined - Measured			4889	3.35	0.73

As shown above the actual bulk density of the mixed treatment media decreased by approximately 17%. This shows that mixing these materials together decreases the amount of void space within the media. In order to document the changes in the percent void space within the media over time a specific yield test was performed at the beginning of this project and at 19 weeks after the system was put on-line.

Before the specific yield test was performed the treatment media was completely saturated. The water level at the beginning of each test was set at the top of the treatment media. The tank was then allowed to drain until the discharge rate fell below 0.01 gpm. The initial test yielded a total discharge of 130 gallons in 201 minutes. The second test yielded 106 gallons in 236 minutes. This shows a decrease in specific yield of almost 20% over a 19 week period. (See Figure 12.)

The permeability of the treatment media in the tank was monitored by measuring the water level in the tank. The outlet of the tank was maintained at the same level throughout the project. An increase in the water level indicates a relative increase in head pressure needed to push the water through the system. (See Table 4.)

Table 4. Comparison of Flow and Relative Head in the Pilot Scale Tank.

Date	2/26/99	3/15/99	4/29/99	5/19/99	6/9/99	6/22/99
Flow (gpm)	0.29	0.28	0.16	0.57	0.52	0.48
Water Height (ft)	2.61	2.57	2.62	2.75	2.66	2.65

By eliminating the 4/29/99 sample from the set, it is observed that an increase in head is needed with higher flow rates. A determination of a general decrease in hydraulic conductivity over time cannot be made from this data set.

Pilot Scale System - Water Quality

In order to compare the effectiveness of a vertical flow system using composted biosolids as and alternative to spent mushroom compost, three water monitoring points were established. (1) Raw water was monitored at the flow splitter box prior to entering the full-scale vertical flow pond. (2) Effluent of the vertical flow pond(VFP) which utilizes spent mushroom compost mixed with #9 limestone as a treatment media. (3) Effluent from the pilot scale tank(tank) which utilized composted biosolids mixed with #9 limestone.

The aluminum-bearing discharge at Jennings requires that a circumneutral pH be maintained in order to effectively facilitate the sustained precipitation of aluminum hydroxide. This was achieved by the biosolids tank throughout the project. The tank actually produced higher pH values than the full-scale vertical flow pond on all but one occasion. (See Figure 3.)

The tank continually neutralized all the acid in the raw water and produced excess alkalinity of about 500 ppm $CaCO_3$. This is comparison to the vertical flow pond that produced excess alkalinity around 180 ppm $CaCO_3$. (See Figure 4.) The presence of dust/fines in the limestone or alkaline material used in the stabilization of the biosolids and/or microbial activity could be responsible for the excess alkalinity generated by the tank.

Iron removal was consistently better in the tank than the VFP on all but one occasion. (See Figure 6.) The VFP generally removed more aluminum than the tank on all but two occasions. (See Figure 7.) The manganese removal trend observed in the tank shows increasing effluent concentrations over time. The latest concentrations were nearing the those observed in the VFP effluent. (See Figure 8.) Sulfate concentrations varied in both the tank and the VFP with a general trend of one better than the other not being found. (See Figure 8.) Conductivity levels were higher at the beginning of the test with a declining trend observed over time. The conductivity levels in the VFP were always lower than the tank and higher than the raw water. (See Figure 10.) Total suspended solids were generally highest in the tank effluent, lower in the VFP, and lowest in the raw water. (See Figure 11.)

One concern with the use of composted biosolids is the presence and potential release of toxic or hazardous metals. A monitoring program documented the dissolved concentration of the following elements: As, Cd, Cr, Ca, Cu, Hg, Mo, Ni, Pb, Se, & Zn. Samples were taken at the beginning, middle and end of the project. All the samples of these metals were filtered in the field using a 0.45 micron filter and fixed with nitric acid.

The tank effluent metals concentration were higher than the raw water concentrations in six of the eleven elements monitored. These include: Ca, Cu, Hg, Mo, Pb, & Se. The VFP had minor increases in only 5 metals, which include: Ca, Cu, Mo, Pb, & Se. Mercury is the only element that was observed to increase in the tank effluent and not the VFP effluent. The increase of Hg from the raw water which was below the detection limit, <0.0001 ppm, to the tank effluent concentration of 0.0001 ppm was very slight and not considered to be significant.

Calcium was significantly increased in both effluent samples due to the presence of limestone in both treatment media. (This increase is a product of the desired generation of bicarbonate alkalinity through limestone dissolution.)

Minor increases were observed at least once in both the tank and VFP in four of the eleven monitored metals. The metals with observed minor increases include: Cu, Mo, Pb, & Se. Though slight increases were observed in some of these metals(Table 5), the maximum concentration observed during the three sampling events for these eleven elements are below EPA drinking water standards(Table 6) were applicable.

Table 5. Increase of Metals Concentration Observed from Raw to Treated Water.

	15-Mar-1999		29-Apr-1999		22-Jun-1999	
Parameter	Tank	VFP	Tank	VFP	Tank	VFP
As	-	-	-	-	-	-
Cd	-	-	-	-	-	-
Cr	-	-	-	-	-	-
Cu	-	-	-	0.004	0.002	0.002
Hg	-	-	0.000*	-	-	-
Mo	0.0034	0.0001	0.0037	0.0002	-	-
Ni	-	-	-	-	-	-
Pb	-	0.0013	-	-	0.0005	-
Se*	-	-	0.0005*	0.0001*	0.0009	0.0005
Zn	-	-	-	-	-	-
Ca	306.93	157.99	288.31	134.49	230.21	139.85

* increase in concentration when raw water was below detection limit concentration: increase difference calculated using detection limit as raw water concentration.
"-" Denotes a decrease or no change. (All concentrations in ppm)

Table 5 shows that for all but calcium, only minor if any increases in the concentrations of these metals were observed.

Table 6. Maximum Concentrations Observed Compared to EPA Drinking Water Standards

Parameter	Maximum Concentration Observed Raw	Tank	VFP	EPA Drinking Water Standards
As	0.0488	0.0107	0.0061	0.05
Cd	0.008	0.001	0.002	0.005
Cr	0.0092	0.0027	<0.0019	0.1
Cu	0.024	0.015	0.020	1.3
Hg	0.0002	0.0001	<0.0001	0.002
Mo	0.0058	0.008	0.0047	NA
Ni	0.62	0.04	0.13	NA
Pb	0.0095	0.0093	0.0108	0.015
Se*	<0.0003	0.0012	0.008	0.05
Zn	0.793	0.016	0.042	5
Ca	108.23	415.16	266.22	NA

Conclusion

The results produced by this project found that the use of composted biosolids is a safe and effective alternative organic media to be used in the construction of both surface flow aerobic and vertical flow anaerobic types of passive treatment systems.

An example of the cost savings that can be realized through the use of composted biosolids as a soil amendment is presented in Table 6.

Table 6. Cost Comparison of Fabricated Substrate With Commercially Available Materials.

	Fabricated Substrate				
Material	Silt	Composted	Topsoil	Topsoil	Spent
Bulk Density	3000lb/CY	850lb/CY	2500lb/CY	2500lb/CY	1100lb/CY
Volume Amount	15 CY	15 CY	30 CY	30 CY	30 CY
Weight Amount	23 T	6.4 T	37.5 T	37.5 T	16.5 T
Cost per ton	$2.50	$2.00	$18.00	$12.00	$15.00
Cost per ton (Delivered)	$4.02	$5.47	$21.30	$13.50	$18.30
	$4.75 (avg.)				
Total Cost	$92.46	$35.00	$798.75	$506.25	$301.95
Comparable	$127.46		$798.75	$506.25	$301.95
Cost per Acre	$2,900.00		$18,300.00	$11,600.00	$6,900.00

For 1900 SF(0.04ac) wetland with 0.4'(5") of substrate

Photo 1. Poster Presented (8/16/1999) at the American Society for Surface Mining and Reclamation 1999 conference in Scottsdale, AZ(abstract published in conference proceedings p. 715). Poster visited by ASSMR members from: USA, Canada, Mexico & Germany.

Photo 2. Channel wetland constructed using composted biosolids and quarry fines as a fabricated substrate continues to grow during winter months at the Jennings Environmental Education Center, Brady Township, Butler County, PA. (1/19/1999)

Photo 3. Channel wetland constructed using composted biosolids and quarry fines as a fabricated substrate sustains a dense and diverse vegetative cover(left) at the Jennings Environmental Education Center, Brady Township, Butler County, PA. (6/9/1999)

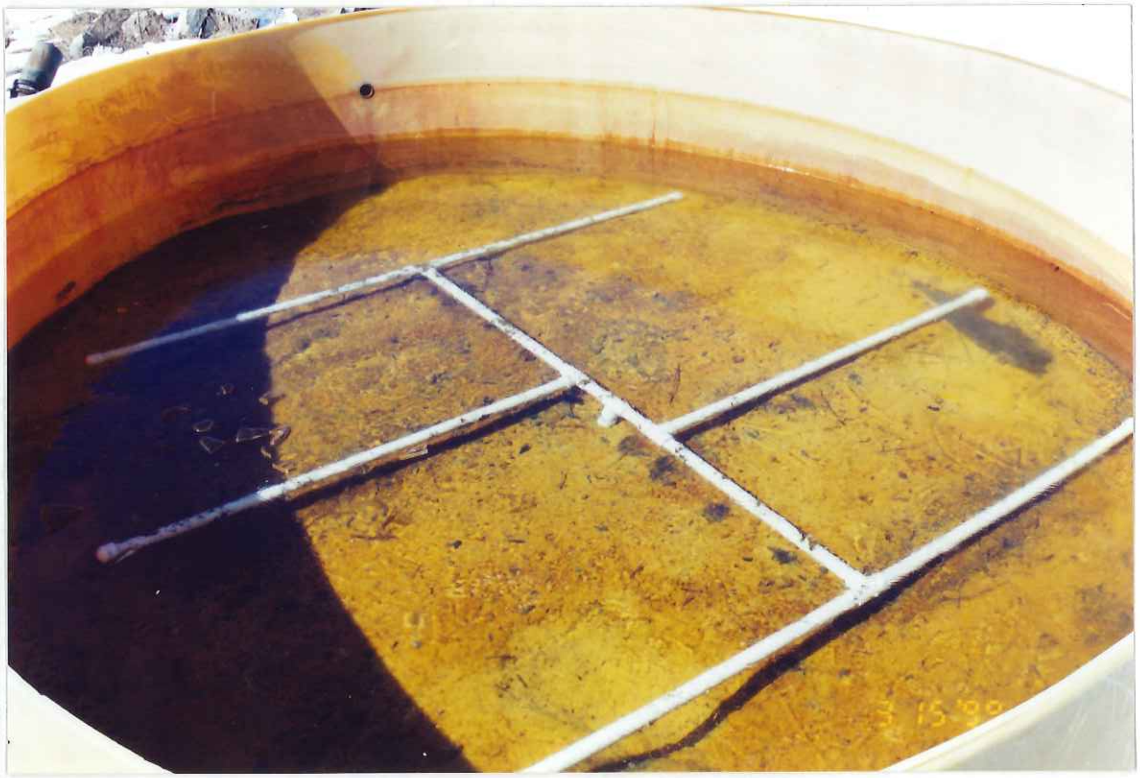
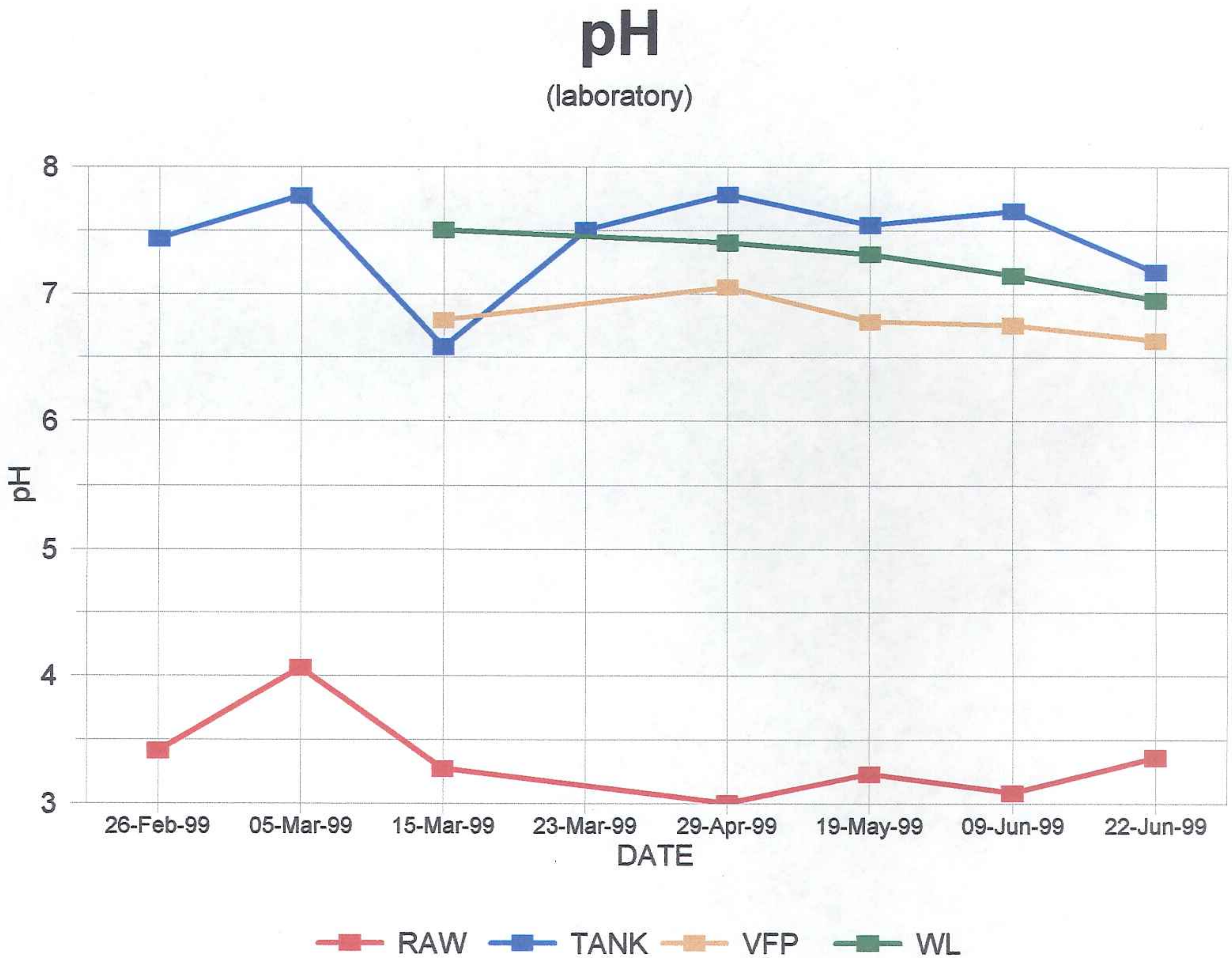


Photo 4. Pilot scale vertical flow tank constructed using composted biosolids and #9 limestone. Overdrain lattice work distributes acid mine drainage received by feeder pipe at center. Jennings Environmental Education Center, Brady Township, Butler County, PA. (3/15/1999)



pH
(laboratory)
8
7
6
5
4
3
pH
26-Feb-99
05-Mar-99
15-Mar-99
23-Mar-99
29-Apr-99
19-May-99
09-Jun-99
22-Jun-99
DATE
RAW
TANK
VFP
WL

Figure 3

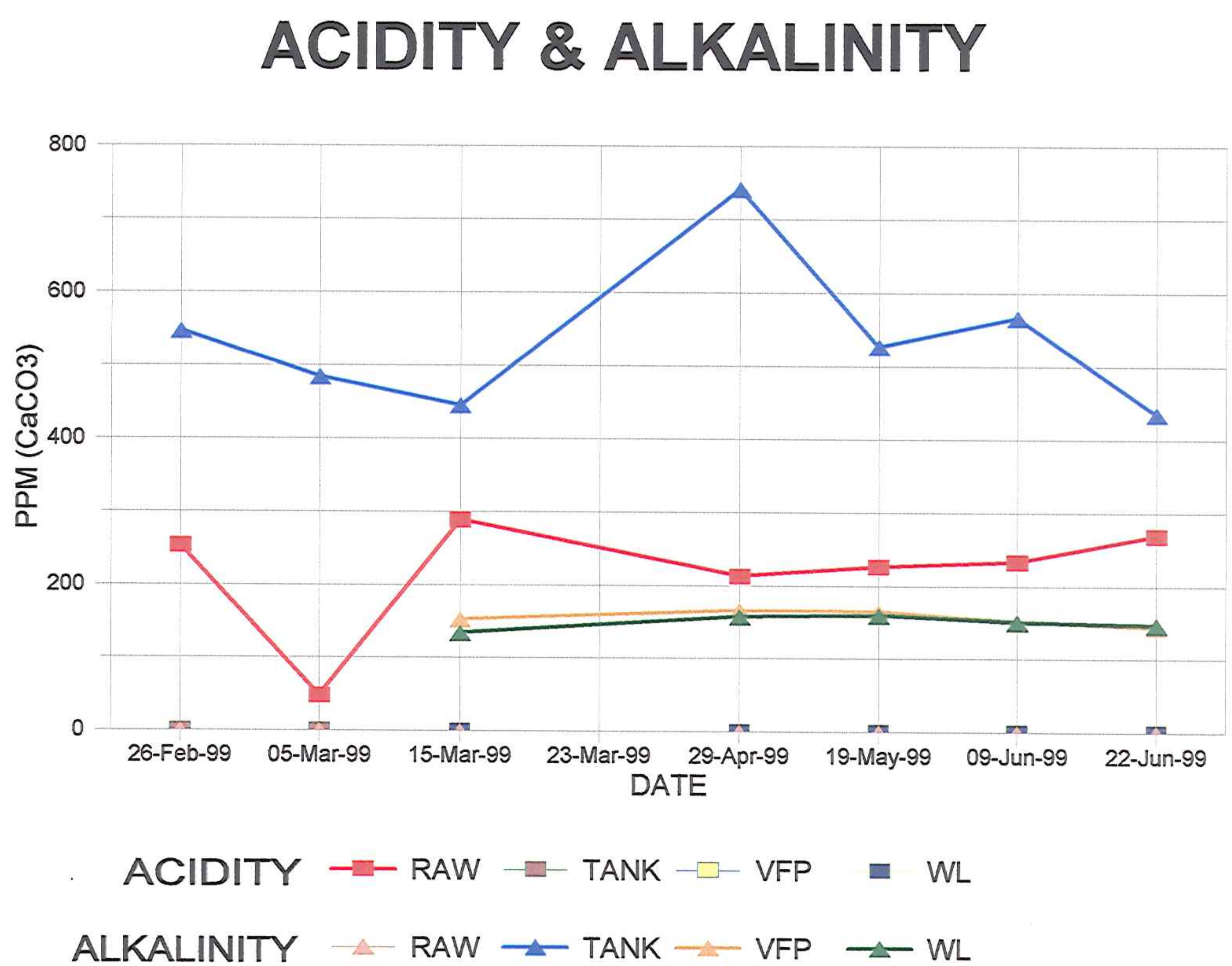

ACIDITY & ALKALINITY
800
600
400
200
0
PPM (CaCO3)
26-Feb-99
05-Mar-99
15-Mar-99
23-Mar-99
29-Apr-99
19-May-99
09-Jun-99
22-Jun-99
DATE
ACIDITY
RAW
TANK
VFP
WL
ALKALINITY
RAW
TANK
VFP
WL

FIGURE 4

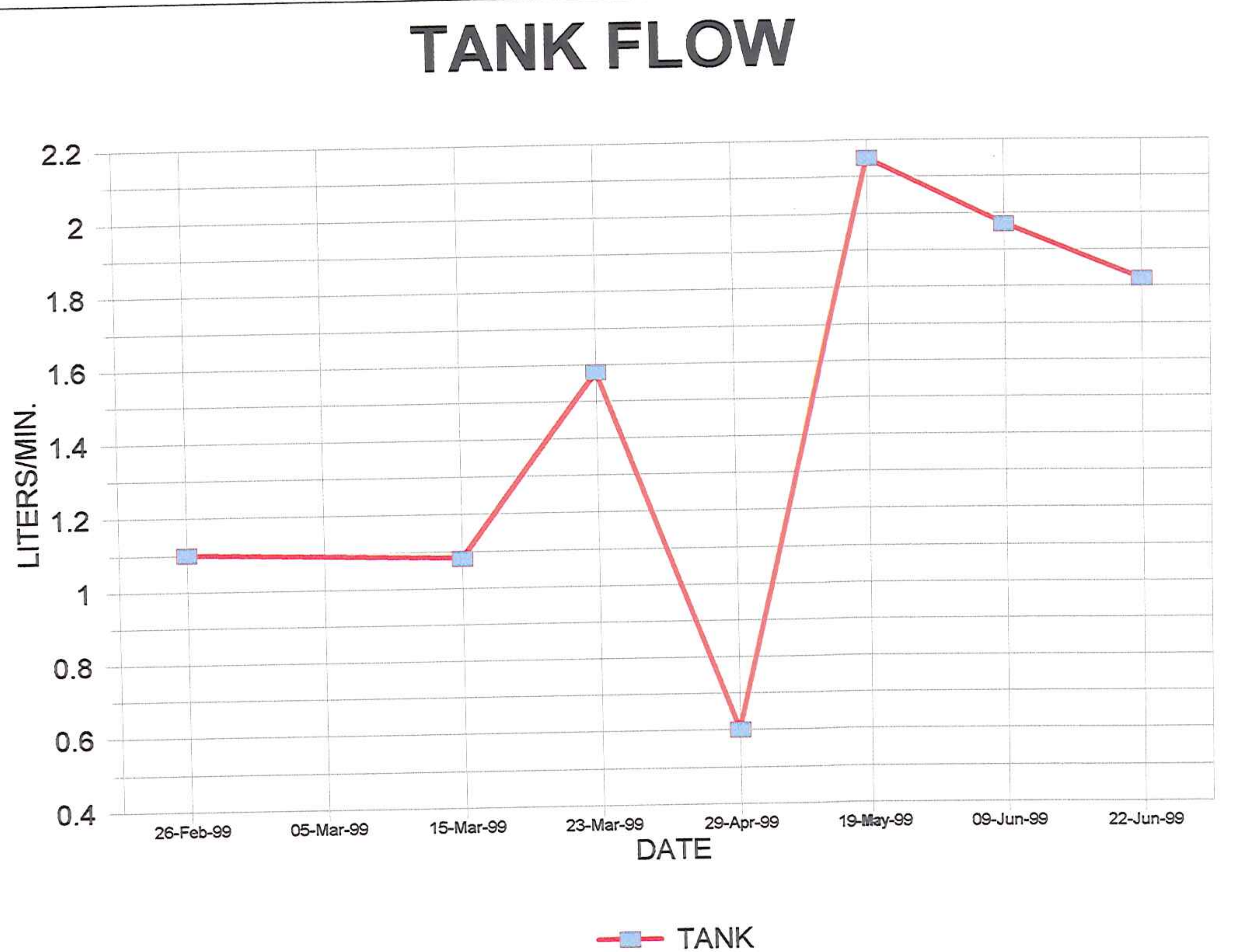

TANK FLOW
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
LITERS/MIN.
26-Feb-99
05-Mar-99
15-Mar-99
23-Mar-99
29-Apr-99
19-May-99
09-Jun-99
22-Jun-99
DATE
TANK

FIGURE 5

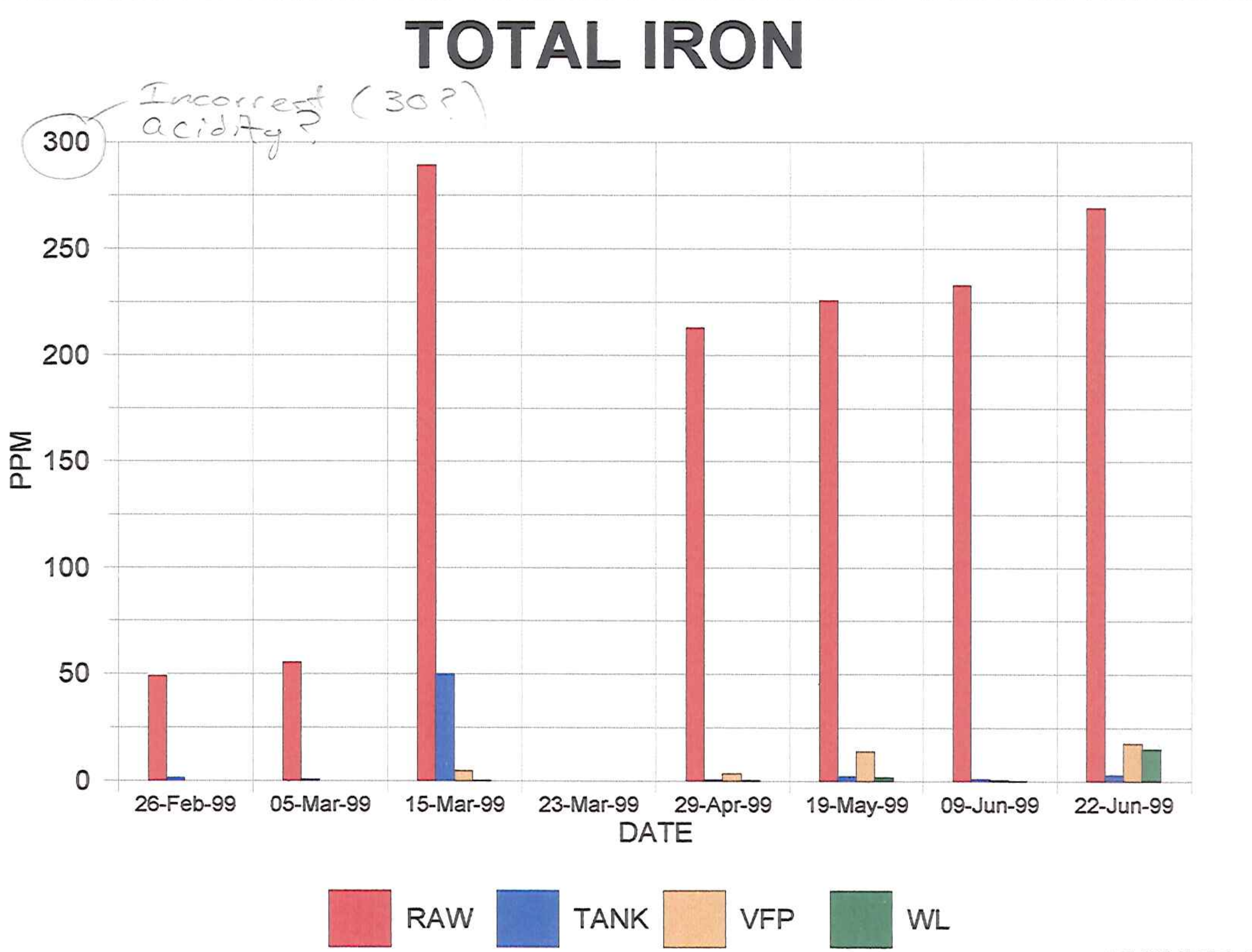

TOTAL IRON
Incorrect (30?)
acidity?
PPM
300
250
200
150
100
50
0
26-Feb-99
05-Mar-99
15-Mar-99
23-Mar-99
29-Apr-99
19-May-99
09-Jun-99
22-Jun-99
DATE
RAW
TANK
VFP
WL

FIGURE 6

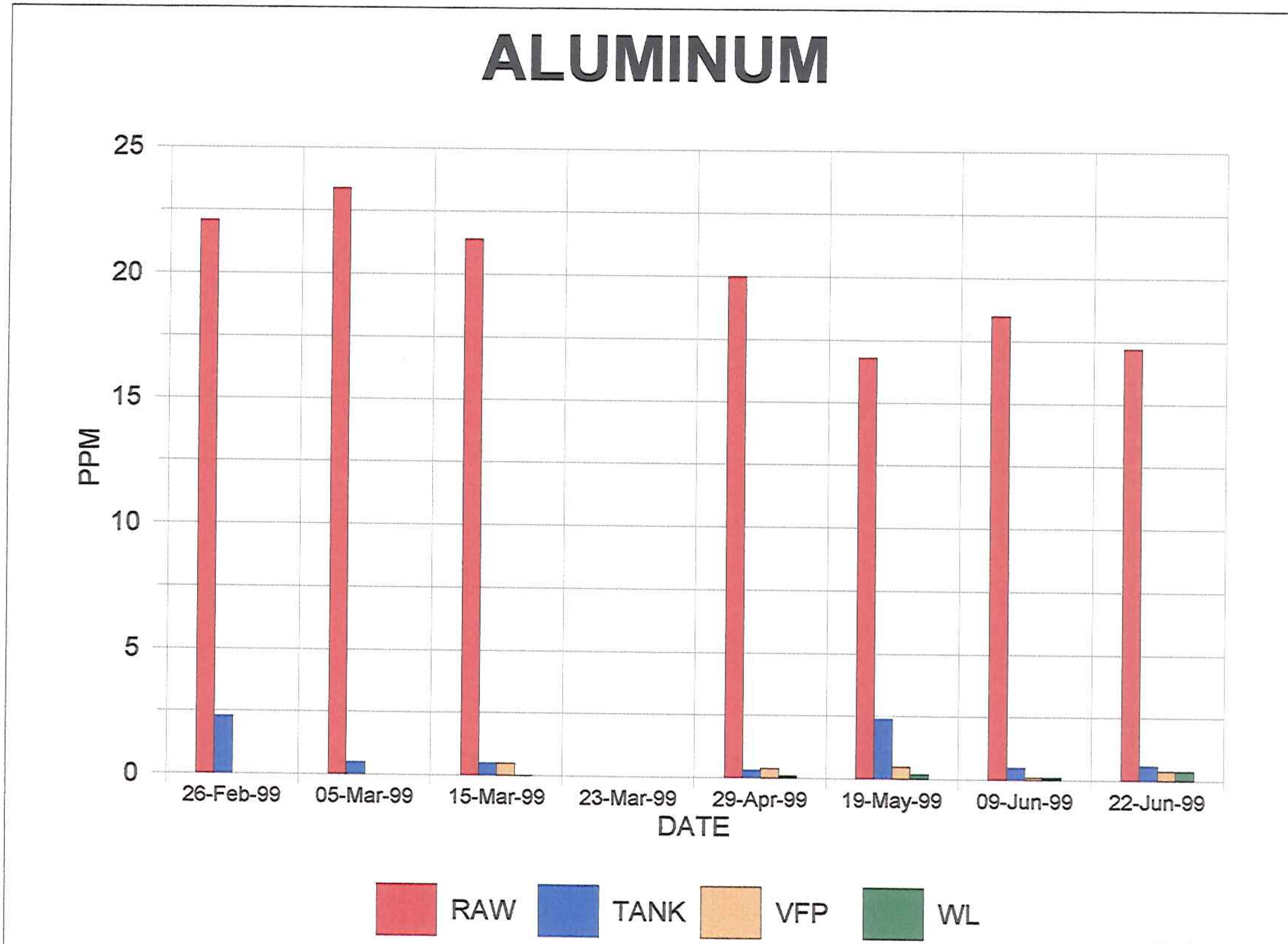

ALUMINUM
25
20
15
10
5
0
PPM
26-Feb-99
05-Mar-99
15-Mar-99
23-Mar-99
29-Apr-99
19-May-99
09-Jun-99
22-Jun-99
DATE
RAW
TANK
VFP
WL

FIGURE 7

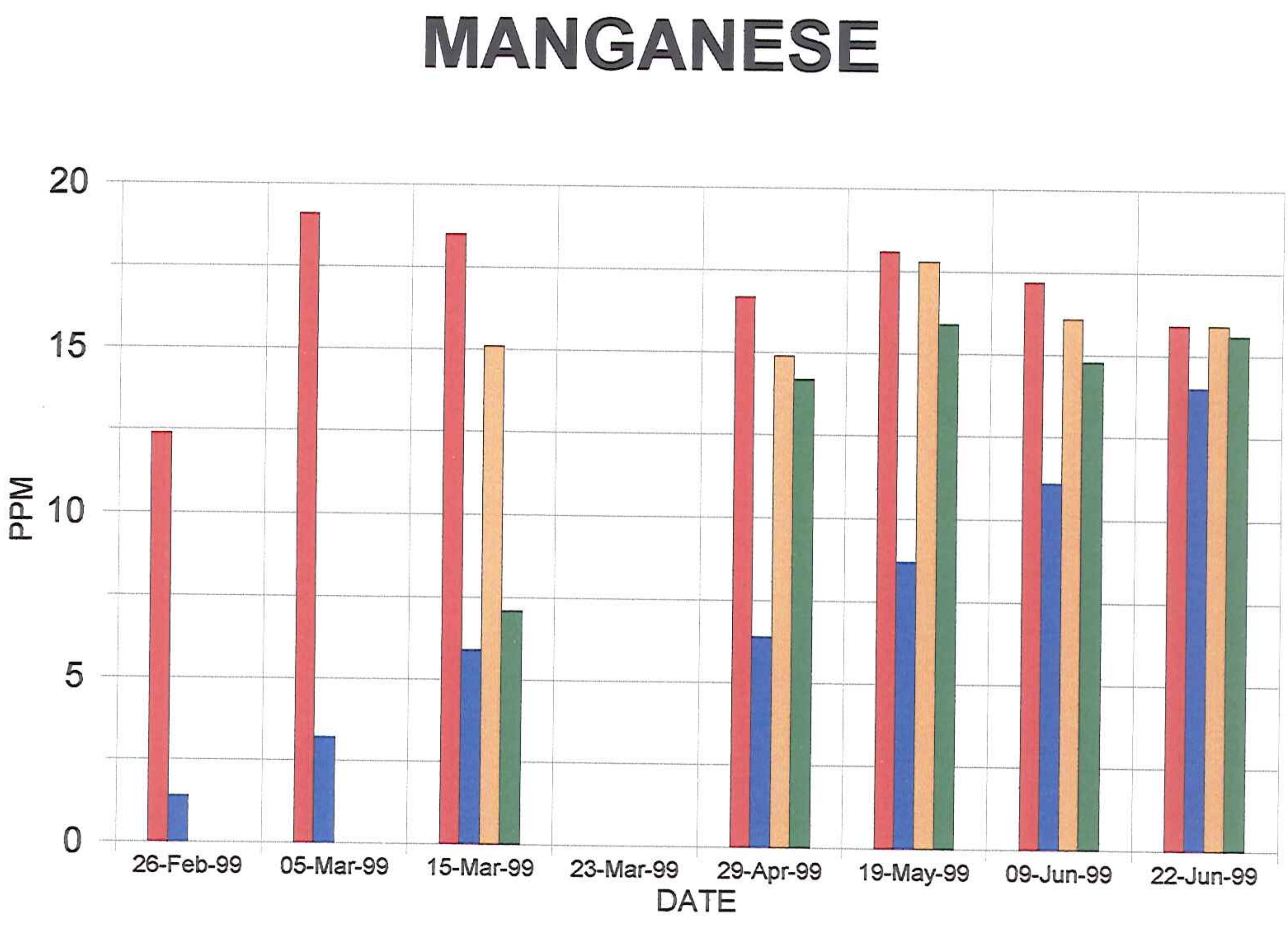
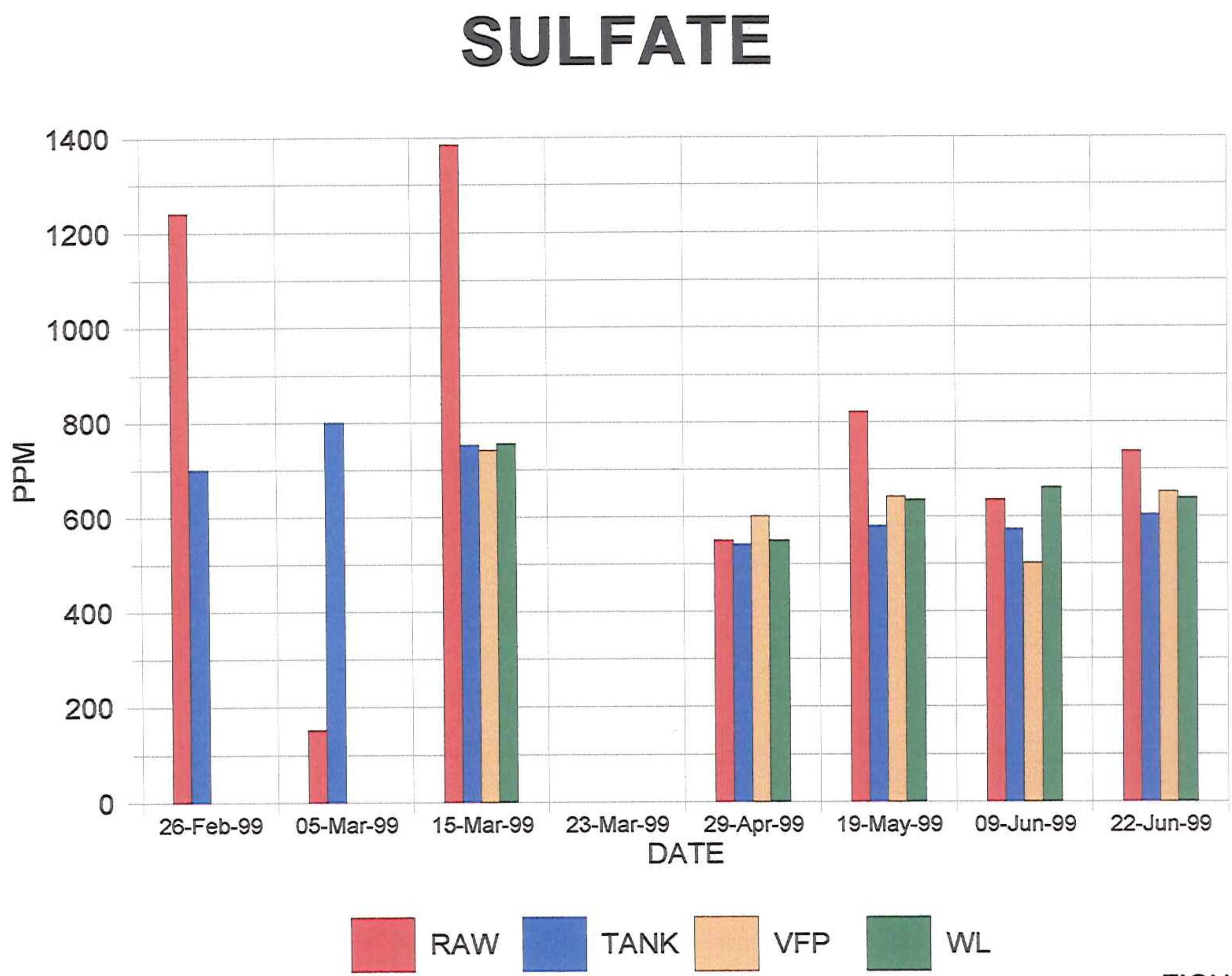

MANGANESE
20
15
10
5
0
PPM
26-Feb-99
05-Mar-99
15-Mar-99
23-Mar-99
29-Apr-99
19-May-99
09-Jun-99
22-Jun-99
DATE
RAW
TANK
VFP
WL

FIGURE 8


SULFATE
PPM
1400
1200
1000
800
600
400
200
0
26-Feb-99
05-Mar-99
15-Mar-99
23-Mar-99
29-Apr-99
19-May-99
09-Jun-99
22-Jun-99
DATE
RAW
TANK
VFP
WL
FIGURE 9

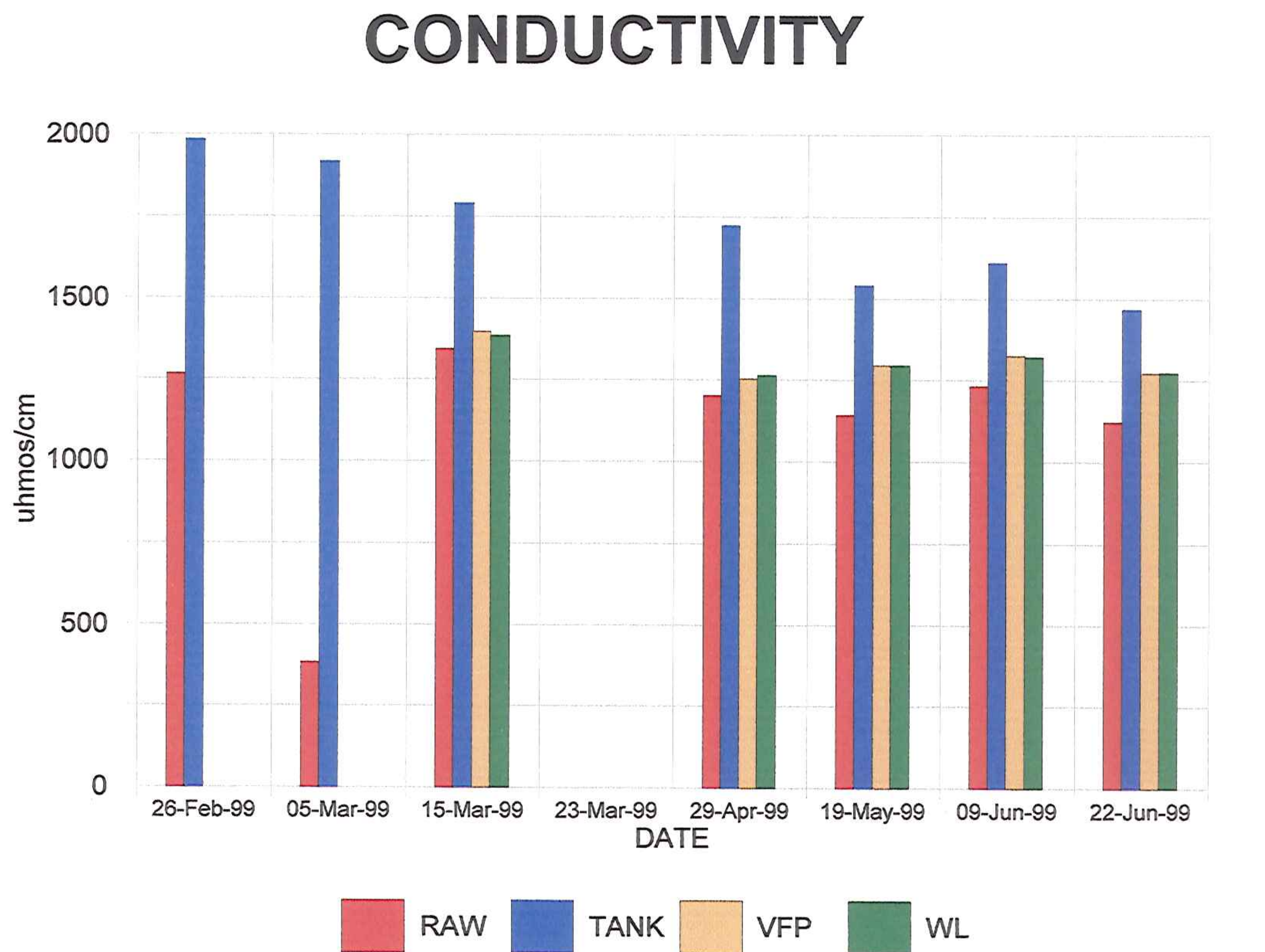

CONDUCTIVITY
2000
1500
1000
500
0
uhmos/cm
26-Feb-99
05-Mar-99
15-Mar-99
23-Mar-99
29-Apr-99
19-May-99
09-Jun-99
22-Jun-99
DATE
RAW
TANK
VFP
WL

FIGURE 10

TOTAL SUSPENDED SOLIDS

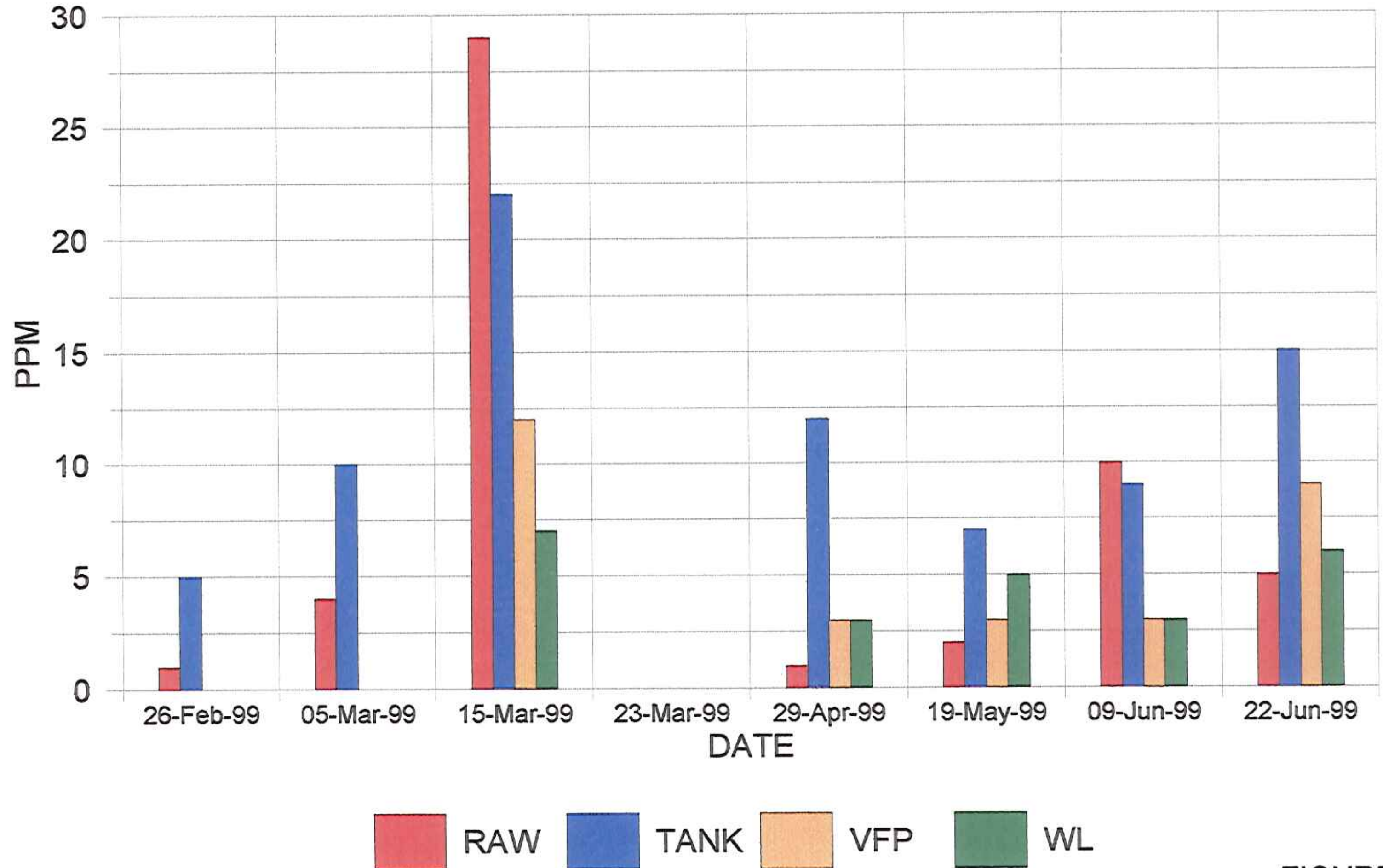


FIGURE 11

SPECIFIC YIELD

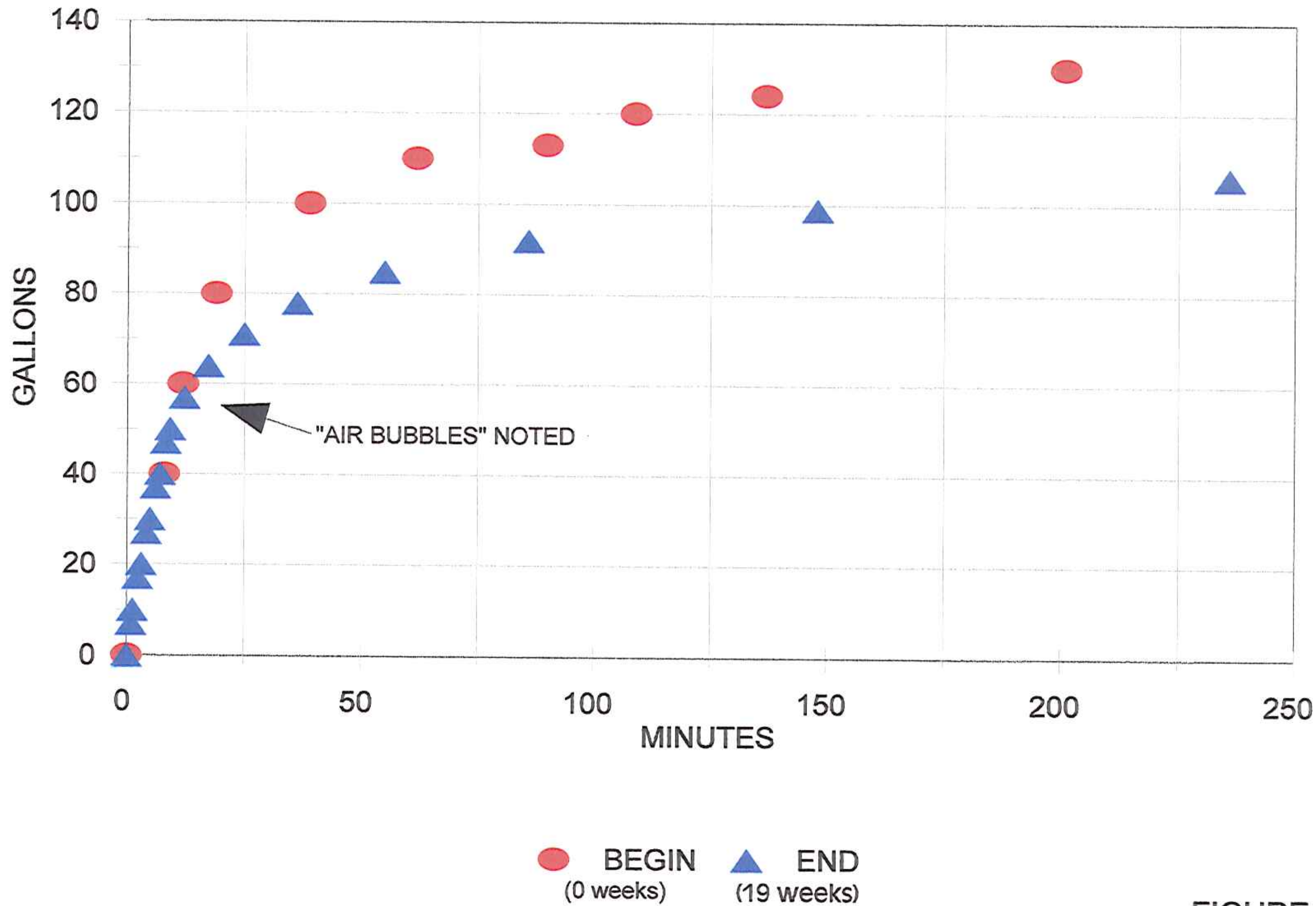


FIGURE 12

THE CATALYST

SLIPPERY ROCK WATERSHED COALITION MONTHLY ACTIVITIES UPDATE

LOOK AT YOUR CALENDARS IT'S APRIL ALREADY!!!!!!!!!!!!!!!!

ₔt's meet at the Community Get-Together this month!! It will be great to discuss new ideas with everyone and look at the past and up-coming SRWC activities! (See below for directions.) Prior meeting (3/10/99) attendees: Todd Colosimo, Steve Smith, Roger Bowman, Fred Brenner, Mike Enright, Valentin Kefeli, Bob Zick, Charlie Cooper, Tim Danehy, Margaret Dunn

1999 SRWC "GET-TOGETHER"

Our "indoor picnic" is to be held **Wednesday, April 14 at the Epiphany Catholic Church, Boyers, PA between 6:00 and 8:00 pm.** Todd Colosimo, Janice Belgredan, Steve Smith, and others have generously offered to place flyers in prominent places throughout the community to make everyone (all ages) feel welcome. We can't wait to enjoy everyone's company. The Camelot from Slippery Rock will be providing "oodles" of yummy food. New, cotton, SRWC ball caps are sure to be a hit, as well as the new mugs and stickers. The PA Game Commission bird feeders and other items for outdoor activities have been donated for door prizes. Posters by Coalition participants, including Girl Scouts, Grove City College and Slippery Rock University students, PA Department of Environmental Protection, and Jennings Water Quality Improvement Coalition will be used to explain the recent activities on a "one on one" basis. This event promises to be a "fun time" and an opportunity to entertain new ideas and answer questions about the efforts and goals of the Coalition. The Epiphany Catholic Church is located in Boyers just north of Forestville Road less than 1 mile west of the post office. There is a sign on Forestville Road. (We will also have signs.) Doors will be open by 5:30 pm for anyone who wishes to help set up. All are invited...drop by any time between 6:00 pm and 8:00 pm...very casual...bring the family!!!

1999 SLIPPERY ROCK WATERSHED COALITION SYMPOSIUM

On Friday, April 16, 1999 at Jennings Environmental Education Center, the Coalition will hold its fourth(!) annual symposium.

Over 100 (!!!) high school students are planning to attend. At the first break, these students will have the opportunity to participate in a field program which includes stream characterization and passive treatment demonstrations at Jennings. This is an exceptional opportunity for them to interact with JoAnn Albert, Will Taylor, and Candy Vild of Jennings and Dr. obert Hedin, an internationally-recognized expert in passive treatment technology.

Robert C. Dolence, Deputy Secretary, PA Department of Environmental Protection, has graciously agreed to be our Guest Speaker. His words of encouragement and support of our restoration efforts have been instrumental in the success that the Coalition has enjoyed. This year we also "re-welcome" George Watzlaf, U.S. Department of Energy, to speak from his "wealth of knowledge" regarding the on-going development of passive treatment technology. Other speakers include Dr. Dean DeNicola, Biologist, SRU and Dr. Fred Brenner, Biologist, Grove City College and the following students :

Steve Stefko, student SRU (Professor: Dr. Dean DeNicola, Biologist)
Brian Lipinski, student SRU (Professor: Dr. Michael Stapleton, Geochemist)
Mike Enright, student GCC (Professor: Dr. Fred Brenner, Biologist)
Pat Dimpfl, Dan McGuirk, Anthony Liguori, master's candidates Sustainable Systems, SRU(Professor: Dr. Valentine Kefeli, Soil Scientist)

One of the highlights last year and no doubt at this event are the presentations by Girl Scouts and homeshool students. (John Oliver, Secretary, Department of Conservation and Natural Resources has personally acknowledged their continuing contributions in the restoration effort.)

A field tour (transportation provided) led by participants in the Coalition, including Roger Bowman and Tim Gillen from the Knox District Mining Office, will be conducted after a "hardy" lunch to an unreclaimed area, an active project, and to a newly completed Anoxic Limestone Drain(SR101A) and Vertical Flow System(SR109). (Tour may be revised depending upon the weather.)

Posters can be installed at Jennings on Thursday afternoon from 3:30 to 5:00 pm and/or from 7:45 to 8:15 am on Friday. Registration (don't forget the coffee/tea/juice and cookies from Fairground Market) will begin at 8:00 am. The field tour is scheduled to return to Jennings around 3:30 pm.
`EE YOU THERE!!!!

PHOTO OF THE MONTH

Student Intern Mike Enright assembles under-drain for the Composted Biosolids & Limestone pilot-scale vertical flow system at Jennings Environmental Education Center, Brady Twp., Butler Co. (2/19/1999). Working with Stream Restoration Incorporated and the Coalition Mike is completing his internship requirement for his Biology degree at Grove City College under the direction of Dr. Fred Brenner, Biology Dept. After assisting in tank construction Mike completed a survey of plant species diversity and density in the channel wetland at Jennings. The channel wetland used composted biosolids mixed with quarry fines to fabricate an economical substrate used for wetland construction. Thanks Mike for all the hard work!!!!!!

SPECIAL THANKS

A special thanks to Mike Sajna for announcing the upcoming Symposium in the March 10, 1999 edition of the Pittsburgh Post-Gazette in his column, "Outdoors" !!!

Thanks to Quality Aggregates Inc., Amerikohl Mining, Inc., and Allegheny Mineral Corporation for their support.

For more information contact: Slippery Rock Watershed Coalition, c/o Stream Restoration Incorporated (PA non-profit), 338 Glen Eden Road, Rochester PA 15074, (724)774-2813, fax (724)774-1219, sri@ccia.com. April Distribution: approx. 340 copies

ESTABLISHMENT OF VEGETATION IN CONSTRUCTED WETLANDS USING BIOSOLIDS AND QUARRY FINES[1]

Timothy P. Danehy[2], Robert Zick[3], Fred Brenner[4], Jerry Chmielewski[5], Margaret H. Dunn[6], and Charles D. Cooper[7]

Abstract

A common problem with constructing wetlands on abandoned mine sites is the lack of adequate soil needed to establish vegetation. One component of a full-scale passive treatment system, built at Jennings Environmental Education Center in Brady Township, Butler County, PA, addressed this issue through the development of a "field trial" to find an inexpensive alternative substrate for wetland plants. A simple soil "recipe" was followed which called for the mixing of an inorganic material with a nutrient-rich organic material. The inorganic constituent used was silt-size pond cleanings from a sand and gravel operation. The organic material used was a composted product made from exceptional quality biosolids. Both soil components were obtained from local sources (less than16 kilometers [12 miles] from the site) and mixed on site with a Caterpillar 943 track loader. The soil was used to construct a channel wetland 3 meters (10 feet) wide by 60 meters (190 feet) long. A seed mixture which contained 22 different wetland plant species native to western Pennsylvania was added to the substrate prior to releasing the water from the vertical flow system into the wetland. After one year, the vegetation was studied to determine the percent cover and species composition in order to document the effectiveness of this method of wetland construction. The preliminary results of this study indicate that this is an effective means to establish and sustain wetland vegetation. The addition of a fabricated substrate consisting of composted biosolids and silt can be a very effective method to establish dense and diverse vegetation in a constructed wetland.

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[1]Paper presented at the National Association of Abandoned Mine Land Programs Conference, Champion, PA, August 22-25,1999.

[2]Timothy P. Danehy, EPI, Environmental Scientist, BioMost, Inc., 338 Glen Eden Road, Rochester, PA 15074.

[3]Robert Zick, Client Services Mgr., Chester Engineers, 600 Clubhouse Dr., Moon Twp., PA 15108.

[4]Dr. Fred Brenner, Professor of Biology, Grove City College, Grove City, PA 16127.

[5]Dr. Gerald Chmielewski, Associate Professor of Biology, Slippery Rock Univ., Slippery Rock, PA 16057.

[6]Margaret H. Dunn, PG, Stream Restoration Inc., 338 Glen Eden Road, Rochester, PA 15074.

[7]Charles D. Cooper, PE, C D S Associates, Inc., 1000 Hiland Ave., Coraopolis, PA 15108.

The development and execution of this project are part of a joint effort of the Slippery Rock Watershed Coalition and Jennings Water Quality Improvement Coalition.

Introduction

This project was conducted as part of an on-going restoration effort at the Jennings Environmental Education Center(Jennings), PA Department of Conservation and Natural Resources, located in Brady Township, Butler County, PA. Jennings is affected by acid mine drainage(AMD) that issues from an abandoned deep mine on the Middle Kittanning coalbed(Allegheny Gp.; Kittanning Fm.). This deep mine, known as the Brydon Mine, was active from 1935 to 1944.

Restoration efforts at this site span a period of more than 30 years. These efforts include: mine seals installed in the 1970s, which subsequently failed in 1984; installation of a 4-cell wetland-type passive treatment system in 1989, that improved the water quality but did not produce the desired circumneutral pH and low metals concentrations; an anoxic limestone drain installed in 1993 that plugged in less than one year due to the precipitation of aluminum hydroxide within the drain; and installation of a vertical flow pond utilizing a mixture of spent mushroom compost and limestone aggregate followed by a channel wetland, open-water wetland and settling pond in 1997, that successfully treat the drainage. (See Figure 1.)

The Vertical Flow System is a Demonstration Project funded by the PA Department of Environmental Protection(PADEP), Bureau of Watershed Conservation through an US Environmental Protection Agency Fiscal Year 1996 Section 319 Grant. Due to the unique nature of this project, many new and innovative passive treatment techniques were applied to abate the dissolved aluminum-bearing discharge at Jennings. One of these techniques allowed members of the Jennings Water Quality Improvement Coalition(JWQIC) to investigate the use of a mixture of composted exceptional quality biosolids and quarry fines as a fabricated substrate for the establishment of vegetation in a constructed wetland.

Substrates Considered

Common Wetland Substrates

As with many passive treatment systems constructed at abandoned mine sites, the supply of an appropriate on-site soil substrate can be extremely scarce or nonexistent. In order to encourage the establishment of vegetation, an off-site source of material is commonly needed. Two commercially available options, topsoil and spent mushroom compost, were evaluated based on purchase, delivery, and installation costs.

Topsoil is generally available from most landscape or garden suppliers with varying qualities and costs. Two types of topsoil were locally available including raw and enriched. Raw topsoil is an un-screened product usually derived from the stripping of soil from land development projects. Enriched topsoil products are usually a screened and nutrient enhanced material. The latter of the two more closely resembles natural wetland soils. Spent mushroom compost is a by-product of the mushroom industry and is widely used in the construction of passive treatment systems. The cost of these materials was prohibitive(See Table 1.); therefore, a more economical alternative was investigated.

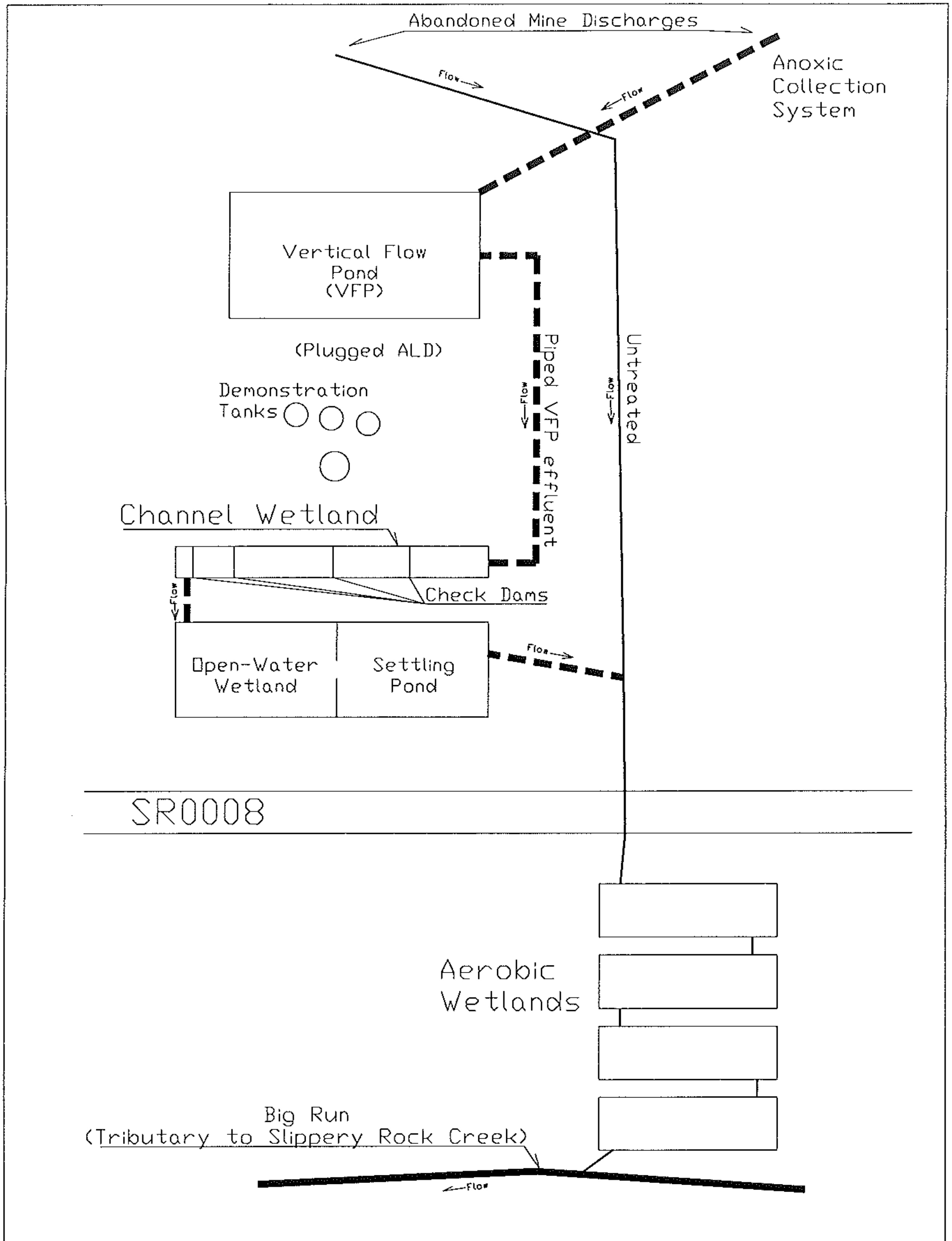


Figure 1. Schematic of Jennings Site

Fabricated Substrate

A collaborative effort of JWQIC participants investigated a potential alternative substrate to be utilized in wetland construction. This alternative follows a simple soil "recipe" where both inorganic and organic materials are mixed in order to fabricate a substrate for wetland vegetation. In order to be cost effective, local sources of inexpensive materials were used.

The local source for the inorganic constituent of the soil "recipe" was a sand and gravel operation about 6 miles from the site. This operation extracts materials from a glacial deposit near Slippery Rock, PA. The product used for this trial is referred to as quarry fines or pond-sand. It is primarily composed of silt-sized particles and has few economically important uses. The material was obtained at about $2.50/ton plus hauling costs.

Table 1. Cost Comparison of Fabricated Substrate With Commercially Available Materials.

	Fabricated Substrate				
Material	**Silt (Quarry Fines)**	**Composted Biosolids**	**Topsoil (enriched)**	**Topsoil (raw)**	**Spent Mushroom Compost**
Bulk Density	3000lb/CY	850lb/CY	2500lb/CY	2500lb/CY	1100lb/CY
Volume Amount	15 CY	15 CY	30 CY	30 CY	30 CY
Weight Amount	23.0 T	6.4 T	37.5 T	37.5 T	16.5 T
Cost per ton (Loaded)	$2.50	$2.00	$18.00	$12.00	$15.00
Cost per ton (Delivered)	$4.02	$5.47	$21.30	$13.50	$18.30
	$4.75 (avg.)				
Total Cost	$92.46	$35.00	$798.75	$506.25	$301.95
Comparable Totals	**$127.46**		**$798.75**	**$506.25**	**$301.95**
Cost per Acre with 5" of Material	**$2,900.00**		**$18,300.00**	**$11,600.00**	**$6,900.00**

Organic material was obtained from a local municipal wastewater treatment facility located about 12 miles from the site in Butler, PA. The Butler Area Sewer Authority currently produces an exceptional quality composted biosolids product. (See Table 2.) This material is available to the general public as a soil-amendment at a cost of $2.00/ton plus hauling.

Table 2. Representative Analysis - Composted Biosolids.

BUTLER AREA SEWER AUTHORITY COMPOST ANALYSES

Sample Date Sample ID Components (reported on dry weight basis)		9/9/93 Cell 8 Compost	3/10/94 Finished Compost	6/2/94 Compost Cell 17	8/24/94 Finished Compost Cell	12/22/94 Finished Compost	2/23/95 Finished Compost Cell 8	3/28/95 Finished Compost	Maximum and Minimum Range of Values	Average Values	EPA Part 503 Conc. Limits for EQ biosolids (mg/kg)	PA DER Maximum Class I biosolids concentrations allowed for land application (mg/kg)
NH_4-N	%	0.008	0.003	0.010	0.006	0.010	0.010	0.01	0.003 - 0.01	0.008	---	---
TKN	%	0.461	1.100	1.000	1.000	1.000	1.200	0.99	0.461 - 1.20	0.960	---	---
Plant Available Nitrogen	%	0.140	0.330	0.300	0.300	0.300	0.360	---	0.140 - 0.36	0.290	---	---
Phosphorous	mg/kg	45.500	8420.000	106.000	2400.000	36.000	140.000	14200.00	36 - 14200	3621.000	---	---
Potassium	mg/kg	720.000	1040.000	996.000	984.000	889.000	1190.000	1000.00	720 - 1190	974.000	---	---
Total Solids	%	68.200	59.400	76.600	83.300	77.100	73.200	69.20	59.4 - 83.3	72.400	---	---
Volatile Solids	%	37.200	44.300	47.200	43.100	51.300	50.800	50.63	37.2 - 51.3	46.400	---	---
Total Organic Carbon	%	20.700	24.600	26.200	23.900	28.500	28.200	28.13	20.7 - 28.5	25.700	---	---
C:N Ratio		44.800	22.400	26.200	23.900	28.500	23.500	28.40	22.4 - 44.8	28.200	---	---
pH		7.800	8.200	9.000	8.800	8.000	7.800	6.90	6.9 - 9.0	8.100	---	---
Arsenic (As)	mg/kg	4.000	2.900	2.300	<6.000	28.000	9.000	2.50	2.3 - 28.0	7.800	41.0	41.0
Barium (Ba)	mg/kg	396.000	NA	NA	NA	NA	NA	NA	396	396.000	---	---
Cadmium (Cd)	mg/kg	3.000	<2.000	2.000	1.000	1.000	<1.000	0.80	0.8 - 3.0	1.500	39.0	25.0
Chromium (Cr)	mg/kg	10.000	20.000	30.000	13.000	13.000	10.000	12.10	10.0 - 30.0	15.400	1200.0	1200.0
Lead (Pb)	mg/kg	40.000	30.000	<12.000	17.000	34.000	21.000	33.60	<12.0 - 40.0	26.800	300.0	300.0
Nickel (Ni)	mg/kg	40.000	34.000	32.000	20.000	21.000	14.000	16.50	14.0 - 40.0	25.400	420.0	420.0
Silver (Ag)	mg/kg	25.000	13.000	16.000	30.000	26.000	29.000	NA	13.0 - 30.0	23.200	---	---
Copper (Cu)	mg/kg	130.000	397.000	145.000	182.000	178.000	252.000	167.50	130.0 - 397.0	207.000	1500.0	1500.0
Zinc (Zn)	mg/kg	378.000	862.000	280.000	435.000	497.000	865.000	529.30	280.0 - 865.0	549.000	2800.0	2800.0
Molybdenum (Mo)	mg/kg	10.000	<20.000	10.000	<10.000	<10.000	<10.000	2.10	2.1 - <20.0	10.300	---	18.0
Sodium (Na)	mg/kg	368.000	611.000	519.000	465.000	514.000	661.000	NA	368.0-661.0	523.000	---	---
Selenium (Se)	mg/kg	1.100	<0.800	0.200	<6.000	<6.000	<7.000	<0.38	0.2 - <7.0	3.100	36.0	36.0
Mercury (Hg)	mg/kg	1.000	0.840	0.930	1.100	1.200	1.200	1.12	0.84 - 1.2	1.050	17.0	17.0
PCB's	mg/kg	<0.100	<0.200	<0.400	<0.100	<0.300	<0.100	NA	<0.1 - <0.4	<0.200	---	2.0

--- = Not Applicable
NA = Not Analyzed

Wetland Installation

Channel Construction

The original purpose of the channel, where this field trial was conducted, was to convey treated mine drainage from the full-scale Vertical Flow Pond at Jennings to an open-water wetland and settling pond. This channel conveys 30 gpm of effluent from the Vertical Flow Pond which discharges through an aeration device at the southern edge of the site to the inlet of the open-water wetland at the northern edge of the site. The channel as constructed is 190 ft long by 10 ft wide at the bottom.

Substrate Placement

The materials were delivered to the site and stockpiled separately. A Caterpillar 943 track loader (Bucket capacity ~1.75 CY) was used to place and to mix the materials in the channel. A bucket of quarry fines was placed and spread with a bucket of biosolids placed and spread on top. The materials were added 1 : 1, by volume, with the teeth of the bucket used to mix the materials by back-dragging. Placement of a total of 30 CY of material took about 2 hours. The average thickness of the substrate as placed is about five inches.

Water Depth Control Structures

Once the substrate was in place check dams were installed. The check dams divide the channel wetland into four cells or "steps" of varying lengths with equal amounts of fall in each cell. Pressure-treated boards(2X10), 12 feet in length, with a 10-foot wide by 0.2-foot deep trapezoidal weir notched into the top, were utilized. These "steps" helped to create micro-topographic relief and varying flow paths while controlling velocity. Within each of these cells a variety of small channels and pools was created. Water depths from the channel wetland and open-water wetland are shown in Tables 3 and 4.

Seeding Procedures

The channel wetland was seeded in mid-August 1997. Prior to allowing the effluent from the Vertical Flow Pond to enter the channel wetland, the substrate was saturated using the effluent from the pilot-scale systems at the site (Approx. 3 gpm flow of treated and untreated water). The substrate was allowed to be completely saturated for a period of about 24 hours before being seeded. The saturated substrate was hand-raked and seeded. (See tables 5a & 5b.) The obligate wetland seed mixture was applied mainly in the center portions of the channel and where greater water depths were anticipated. The Jennings Mix containing a higher number of facultative species was primarily applied along the edges of the wetland and where shallower water depths were anticipated. Vegetation was observed within the first week after seeding.

The wetland was allowed to establish after seeding for approximately two weeks before the effluent from the full-scale Vertical Flow Pond was introduced to the wetland. After initial introduction of the treated effluent some erosion of the substrate occurred due to lack of vegetation and significant precipitation events.

Comparison of Water Depths: Channel Wetland vs. Large Wetland

Table 3. Water depth measured in Channel Wetland 7/17/99

Row #	Distance from final Check Dam (m)	West Depth (ft)	Center Depth (ft)	East Depth (ft)	Avg. Depth (ft)	Avg. Depth (cm)	
1	0	0.10	0.05	0.00	0.05	1.52	Check dam
2	2	0.14	0.04	0.20	0.13	3.86	
3	4	0.21	0.41	0.39	0.34	10.26	
4	6	0.20	0.02	0.22	0.15	4.47	
5	8	-0.08	0.35	0.00	0.09	2.74	Check dam
6	10	0.38	0.05	0.02	0.15	4.57	
7	12	0.12	0.00	0.19	0.10	3.15	
8	14	0.00	0.50	0.00	0.17	5.08	
9	16	0.15	0.09	0.14	0.13	3.86	FLOW →
10	18	0.10	0.05	0.15	0.10	3.05	
11	20	0.06	0.50	0.25	0.27	8.23	
12	22	0.03	0.35	-0.05	0.11	3.35	
13	24	0.10	0.03	0.08	0.07	2.13	
14	26	0.08	0.40	0.10	0.19	5.89	
15	28	0.01	0.07	-0.03	0.02	0.51	Check dam
16	30	0.18	0.15	0.03	0.12	3.66	
17	32	0.01	0.12	0.00	0.04	1.32	
18	34	0.10	0.10	0.24	0.15	4.47	
19	36	0.03	0.32	0.08	0.14	4.37	
20	38	0.00	0.15	0.07	0.07	2.24	
21	40	0.01	0.30	0.08	0.13	3.96	
22	42	-0.15	0.02	0.14	0.00	0.10	Check dam
23	44	0.23	0.00	0.16	0.13	3.96	
24	46	0.00	0.05	0.10	0.05	1.52	
25	48	0.03	0.15	-0.05	0.04	1.32	
26	50	-0.10	0.28	0.05	0.08	2.34	
Avg. Depth in ft		0.07	0.18	0.10	0.12		
Avg. Depth in cm		2.27	5.33	3.00	3.54		

Range: 0.15 ft above WL to 0.50 ft deep
Range: 4.47 cm above WL to 15.24 cm deep

Average Water Depth: 0.12 ft
Average Water Depth: 3.54 cm

Table 4. Water depth measured in Open-Water Wetland 7/17/99

Row	West Depth (ft)	Center Depth (ft)	East Depth (ft)	Avg. Depth (ft)	Avg. Depth (cm)	
1	0.55	0.65	0.72	0.64	19.51	
2	0.73	0.83	0.63	0.73	22.25	
3	0.62	0.70	0.83	0.72	21.84	FLOW →
4	0.81	0.84	0.73	0.79	24.18	
5	0.72	0.80	0.80	0.77	23.57	
6	0.65	0.80	0.55	0.67	20.32	
Avg. Depth in ft	0.68	0.77	0.71	0.72		
Avg. Depth in cm	20.73	23.47	21.64	21.95		

Range: 0.55 ft deep to 0.84 ft deep
Range: 16.76 cm deep to 25.60 cm deep

Average Water Depth: 0.72 ft
Average Water Depth: 21.95 cm

Table 5a. Obligate Wetland Mix

Species	Botanical Name	Percent*
Arrow Arum	*Peltandra virginica*	20.00%
Giant Bur-Reed	*Sparganium eurycarpyum*	20.00%
Green Bulrush	*Scirpus atrovirens*	18.00%
Button Bush	*Cephalanthus occidentalis*	10.00%
Soft-Stem Bulrush	*Scirpus validus*	6.00%
Cosmos Sedge	*Carex comosa*	5.00%
Pickerel Weed	*Pontedera cordata*	5.00%
Lake Bank Sedge	*Carex lacustris*	4.50%
Hard-Stem Bulrush	*Scirpus acutus*	4.00%
Nodding Bur Marigold	*Bidens cernua*	3.00%
Monkey Flower	*Mimulus ringens*	2.00%
Turtlehead	*Chelone glabra*	1.00%
Rough Leaved Goldenrod	*Solidago patula*	1.00%
Virgins Bower	*Clematis virginiana*	0.50%

Table 5b. Jennings Mix

Species	Botanical Name	Percent*
Meadow Foxtail	*Alopecurus pratensis*	33.30%
Virginia Wild Rye	*Elymus virginicus*	33.30%
Rice Cut Grass	*Leersia oryzoides*	10.80%
Nodding Bur-Marigold	*Bidens cernua*	6.70%
Lesser Bur-reed	*Sparganium americanum*	5.30%
Green Bulrush	*Scirpus atrovirens*	2.70%
Blue Vervain	*Verbena hastata*	2.70%
Squarestem Monkey Flower	*Mimulus rigens*	1.30%
Wool Grass	*Scirpus cyperinus*	1.30%
Small Seeded Bulrush	*Scirpus microcarpus*	1.30%
Many Leaved Bulrush	*Scirpus polyphyllus*	1.30%

*Percent by weight. Each seed mix: net weight one pound

System Monitoring

Wetland Surveys

On three occasions the channel wetland was surveyed to determine plant type composition and percent coverage. On 10/26/1998, the wetland was surveyed by undergraduate students from Slippery Rock University under the direction of Dr. Gerald Chmielewski, Department of Biology. 29 transects of the wetland were surveyed to determine the species present and visually estimate the percent coverage. The results of this survey are presented in Table 6.

The second and third surveys were completed between 3/15-17/1999 by Michael Enright and 6/16-21/1999 by Charlene Wick, respectively. (Both undergraduate interns studied under Dr. Fred Brenner, Department of Biology, Grove City College.) A portable 1 m^2 grid divided into 4 cm^2 blocks was placed at each meter along the length of the wetland and moved across the wetland. The percent coverage was estimated by counting the number of 4 cm^2 blocks in which each plant type was found and converting this number into square meters. If more than one plant type was found within a 4 cm^2 block, the plant type with the most stems was given that block. The results of these surveys are shown in Table 6.

The 10/26/98 survey yielded a coverage of 113.8%. This is attributed to the visual method of estimation used. This allows for multiple levels of coverage to be counted. One species that is representative of obtaining greater than 100% coverage by this method is *Lemna minor* which was estimated to cover 26.55% of the entire wetland. This is in comparison to the grid method which did not count *Lemna minor*. This example is one reason for the difference in percent coverage between the two methods.

One other factor in considering the percent coverages is the increased vegetated area between the March and June surveys. This increased the total area surveyed due to the expansion of the wetland vegetation beyond the channel bottom. An additional 1m^2 per row was used as the base to calculate the percent coverage. By including this area which was not part of the substrate amended channel, a lower percent coverage was realized.

Of the 22 species in the seed mixtures only10 were documented as being established between 14 and 22 months after being planted; therefore, 12 species were planted and not observed. In contrast, 21 different plants were observed in the wetland which were not included in the seed mixture. The species with the highest estimated percent coverage(53.31%) was *Alopercurus pratensis*. Overall, the plants most observed belonged to the grass family with percent total coverage ranging from 37.00% to 65.00%.

Although not part of the original seed mixture, *Lemna minor* was the plant observed with the next highest documented total percent coverage(26.55%). This species dominates the open-water wetland below the channel wetland(estimated coverage is about 100%). The reason for the high populations of duckweed in both of these wetlands is not known; however, very high *Lemna minor* populations have been observed in other vertical flow-type passive treatment systems. This may be attributed to the elevated nutrient levels of water treated with organic materials.

The reason for the successful invasion of volunteer plants is not known. The establishment of these plants may be attributed to natural distribution processes, an impure seed mix, the placement of hay bales below check dams, and upgradient site stabilization. A variety of wildlife has been observed within the channel wetland, even during the winter months, which may contribute to the introduction of non-planted species.

Cattails, purposefully excluded from the original seed mix, were observed in increasing numbers throughout the three surveys. It is anticipated that the percentage of cattails will continue to

Table 6. Establishment of Vegetation.

Percent coverage of wetland observed on three occasions.
Visual estimation technique used for 10/26/98 survey.
Portable 1 m^2 grid used to estimate coverages during 3/16/99 & 6/20/99 surveys.

	Seeding					% COVERAGE OBSERVED		
	Rate lb/ac	Common Name	Family	Genus	Species	10-26-98	3-16-99	6-20-99
1		Maple Trees	Aceraceae	Acer	rubrum	0.02%		
2		Yarrow	Asteraceae	Achillea	millefolium	0.09%		
3		Grey Goldenrod	Asteraceae	Solidago	nemoralis	0.03%		
4		Flat-topped Goldenrod	Asteraceae	Euthamia	graminifolia	0.07%		
5	2.2	Nodding Bur Marigold	Asteraceae	Bidens	ceruna	2.52%		
6	4.8	Green Bulrush	Cyperaceae	Scripus	atrovirens		observed	4.41%
7	1.4	Soft-Stemmed Bulrush	Cyperaceae	Scripus	validus			3.95%
8		Marsh Straw Sedge	Cyperaceae	Carex	hormathodes			
9	1.2	Cosmos Sedge	Cyperaceae	Carex	comosa	0.34%	observed	2.50%
10	1	Lake Bank Sedge	Cyperaceae	Carex	lacustris			
11		Flatsedge	Cyperaceae	Cyperus	sp.	1.69%		
12		Three way sedge	Cyperaceae	Dulichium	arundinaceum	0.19%	1.00%	0.00%
13		Soft Rush	Juncaceae	Juncus	effuses	3.31%	2.00%	5.39%
14		Lesser Duckweed	Lemnaceae	Lemna	minor	26.55%		
15		Wild Onion	Lileaceae	Allium	sp.	0.19%		
16		Purple-leaved Willow herb	Pimulaceae	Epilobium	coloratum	1.90%		
17	7.6	Virginia Wild Rye	Poaceae	Elymus	virginicus	11.66%		
18	2.5	Rice Cut Grass	Poaceae	Leersia	oryzoides			
19		Crown Vetch	Poaceae	Coronilla	varia	0.03%		
20		Reed Grass	Poaceae	Phragmites	maximus		37.00%	45.87%
21		Kentucky Bluegrass	Poaceae	Poa	pratensis			
22		Bentgrass	Poaceae	Agrostis	sp.			
23		Cord Grass	Poaceae	Spartina	pectinata			
24	7.6	Meadow Foxtail	Poaceae	Alopecurus	pratensis	53.31%		
25		Docks	Polygonaceae	Rumex	sp.	0.17%		
26		Smartweed	Polygonaceae	Polygonum	sp.	6.66%		
27		Meadowsweet	Rosaceae	Spiraea	sp.	0.03%		
28		Aspen Trees	Salicaceae	Poplus	sp.			observed
29	0.8	Monkey Flower	Scrophlariaceae	Mimulus	ringens	0.09%		
30		Cattails	Typhaceae	Typha	sp.	3.52%	7.00%	12.82%
31	0.6	Blue Vervain	Verbanaceae	Verbena	hastata	1.43%		
32	0.2	Turtlehead	Scrophlariaceae	Chelone	glabra			
33	0.1	Virgins Bower	Ranunculaceae	Clematis	virginiana			
34	0.9	Hard-Stem Bulrush	Cyperaceae	Scirpus	acutus			
35	2.3	Button Bush	Rubiaceae	Cephalanthus	occidentalis			
36	0.3	Wool Grass	Cyperaceae	Scirpus	cyperinus			
37	0.3	Small Seeded Bulrush	Cyperaceae	Scirpus	microcarpus			
38	1.2	Pickerel Weed	Ponteriaceae	Pontederia	cordata			
39	1.4	Soft-Stem Bulrush	Cyperaceae	Scirpus	validus			
40	0.2	Rough Leaved Goldenrod	Asteraceae	Solidago	patula			
41	1.2	Lesser Bur-reed	Sparganiaceae	Sparganium	americanum			
42	4.6	Giant Bur-reed	Sparganiaceae	Sparganium	eurycarpum			
43	4.6	Arrow Arum	Araceae	Peltandra	virginica			
					Total Percent Coverage Observed:	113.80%	47.00%	74.94%

Planted and Established (Observed)
Not Planted and Established (Observed)
Planted and Not Established (Not Observed)

Number of Planted Species Observed: 10
Number of Non-Planted Species Observed: 21
Number of Planted Species Not Observed: 12

Welland surveys performed by the following groups and invidusls:
10-26-98 by Slippery Rock University students under the direction of Dr. Jerry Chmielewski Dept. of Biology.
3-16-99 by Micheal Enringht, Grove City College under the direction of Dr. Fred Brenner, Dept. of Biology.
6-20-99 by Charlene J. Wick, Biologist, with assistance from Dr. Fred Brenner, Dept. of Biology, Grove City College.

Some information from the above table was revised according to USDA NRCS on-line database *http://plants.usda.gov/plants/fr_scilist.cgi* increase over time. The dominant nature of cattails is one of the reasons they were excluded from the seed mixtures.

Unsuccessful establishment of planted species may be due to erosion, competition, consumption by wildlife, and less than favorable conditions, relating to water quality and depth and substrate composition.

Water Quality Monitoring

One concern with the use of biosolids is the presence of metals. The composted product used in this trial exceeds all of the federal and state requirements for exceptional quality biosolids(See Table 2.); however, grab samples were collected in the winter, spring and summer of 1999 and analyzed for standard mining parameters and a suite of metals. (See table 7.) Monitoring stations included: (1) RAW - untreated mine drainage sampled before entering the Vertical Flow Pond. (2) VFP - effluent from the Vertical Flow Pond equal to influent of the channel wetland. (3) WL - effluent of the wetland prior to entering the open-water wetland.

In general, there was a decrease in all metals(except Mn and Ca) from the RAW water to the VFP effluent. A minor decrease in all metals was observed from the channel wetland influent compared to effluent, except for lead on two occasions. Increases of 0.0001 mg/L and 0.0005 mg/L were documented on 4/29/1999 and 6/22/1999, respectively. Although there was an increase in lead concentrations observed, the highest total concentration of lead discharging from the channel wetland was still 8X below the EPA primary drinking water standards.

Monitoring of standard mining parameters demonstrated the effectiveness of the vertical flow pond in treating the acid mine drainage. The channel wetland had very little affect on the standard mining parameters as expected based on its small surface area. A slight increase in pH was observed probably due to the release of carbon dioxide gas. A slight decrease was seen in aluminum, iron, and manganese. It appears that the expected increase in alkalinity with temperature due to microbial activity was also observed within the wetland. Except for iron, manganese, aluminum, and sulfate, the effluent of the channel wetland met EPA drinking water standards for the parameters monitored.

Summary

Preliminary results, based on this field trial, indicate that addition of a substrate fabricated from exceptional quality composted biosolids and quarry fines is both economical and effective for successful establishment of vegetation in a constructed wetland.

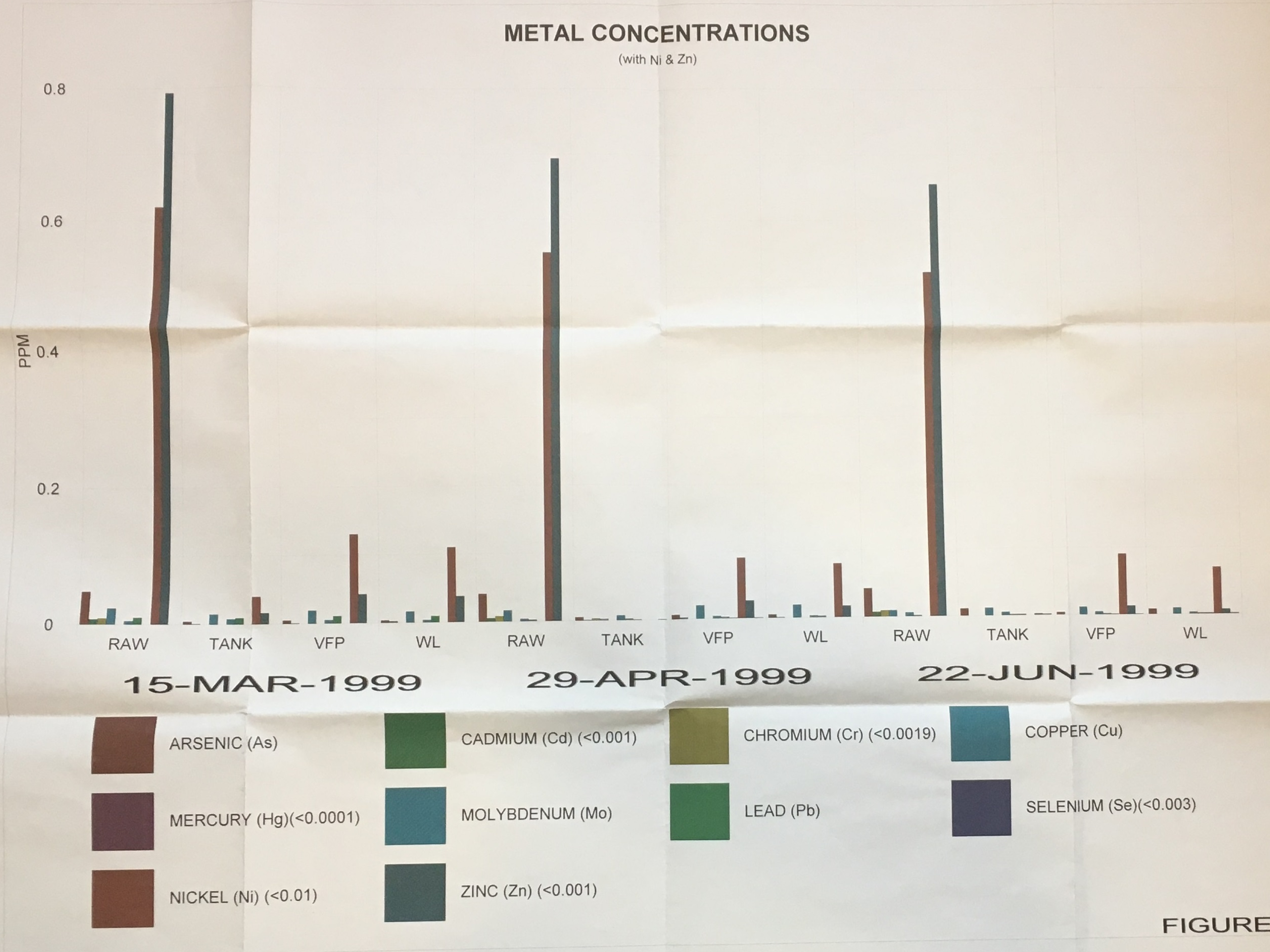
These results were obtained by monitoring a wetland receiving treated, net-alkaline mine drainage from a Vertical Flow Pond. Based on the preliminary findings, this mixture appears to be a promising alternative substrate for this and other types of constructed wetlands. The vegetative growth observed even during winter months is attributed to the relatively warm water received from the Vertical Flow Pond coupled with significant water velocities relative to those velocities that would be present in larger and broader wetlands (i.e., the open-water wetland which did freeze during winter months).

Table 7. Water Monitoring Data.

(1) RAW - untreated mine drainage sampled before entering the Vertical Flow Pond. (2) VFP - effluent from the Vertical Flow Pond equal to the influent of channel wetland. (3) WL - effluent of the wetland prior to entering the open-water wetland.

PARAMETER	15-Mar-99			29-Apr-99			22-Jun-99			EPA DRINKING WATER STANDARDS
	RAW	VFP	WL	RAW	VFP	WL	RAW	VFP	WL	
FLOW (LPM)		95.54			118.67			84.37		NA
FLOW (GPM)		25.24			31.35			22.29		NA
FIELD pH	4.0	6.6	7.2	4.0	6.5	7.3	4.0	6.4	7.1	6.5-8.5
LAB pH	3.27	6.79	7.50	3.00	7.05	7.40	3.36	6.63	6.95	6.5-8.5
FIELD TEMPERATURE (°C)	7	7	7	11	14	14	12	19	21	NA
ACIDITY (mg/L $CaCO_3$)	289	0	0	213	0	0	269	0	0	NA
ALKALINITY (mg/L $CaCO_3$)	0	152	133	0	166	157	0	143	146	NA
CONDUCTIVITY (umhos/cm)	1344	1397	1385	1201	1254	1264	1124	1274	1275	NA
SULFATE (mg/L)	1385	741	756	551	601	551	738	652	640	250
TOTAL IRON (mg/L)	42.0	4.8	0.2	35.1	3.6	0.5	43.6	17.8	15.2	0.3
MANGANESE (mg/L)	18.5	15.1	7.1	16.7	14.9	14.2	15.9	15.9	15.6	0.05
ALUMINUM [<0.04]* (mg/L)	21.4	0.5	0.0	20.0	0.4	0.1	17.2	0.4	0.4	0.05
TOTAL SUS. SOLIDS (mg/L)	29	12	7	1	3	3	5	9	6	NA
ARSENIC (mg/L)	0.0488	0.0049	0.0035	0.0411	0.0061	0.0048	0.0419	0.0035	0.008	0.05
CADMIUM [<0.001]* (mg/L)	0.008	0.001	0.002	0.005	0.002	0.001	0.007	0	0	0.005
CHROMIUM [<0.0019]* (mg/L)	0.0089	0	0	0.0076	0	0	0.0092	0	0	0.1
CALCIUM (mg/L)	108.23	266.22	258.14	97.06	231.55	231.33	92.13	231.98	228.98	NA
COPPER (mg/L)	0.024	0.019	0.16	0.016	0.02	0.019	0.009	0.011	0.009	1.3
MERCURY [<0.0001]* (mg/L)	0.0002	0	0	0	0	0	0.0001	0	0	0.002
MOLYBDENUM (mg/L)	0.0046	0.0047	0.0033	0.0033	0.0035	0.003	0.0058	0.0043	0.003	NA
NICKEL [<0.01]* (mg/L)	0.62	0.13	0.11	0.55	0.09	0.08	0.52	0.09	0.07	NA
LEAD (mg/L)	0.0095	0.0108	0.0088	0.0019	0.0018	0.0019	0.0012	0.0012	0.0017	0.015
SELENIUM [<0.003]* (mg/L)	0	0	0	0	0.0004	0	0	0.008	0.0017	0.05
ZINC [<0.001]* (mg/L)	0.793	0.042	0.038	0.694	0.026	0.017	0.655	0.013	0.007	5

* A value of 0 represents a sample with a concentration below the detection limit as noted to the right of the parameter.



METAL CONCENTRATIONS
(with Ni & Zn)
0.8
0.6
PPM 0.4
0.2
0
RAW
TANK
VFP
WL
RAW
TANK
VFP
WL
RAW
TANK
VFP
WL
15-MAR-1999
29-APR-1999
22-JUN-1999
ARSENIC (As)
CADMIUM (Cd) (<0.001)
CHROMIUM (Cr) (<0.0019)
COPPER (Cu)
MERCURY (Hg)(<0.0001)
MOLYBDENUM (Mo)
LEAD (Pb)
SELENIUM (Se)(<0.003)
NICKEL (Ni) (<0.01)
ZINC (Zn) (<0.001)

FIGURE 1

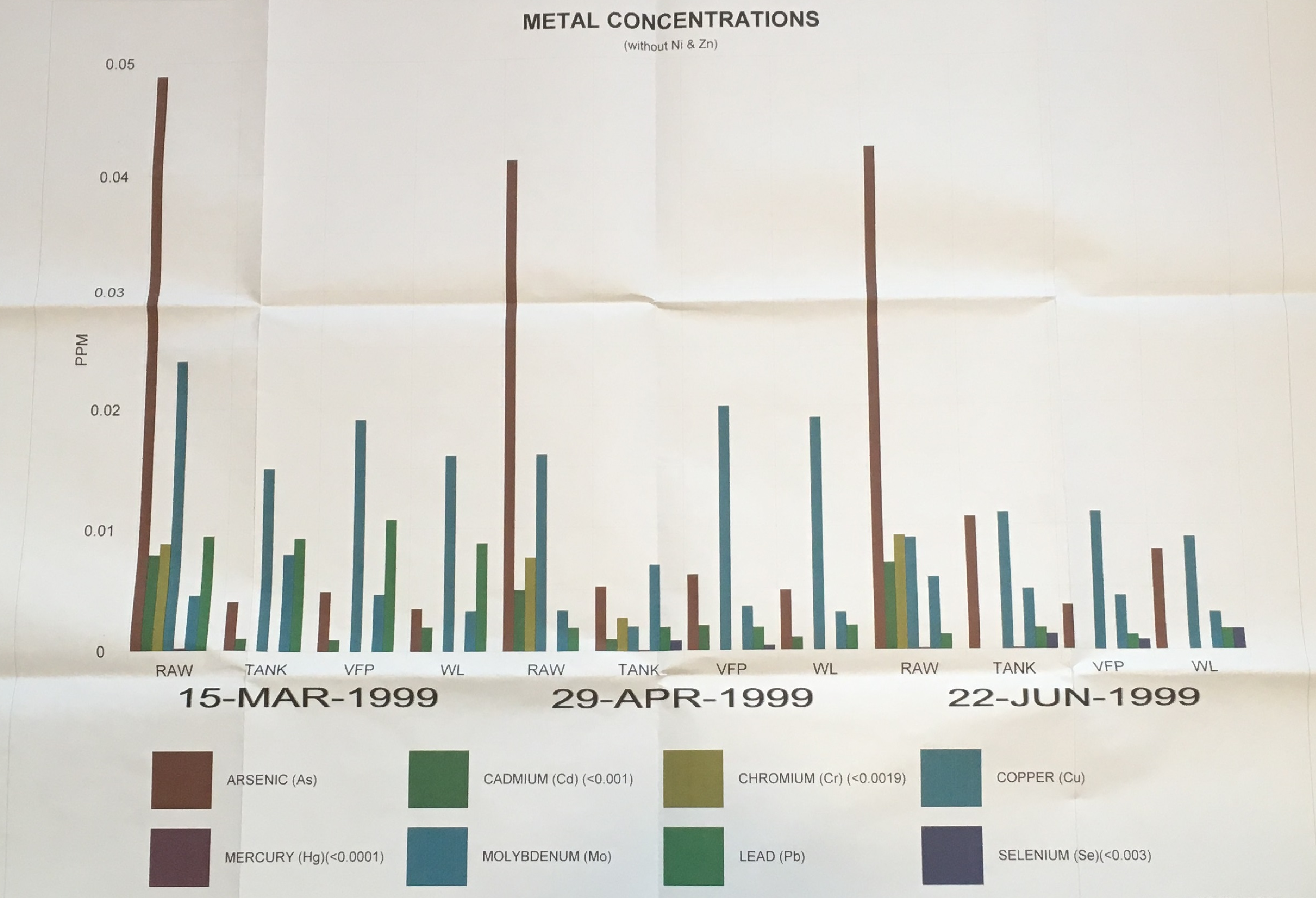

METAL CONCENTRATIONS
(without Ni & Zn)
PPM
0.05
0.04
0.03
0.02
0.01
0
RAW
TANK
VFP
WL
RAW
TANK
VFP
WL
RAW
TANK
VFP
WL
15-MAR-1999
29-APR-1999
22-JUN-1999
ARSENIC (As)
CADMIUM (Cd) (<0.001)
CHROMIUM (Cr) (<0.0019)
COPPER (Cu)
MERCURY (Hg)(<0.0001)
MOLYBDENUM (Mo)
LEAD (Pb)
SELENIUM (Se)(<0.003)

FIGURE 2