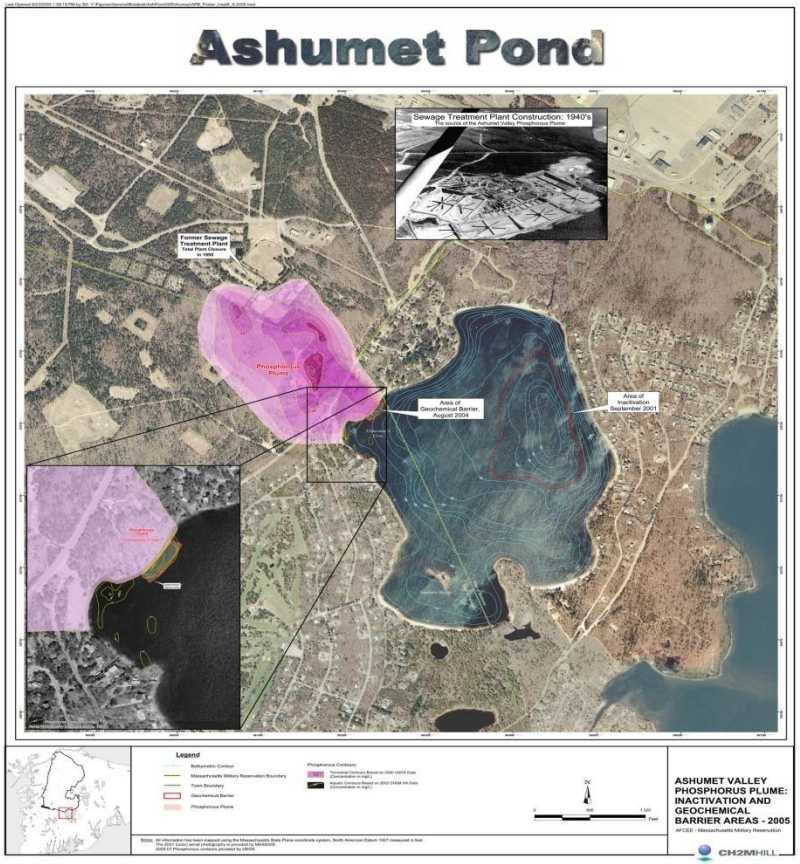
2009 Ashumet Pond Update

10 February 2010 MMRCT Meeting



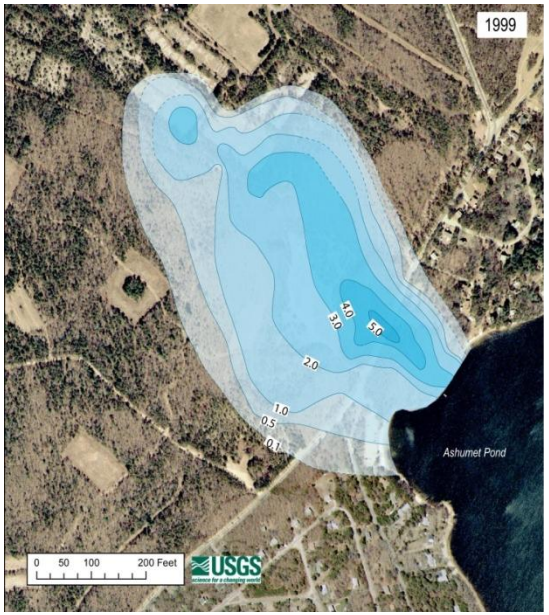
Problem

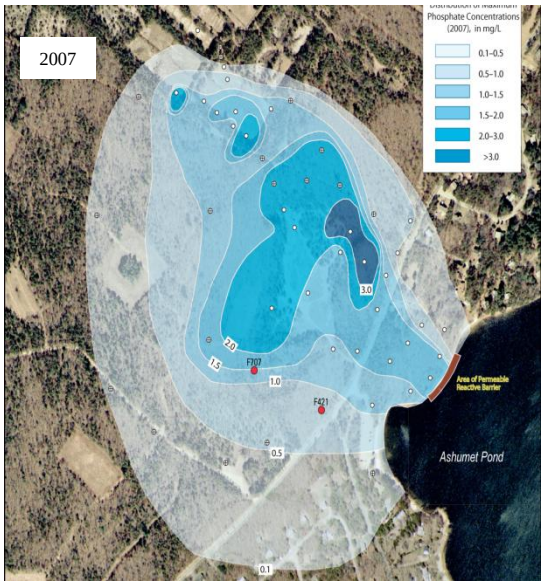
- Trophic health of Ashumet Pond declined from 1960's to 2000.
  - A general reduction in the water clarity of the pond.
  - Increased algae blooms.
  - Decreased oxygen levels in the deep parts (hypolimnion) of the pond during the summer.
- These changes were largely driven by an increase in the amount of phosphorus entering the pond.
  - Increased housing development has increased phosphorus loading to Ashumet Pond and to many other Cape Cod ponds.
  - However, a substantial amount of the increased phosphorus loading to Ashumet Pond was derived from the discharge of a wastewater-contaminated groundwater plume from the former MMR wastewater treatment plant.

Remedial Actions Implemented to Improve Pond Health

- The former MMR treatment plant was closed in 1995, substantially reducing the introduction of phosphorus to the groundwater.

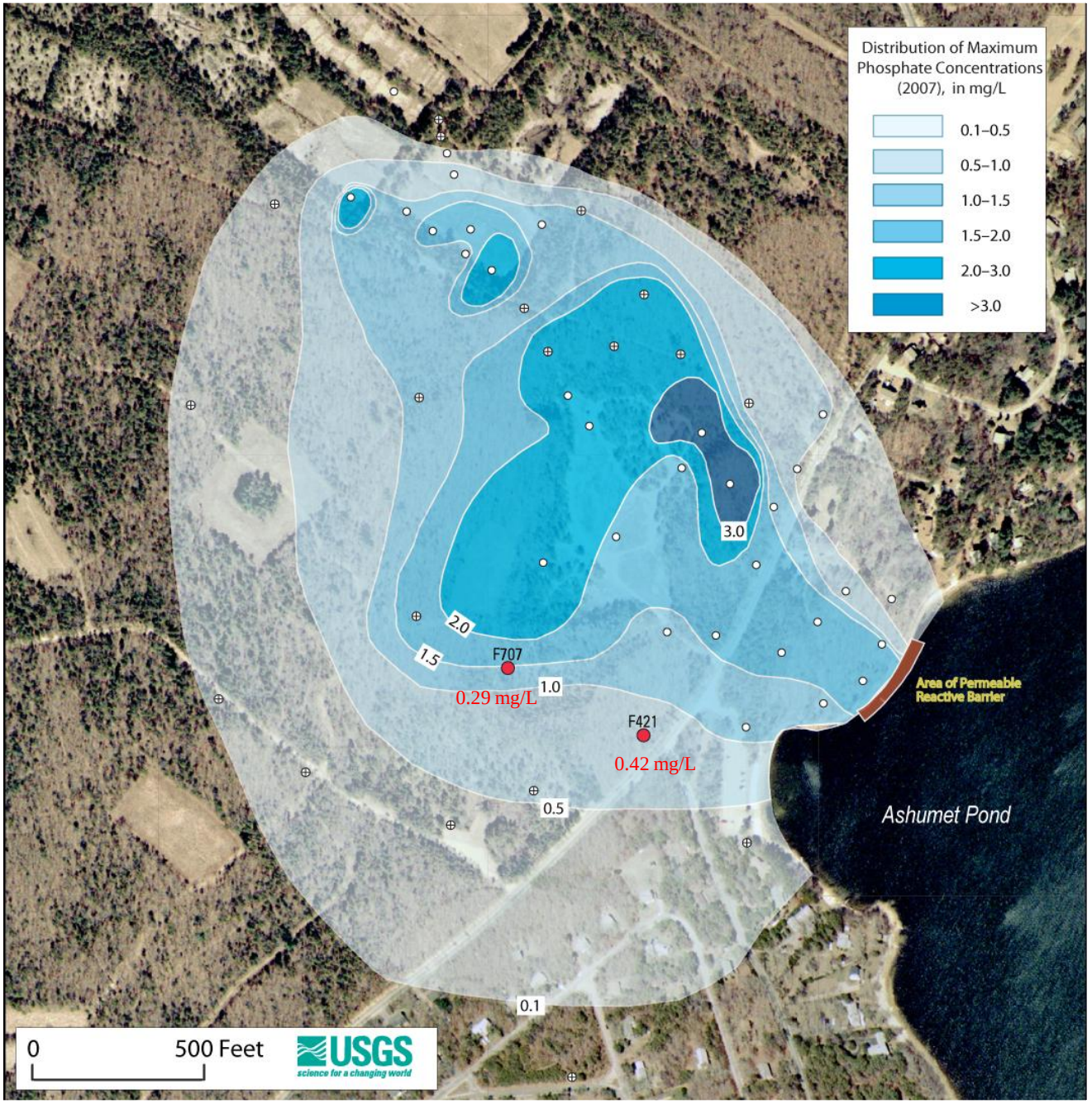
- Long-term monitoring of the pond and the plume began in 1999.





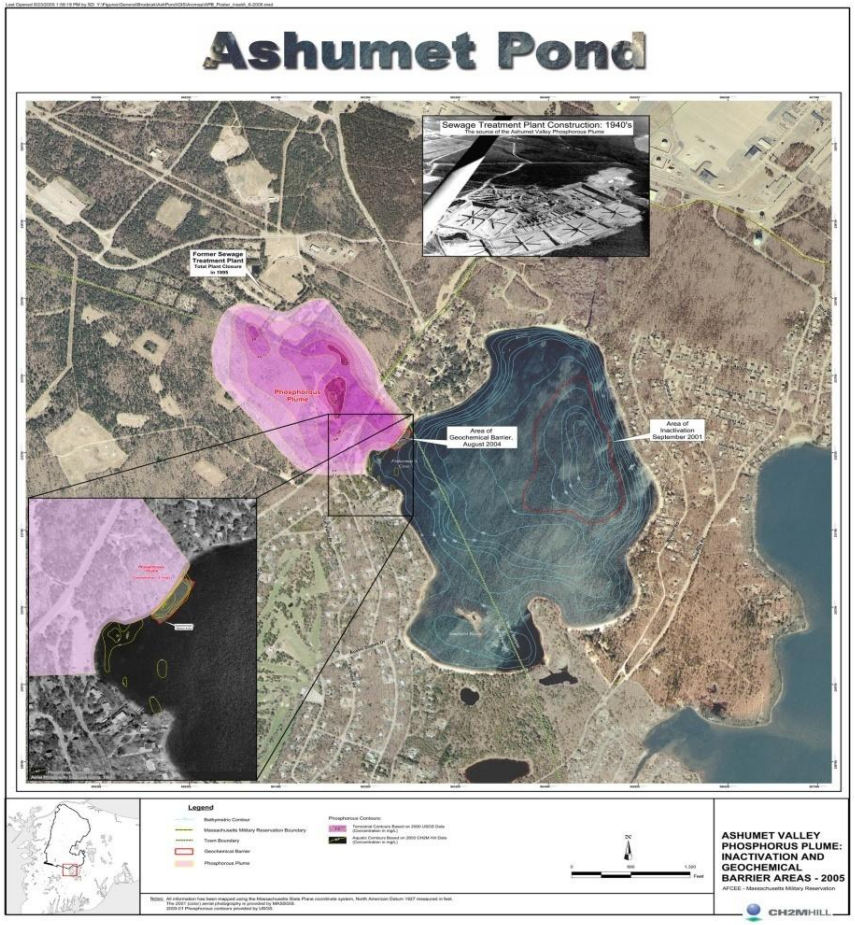
2007 Phosphate Plume

Two new wells (F707 and F421) installed in 2009.



Remedial Actions Implemented (cont'd).

- An alum treatment of the pond was conducted in September 2001.
- A geochemical barrier was installed in August 2004 to reduce phosphorus loading to the pond.



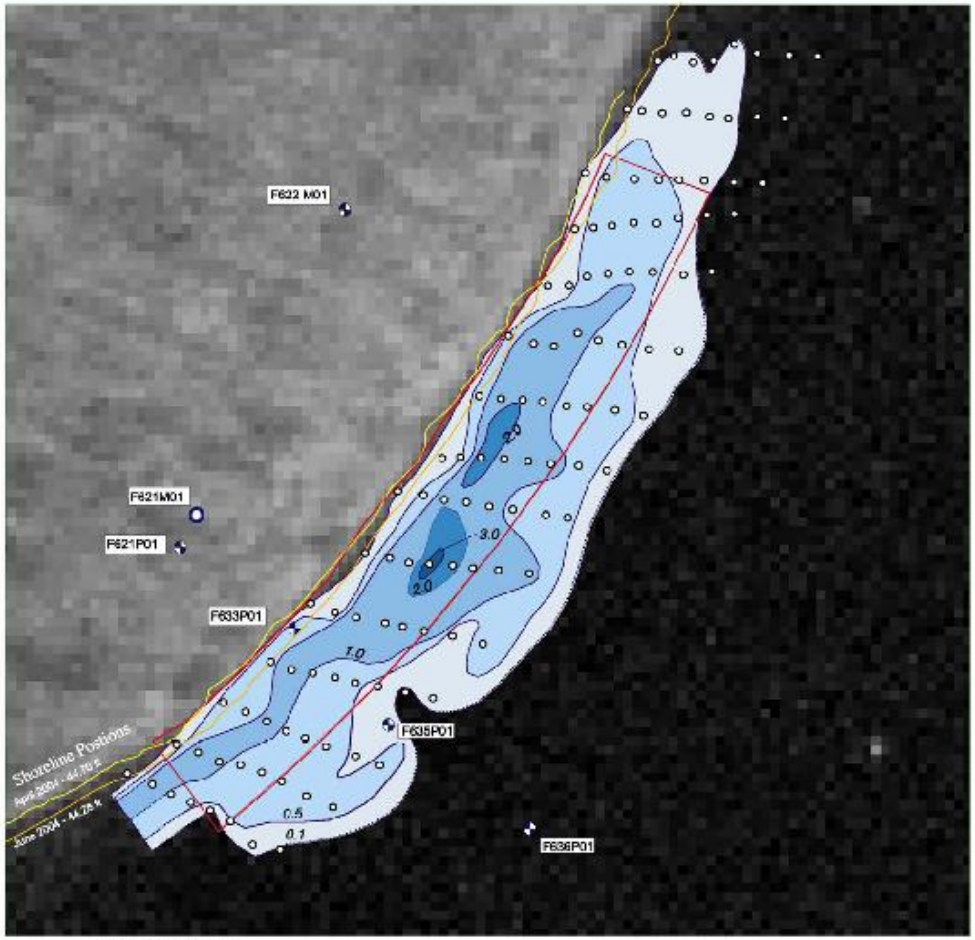
Geochemical Barrier

- The Zero Valent Iron (ZVI) barrier is 300 ft long, 40 ft wide, and 3 ft thick.

- Native sandy sediments mixed with 3% ZVI (by weight) to create permeable barrier along the pond bottom where highest phosphorus levels are discharging.

- The ZVI barrier removes phosphorus from the plume, thereby reducing the levels entering the pond and helping to keep the levels from returning to the higher levels observed prior to the alum treatment.

- The lifespan of ZVI barrier was estimated to be 20-25 years.



EXPLANATION

AREAL EXTENT OF DISSOLVED PHOSPHORUS IN POND-BOTTOM GROUND WATER (2004)- Concentration intervals in milligrams per liter as phosphorus are varied. Contour is dashed where inferred.

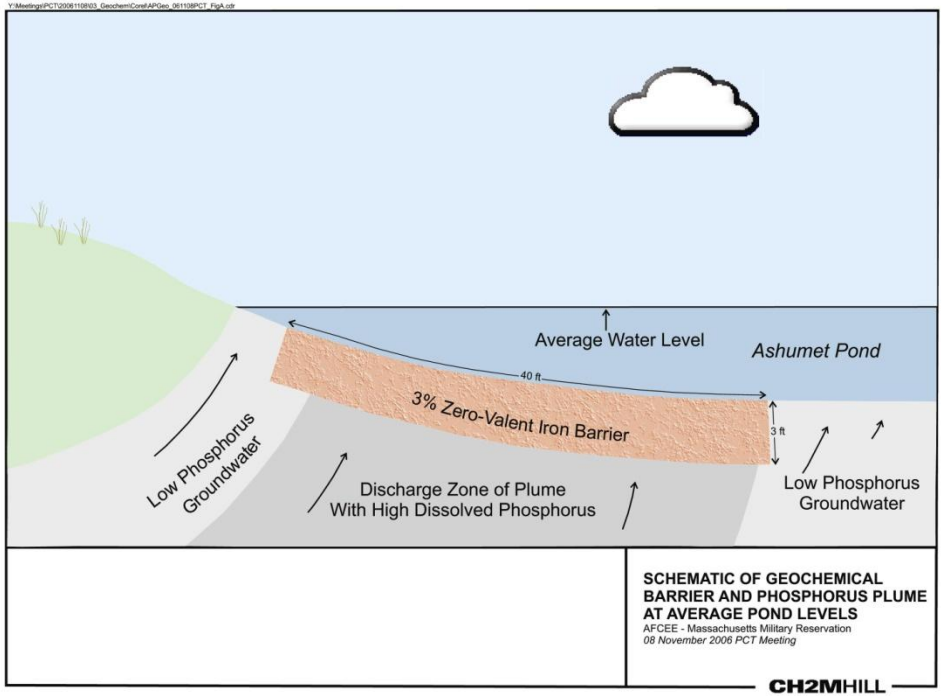
- > 3.0
- 2.0 - 3.0
- 1.0 - 2.0
- 0.5 - 1.0
- 0.1 - 0.5

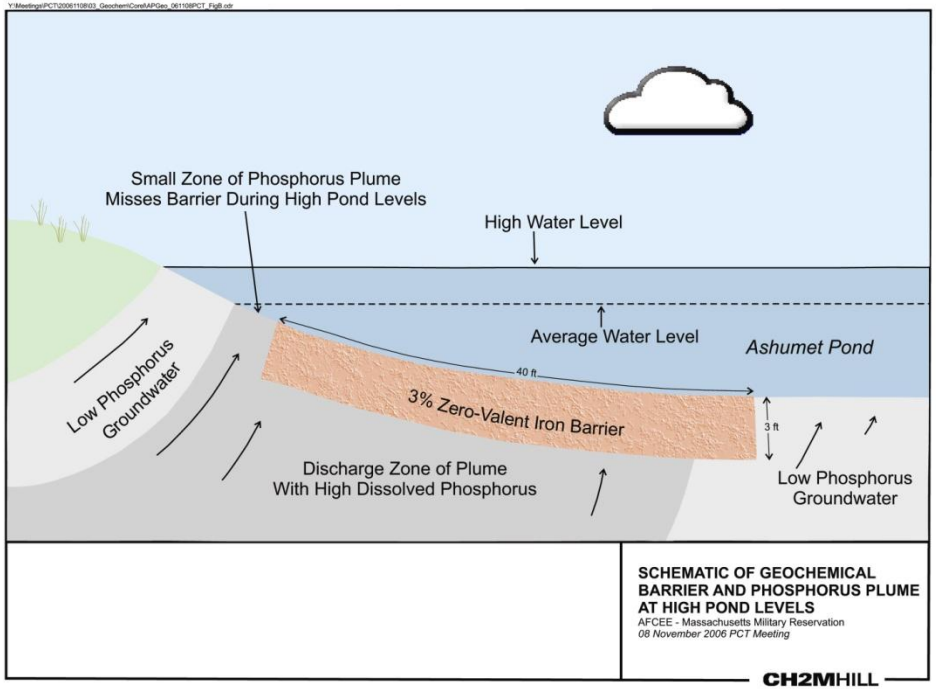
- MULTILEVEL SAMPLER
- PIEZONETER CLUSTER
- TEMPORARY POND-BOTTOM DRIVE POINT SAMPLER

Figure Areal distribution of dissolved phosphorus in pond-bottom ground water in the proposed geochemical barrier area, Ashumet Pond, Massachusetts, June 29 - July 2, 2004.

CH2MHILL

FIGURE 6
Preinstallation Baseline Monitoring – Dissolved Phosphorus in Pond-Bottom Groundwater


Average Water Level
Ashumet Pond
40 ft
3% Zero-Valent Iron Barrier
3 ft
Low Phosphorus Groundwater
Discharge Zone of Plume With High Dissolved Phosphorus
Low Phosphorus Groundwater
SCHEMATIC OF GEOCHEMICAL BARRIER AND PHOSPHORUS PLUME AT AVERAGE POND LEVELS
AFCEE - Massachusetts Military Reservation
08 November 2006 PCT Meeting
CH2MHILL


Small Zone of Phosphorus Plume Misses Barrier During High Pond Levels
High Water Level
Average Water Level
Ashumet Pond
40 ft
3% Zero-Valent Iron Barrier
3 ft
Low Phosphorus Groundwater
Discharge Zone of Plume With High Dissolved Phosphorus
Low Phosphorus Groundwater
SCHEMATIC OF GEOCHEMICAL BARRIER AND PHOSPHORUS PLUME AT HIGH POND LEVELS
AFCEE - Massachusetts Military Reservation
08 November 2006 PCT Meeting
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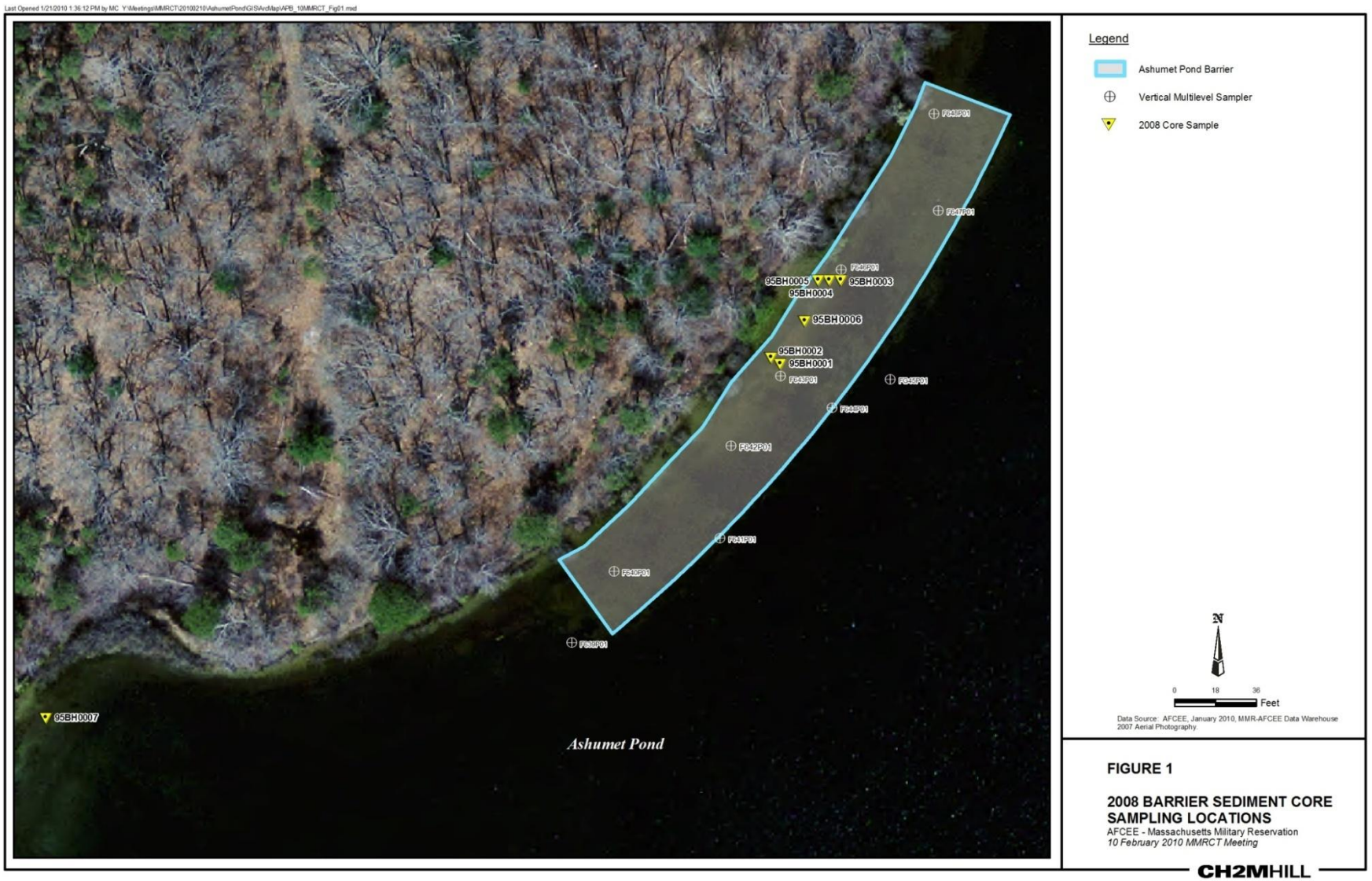
Prior to Installation

Approx. 1 Year After

2008 Barrier Core Sampling

- Objectives:
  - Collect cores from representative areas of the barrier.
  - Visually observe the changes in the barrier samples with depth and location.
  - Examine the core materials using a scanning electron microscope and identify how the barrier is removing phosphorus.

2008 Barrier Core Sampling Locations

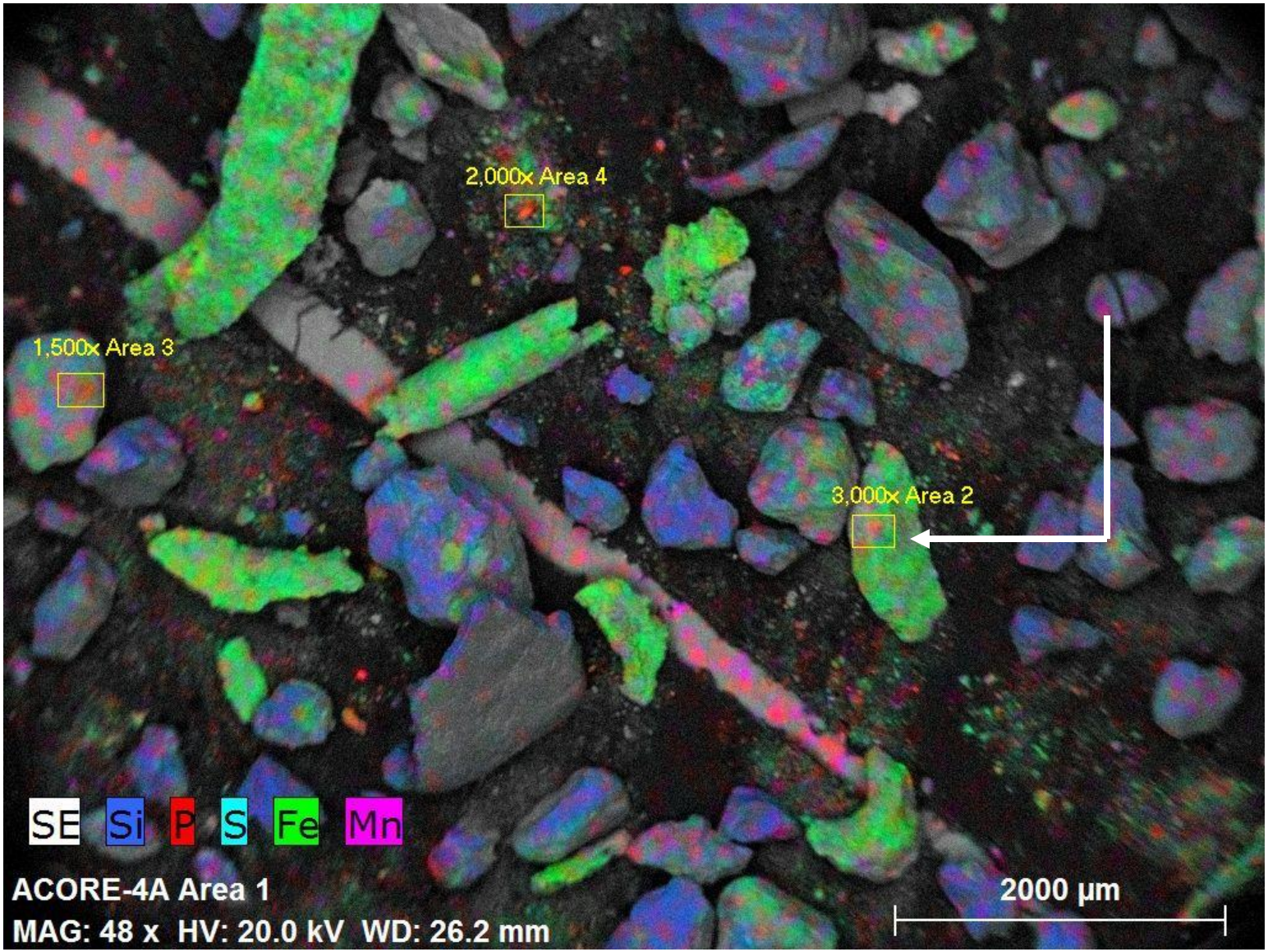


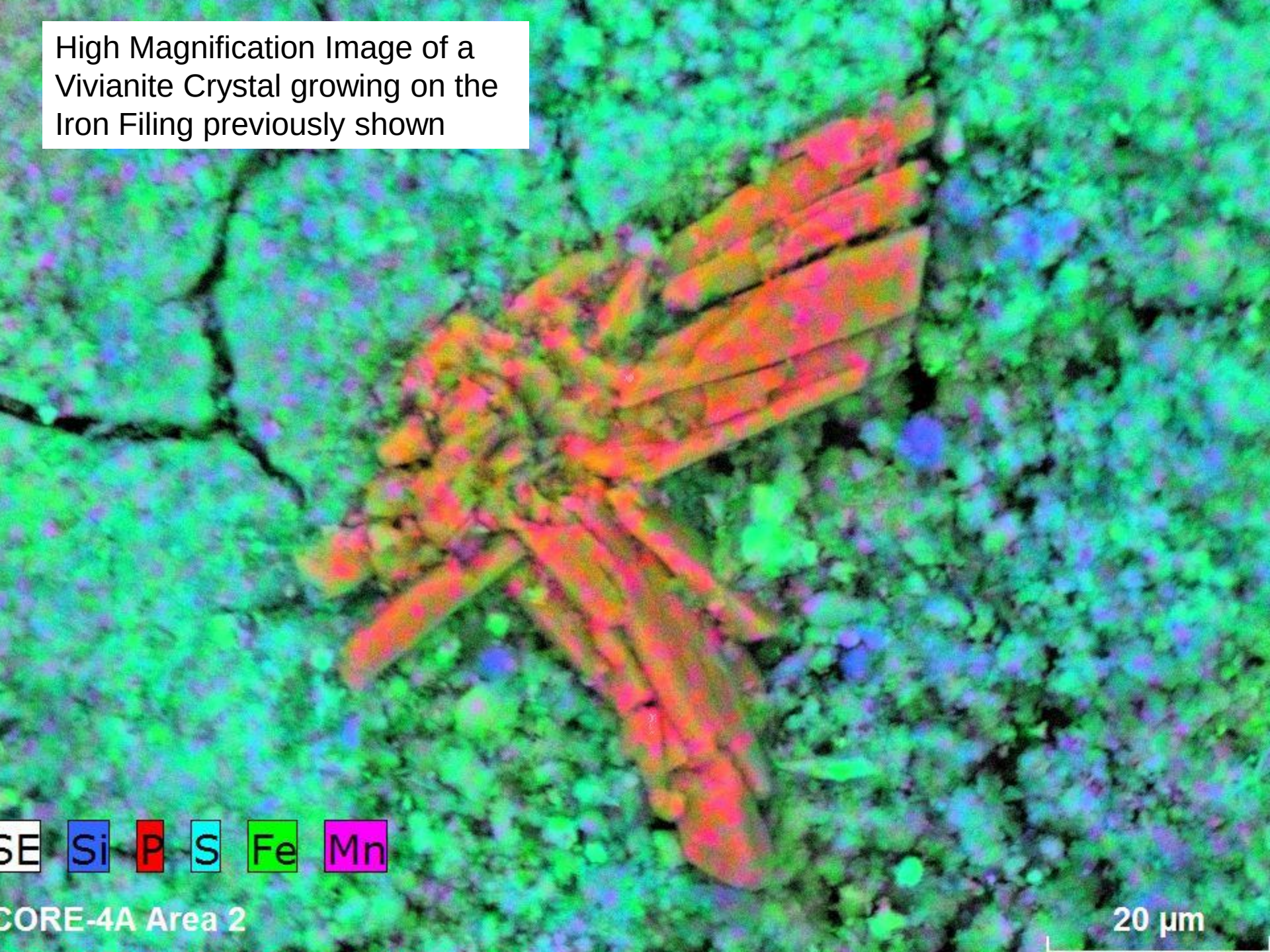

2B

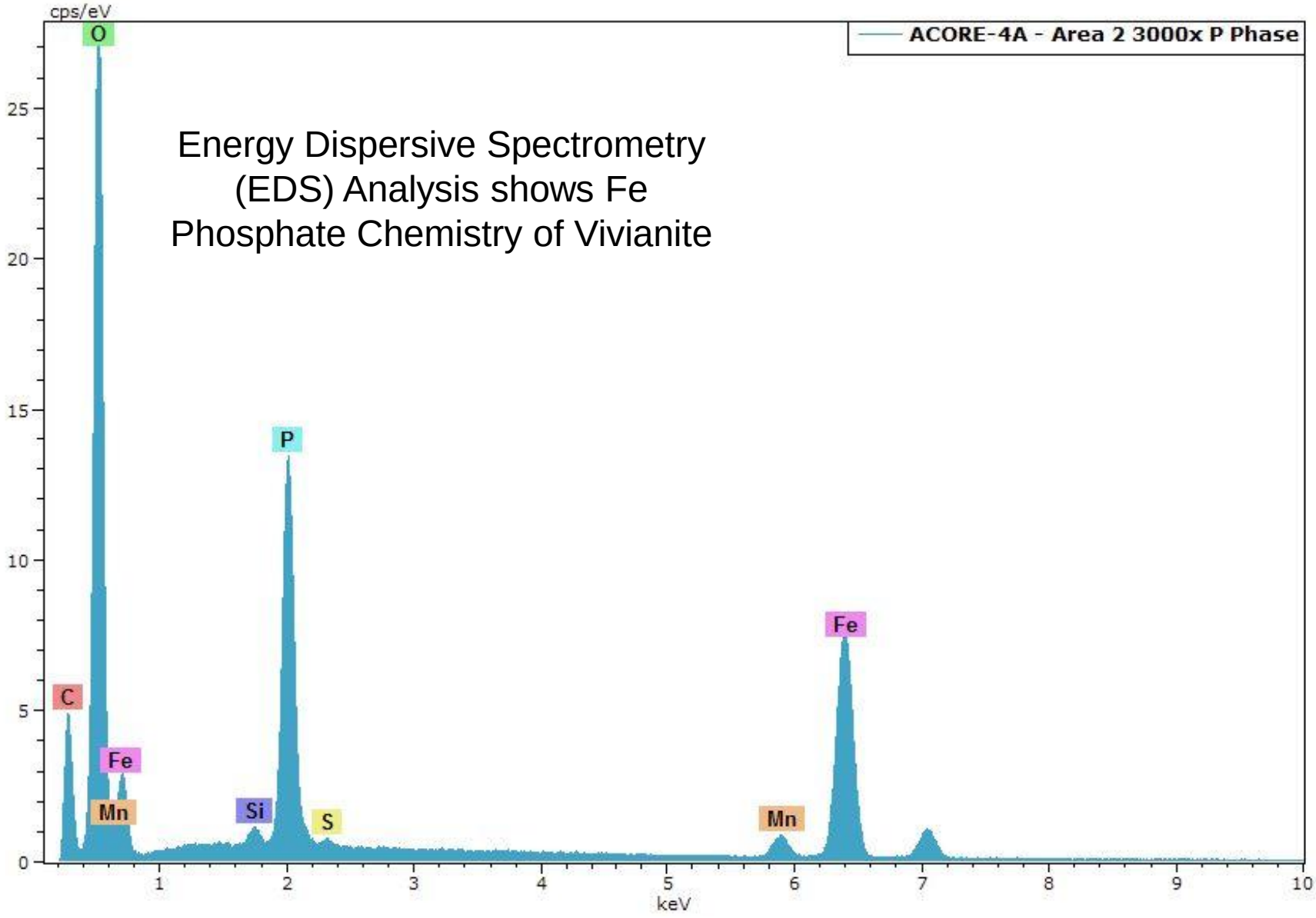
Mineral Identification of Barrier Samples

- Magnetic fractions of core samples were examined, chemically analyzed, and photographed using a scanning electron microscope.

Green Phases are Iron Filings. Most Red Spots are Phosphorus-rich areas.
Next slide shows close-up of Area 2 and a chemical Analysis

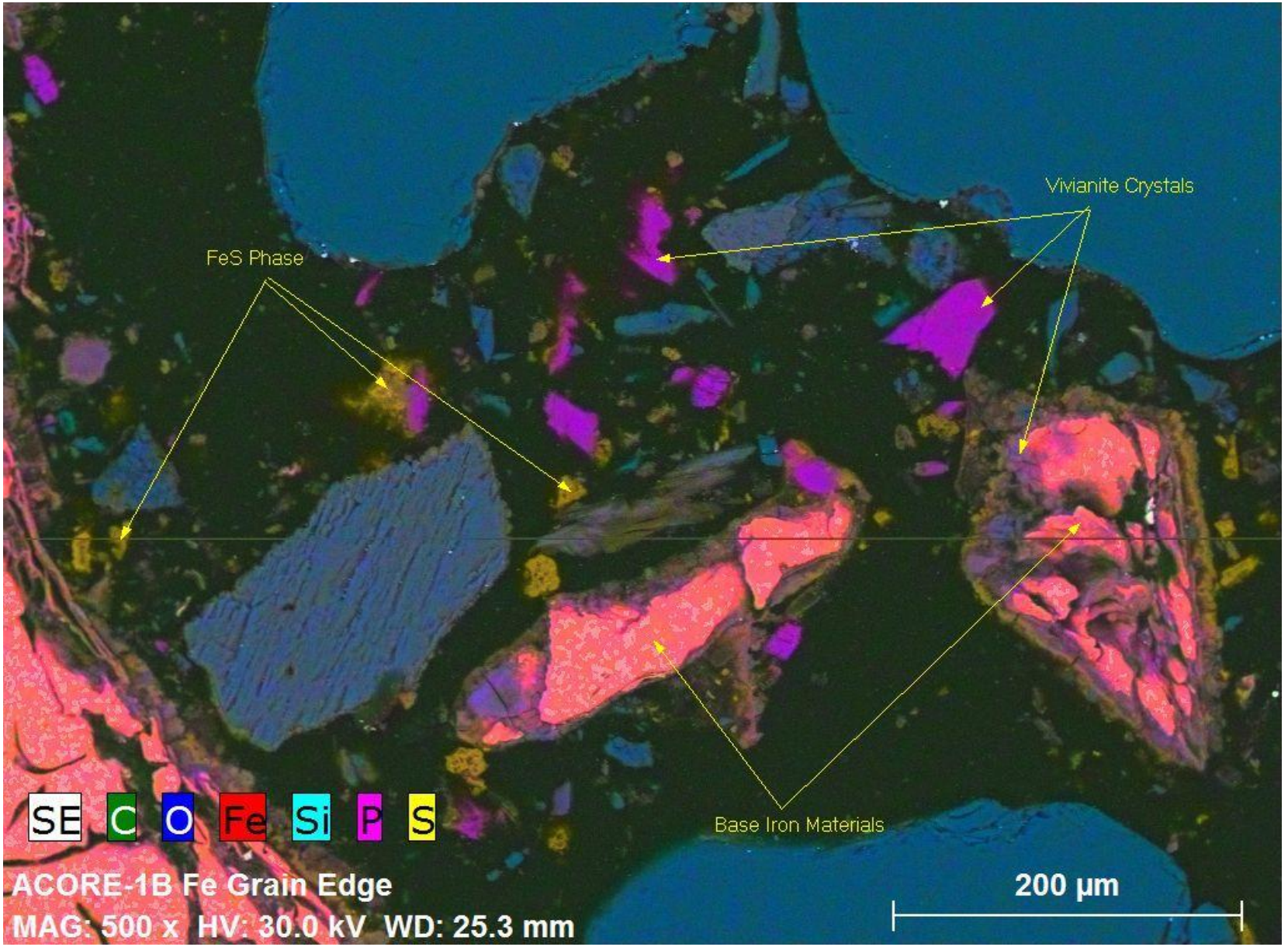


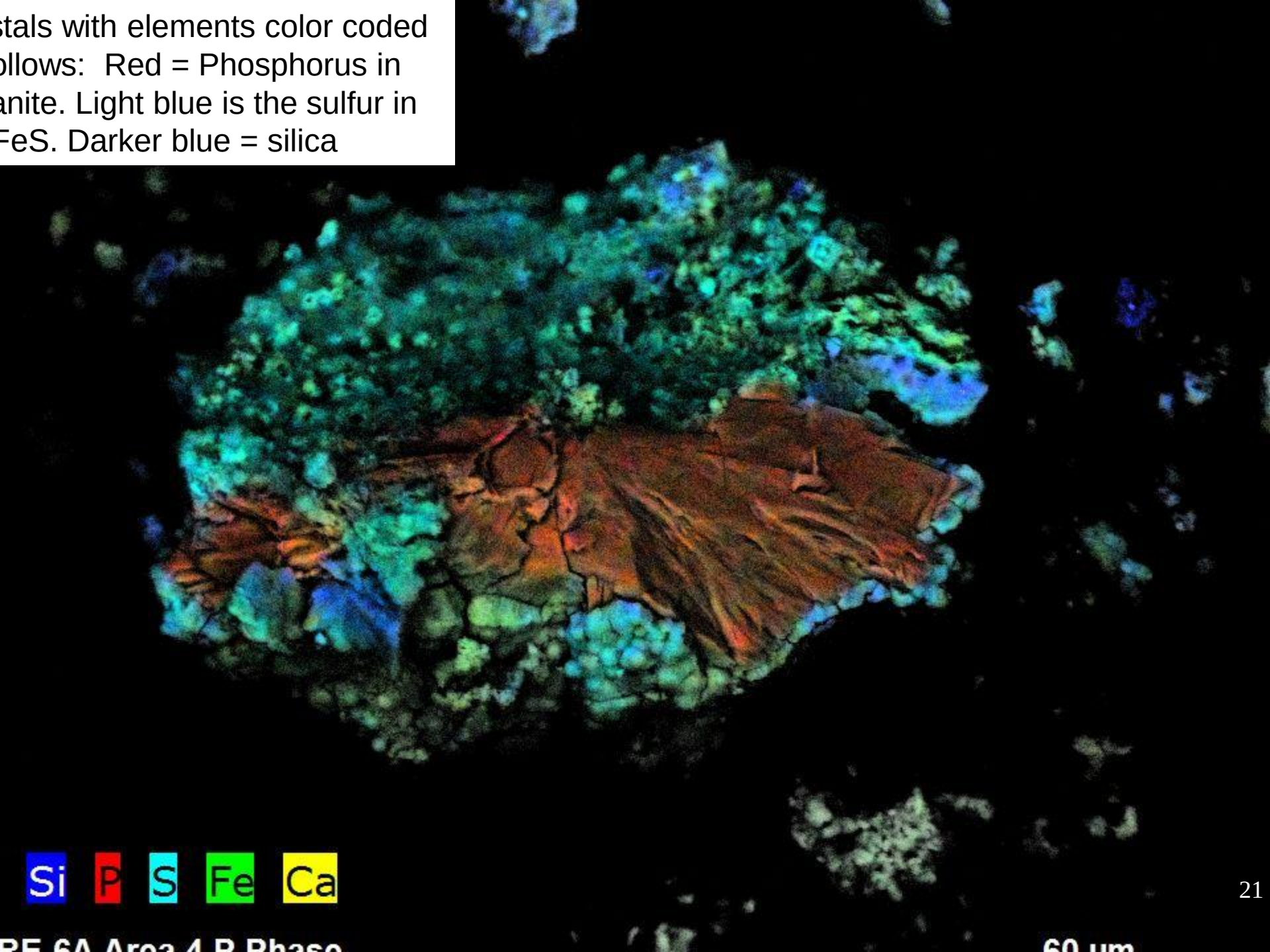

High Magnification Image of a Vivianite Crystal growing on the Iron Filing previously shown
SE
Si
P
S
Fe
Mn
CORE-4A Area 2
20 µm

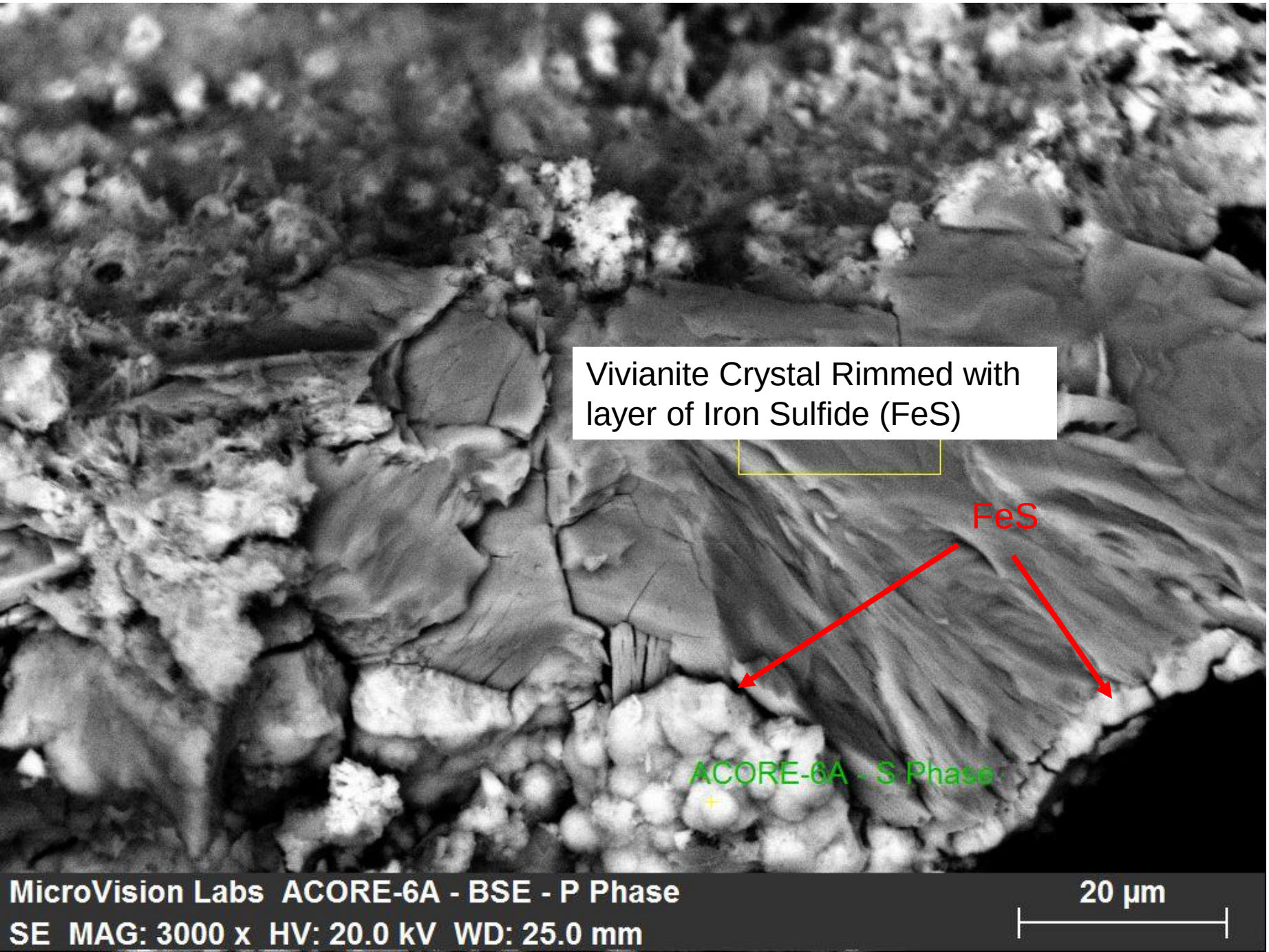


Energy Dispersive Spectrometry (EDS) Analysis shows Fe Phosphate Chemistry of Vivianite

A Core 1B Section 500X Phases



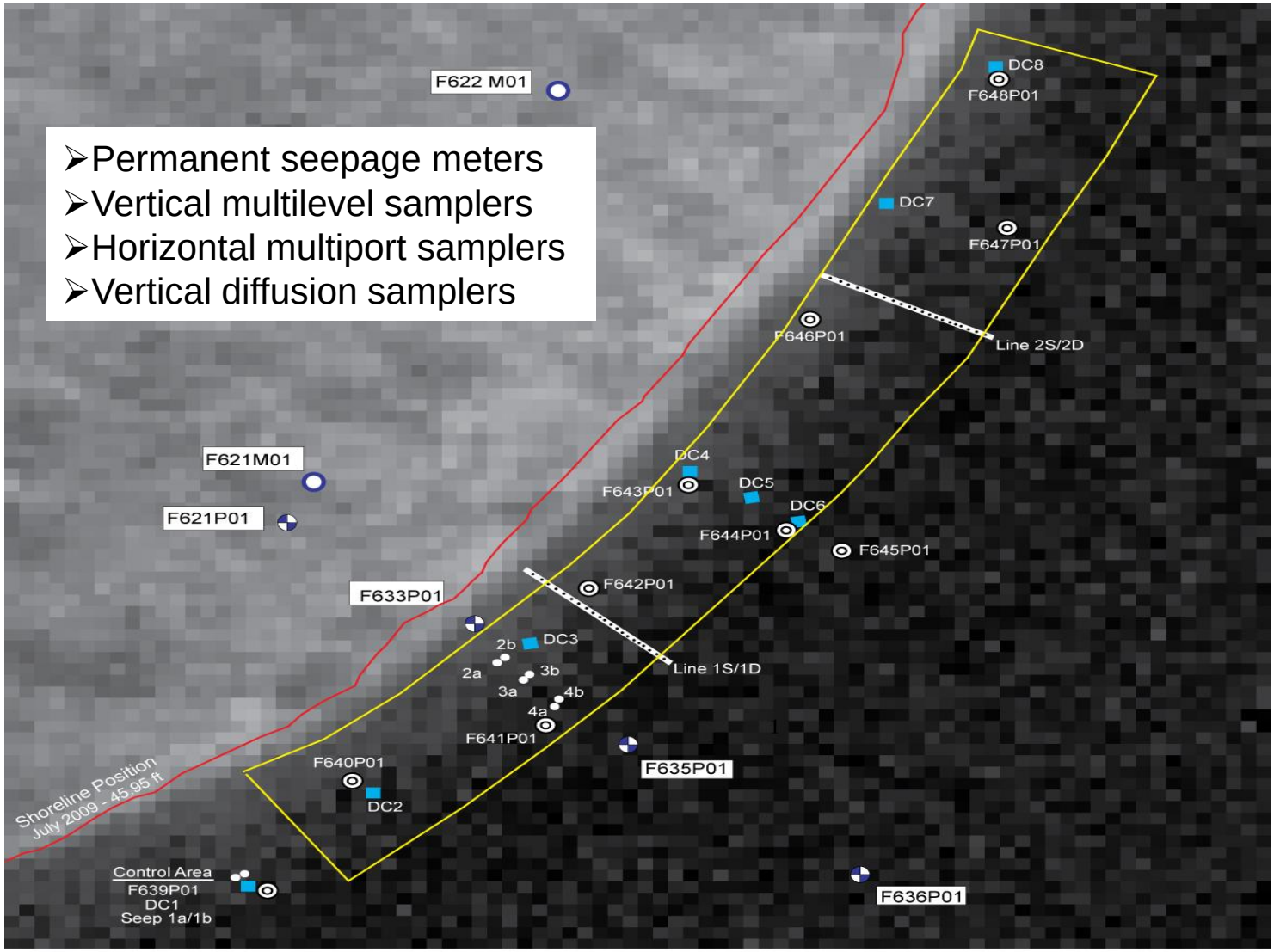

stals with elements color coded
ollows: Red = Phosphorus in
anite. Light blue is the sulfur in
FeS. Darker blue = silica
Si
P
S
Fe
Ca
60 um


Vivianite Crystal Rimmed with layer of Iron Sulfide (FeS)
FeS
ACORE-6A - S Phase
MicroVision Labs ACORE-6A - BSE - P Phase
SE MAG: 3000 x HV: 20.0 kV WD: 25.0 mm
20 µm

2009 Barrier Performance Monitoring

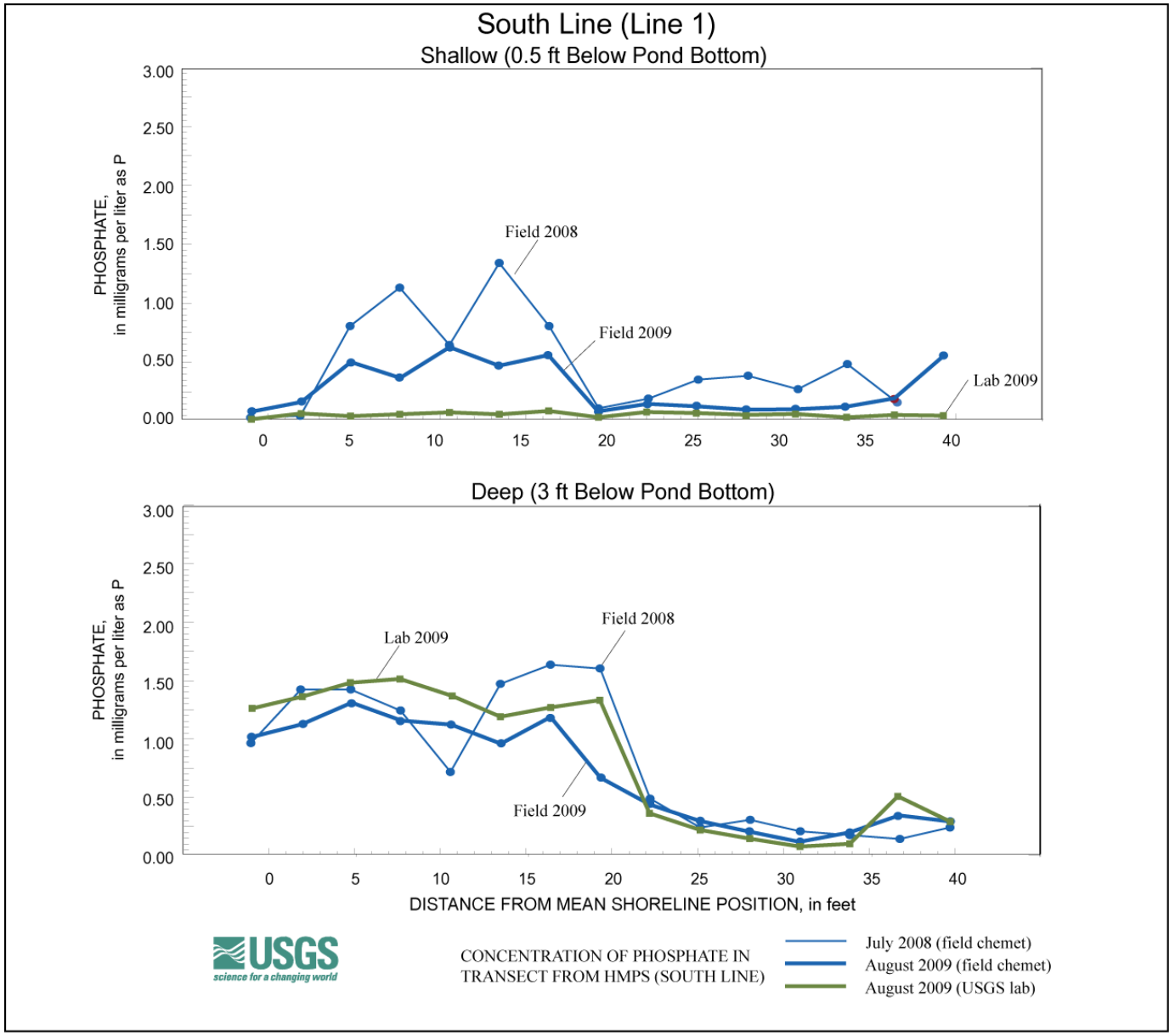
- USGS Permanent Monitoring Network and Drive Point Sampling
  - Objectives:
    - Evaluate barrier effectiveness
    - Identify changes in phosphorus levels entering the barrier over time

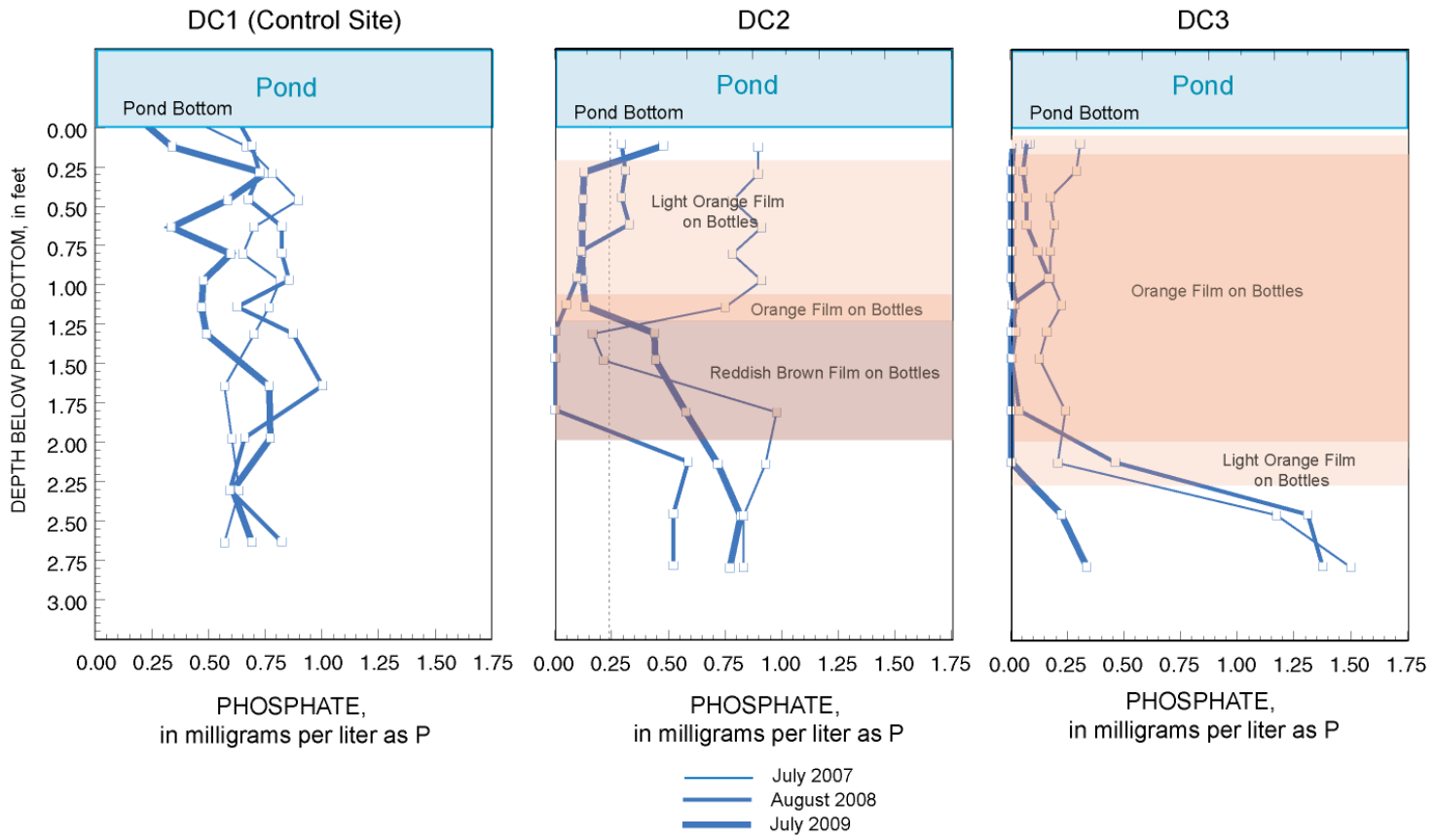
USGS Permanent Sampling Network



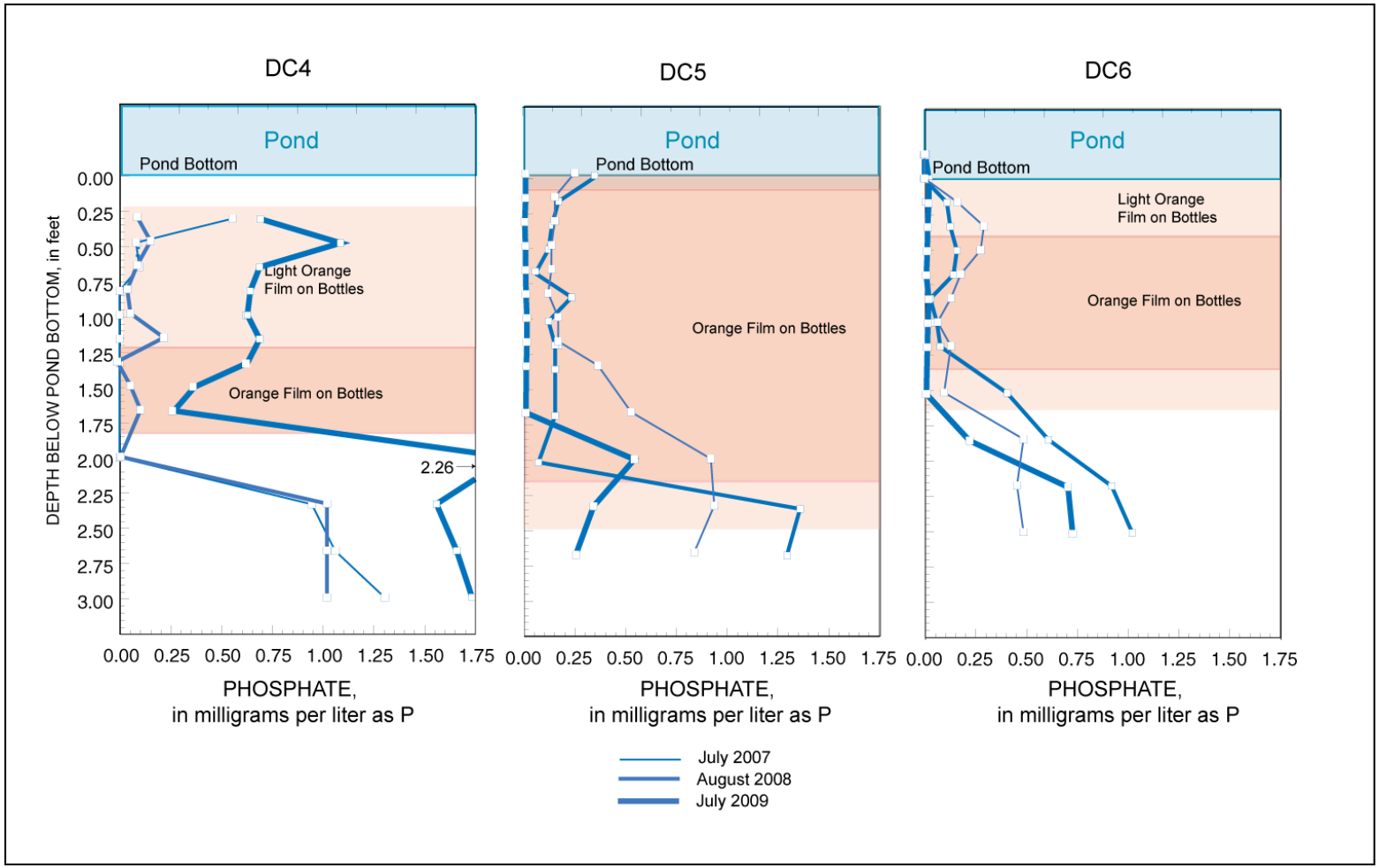
Comparison of 2009 Lab Phosphate Data with 2008 and 2009 Field Phosphate Data

(Southernmost Horizontal Multi-Port Sampler)

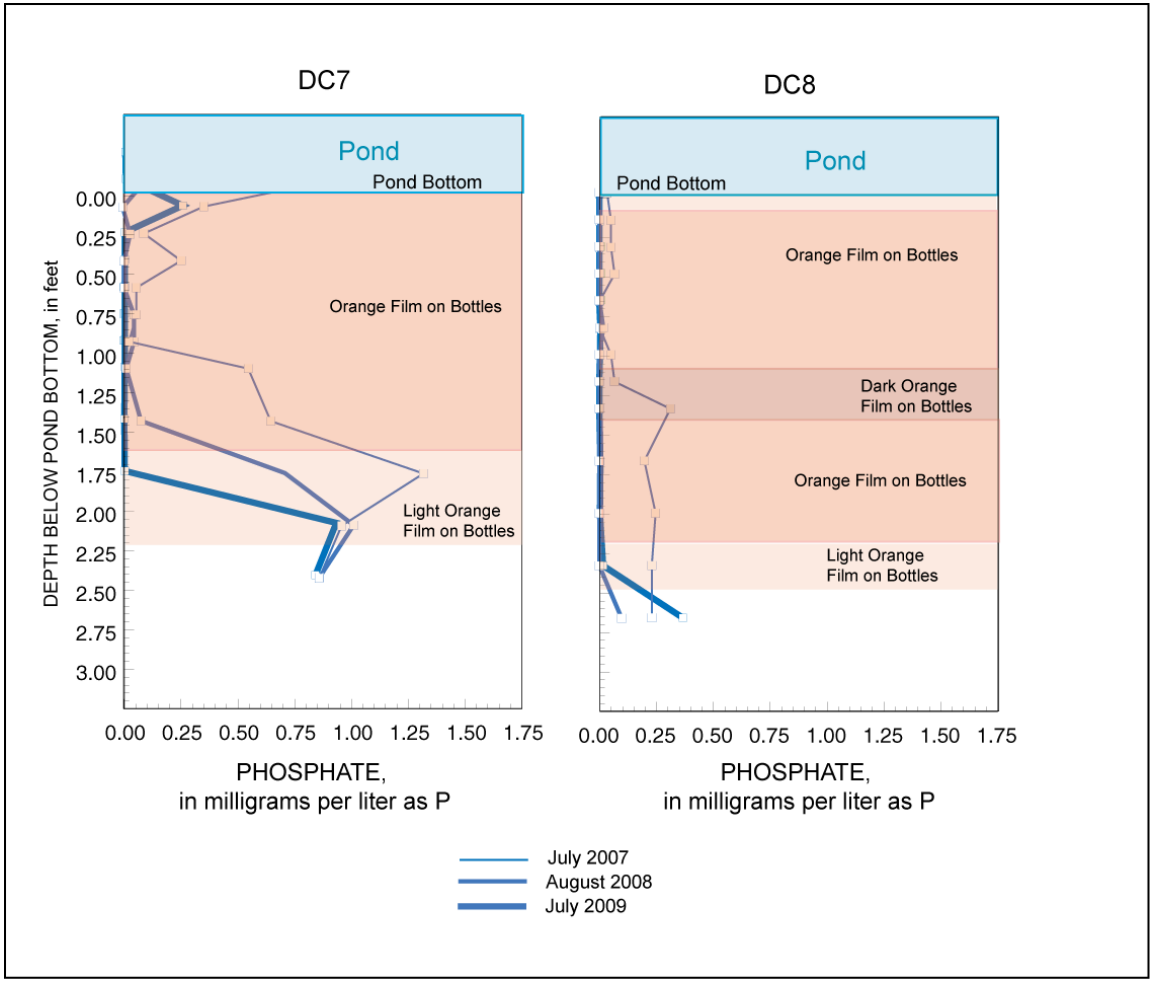




Phosphate Concentration Profiles from Pond-Bottom Vertical Diffusion Chambers (DCs) at 3, 4, and 5 years after PRB Installation

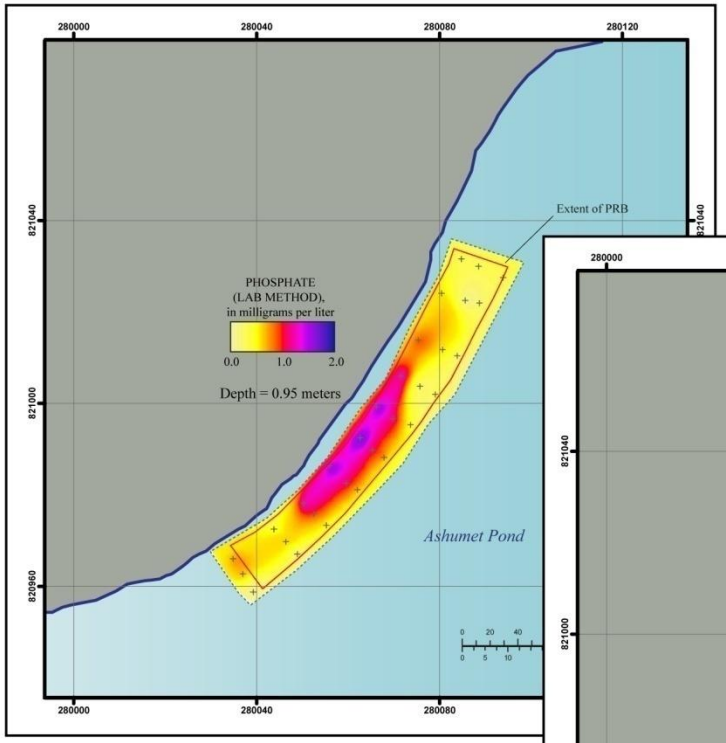


Phosphate Concentration Profiles from Pond-Bottom Vertical Diffusion Chambers (DCs) at 3, 4, and 5 years after PRB Installation

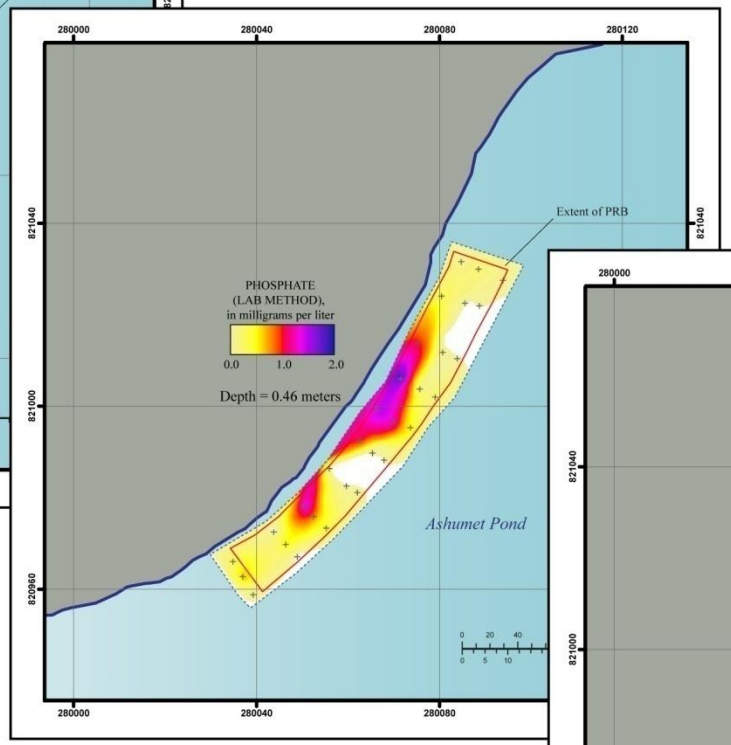


Phosphate Concentration Profiles from Pond-Bottom Vertical Diffusion Chambers (DCs) at 3, 4, and 5 years after PRB Installation

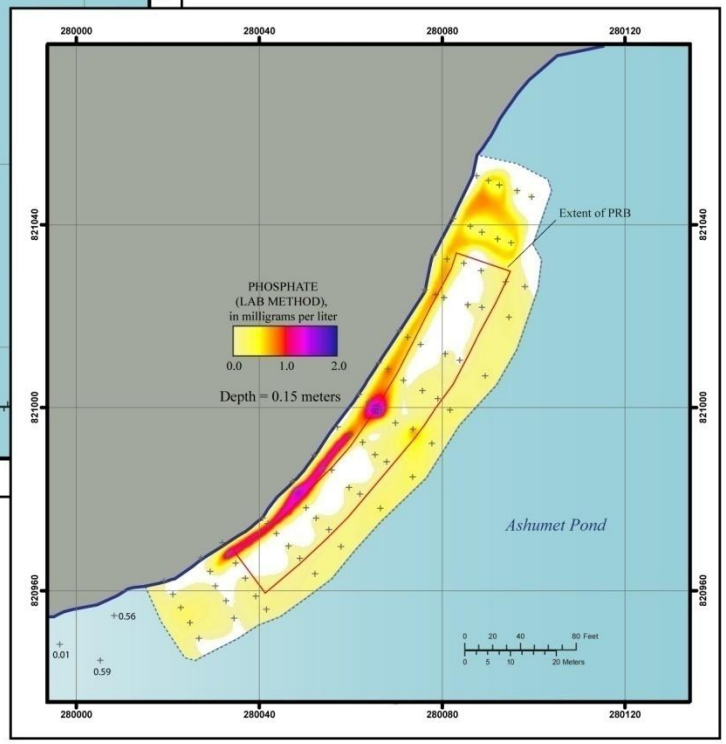
PHOSPHATE (LAB METHOD) - August 2009



0.95 meters

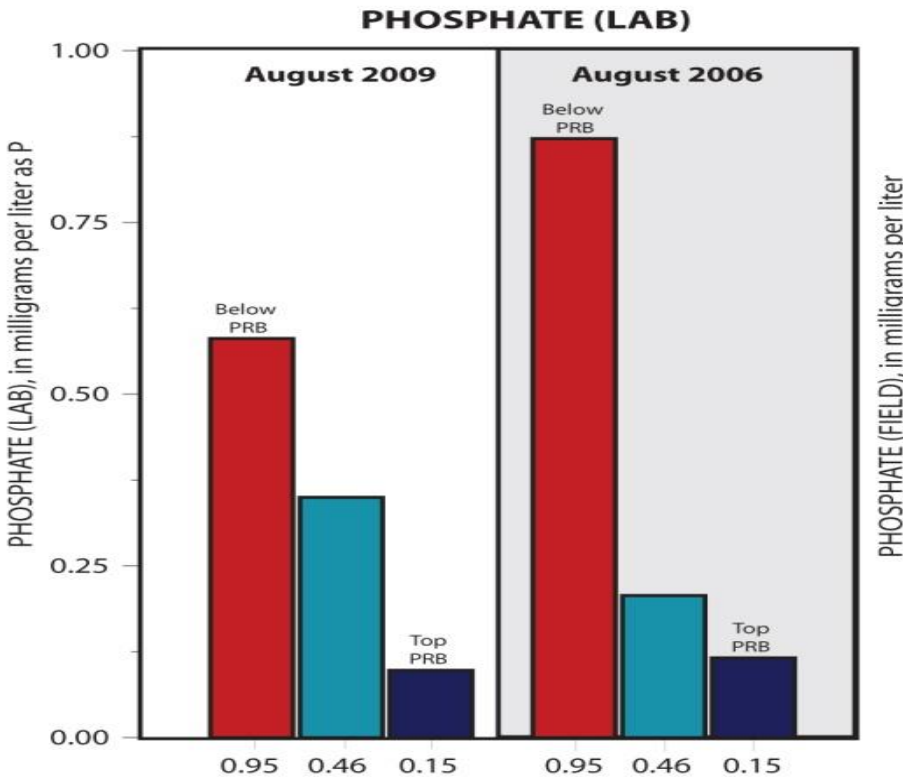


0.45 meters



0.15 meters

Comparison of Average Phosphorus Entering the Barrier in 2006 and 2009



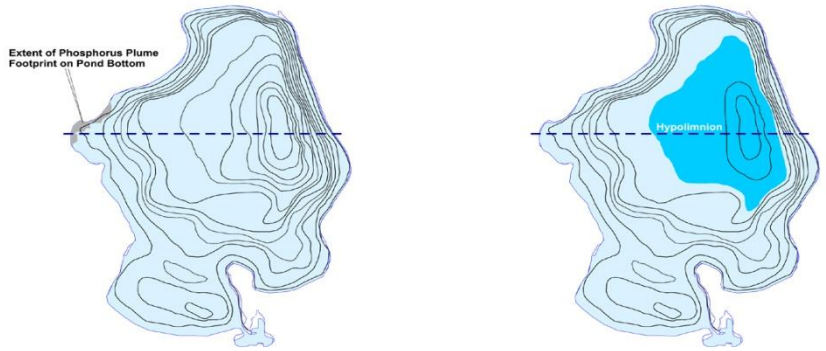
Evaluation of Pond Water Quality Trends

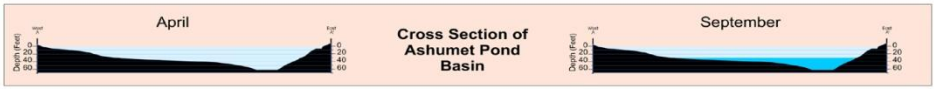
- Criteria for evaluation of trophic health of Ashumet Pond:
  - lower phosphorus levels in the epilimnion
  - lower phosphorus levels in the hypolimnion
  - reduced production of algae (Chlorophyll a)
  - increased water clarity
  - increased oxygen in the hypolimnion
  - lower ammonium in the hypolimnion
  - improvements in the Trophic State Index

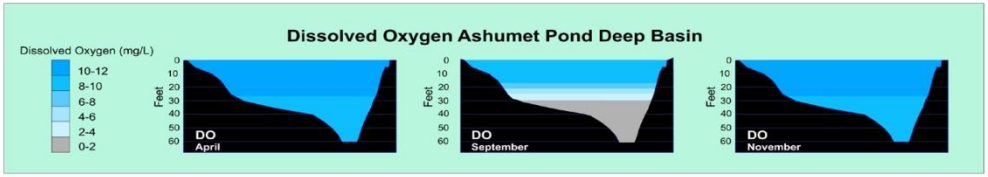
- Using these criteria, evaluate how the water quality of the pond has changed since the 2001 alum treatment and the 2004 barrier installation.

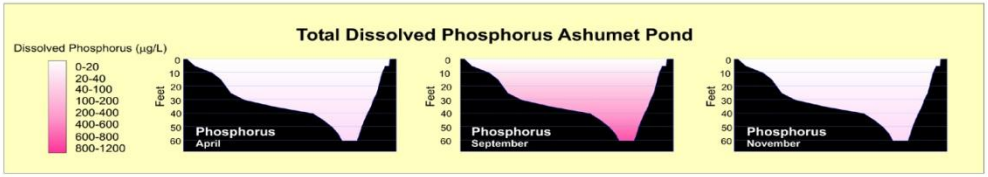
- Determine if any additional remedial actions (Alum Treatment) are needed.

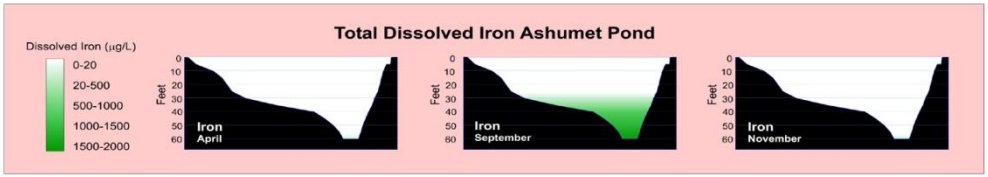
Typical Seasonal Changes in Ashumet Pond

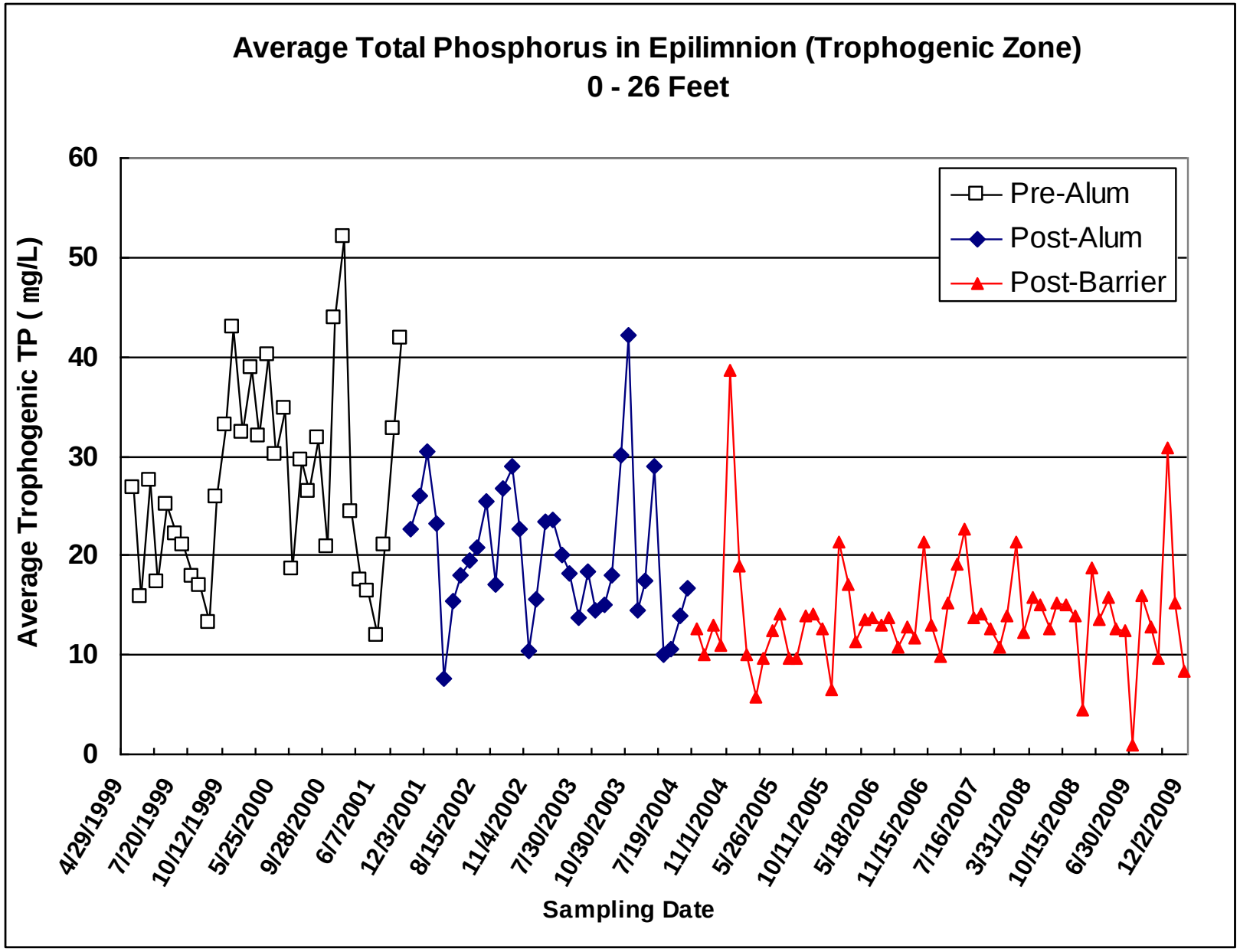


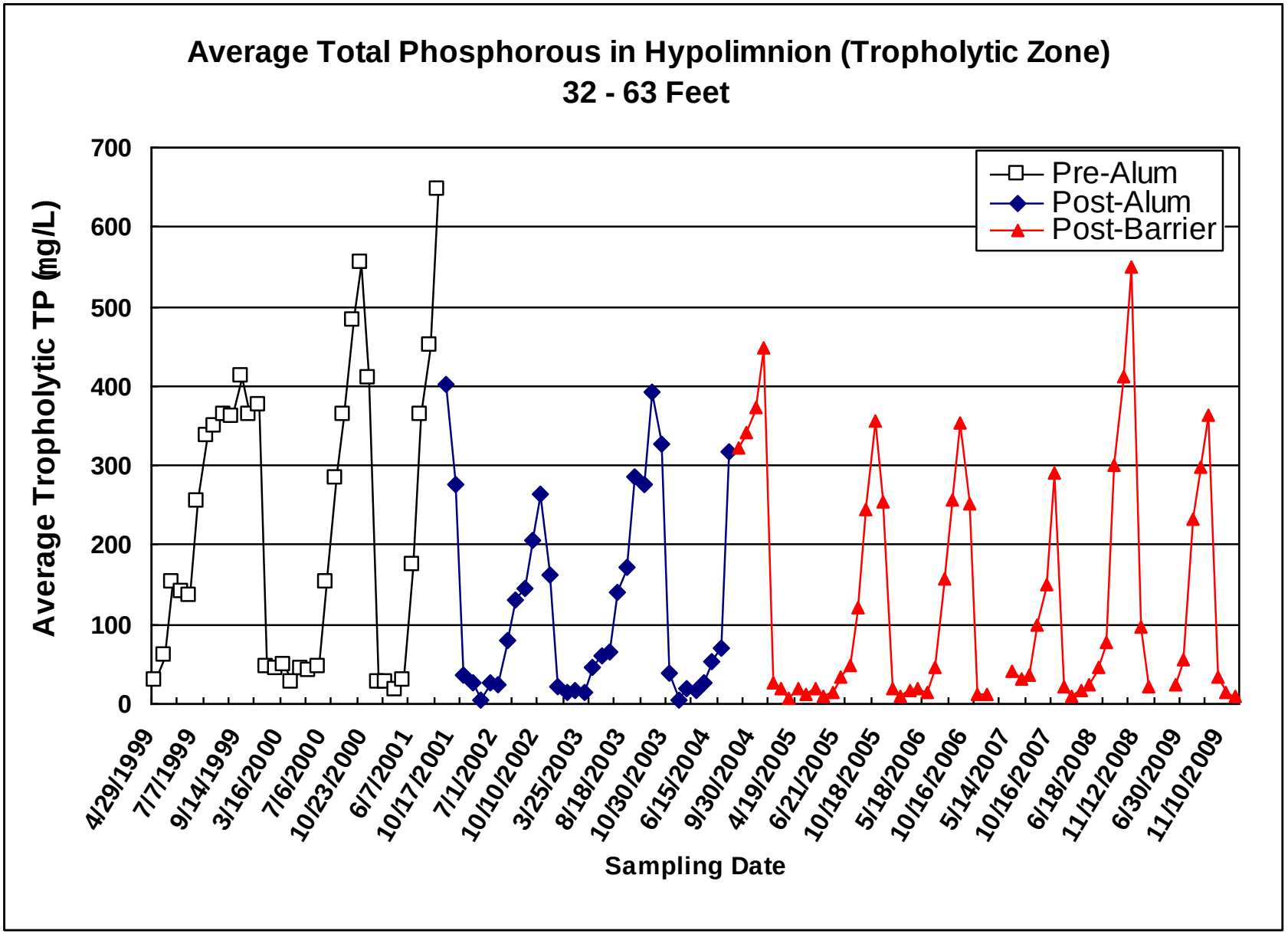






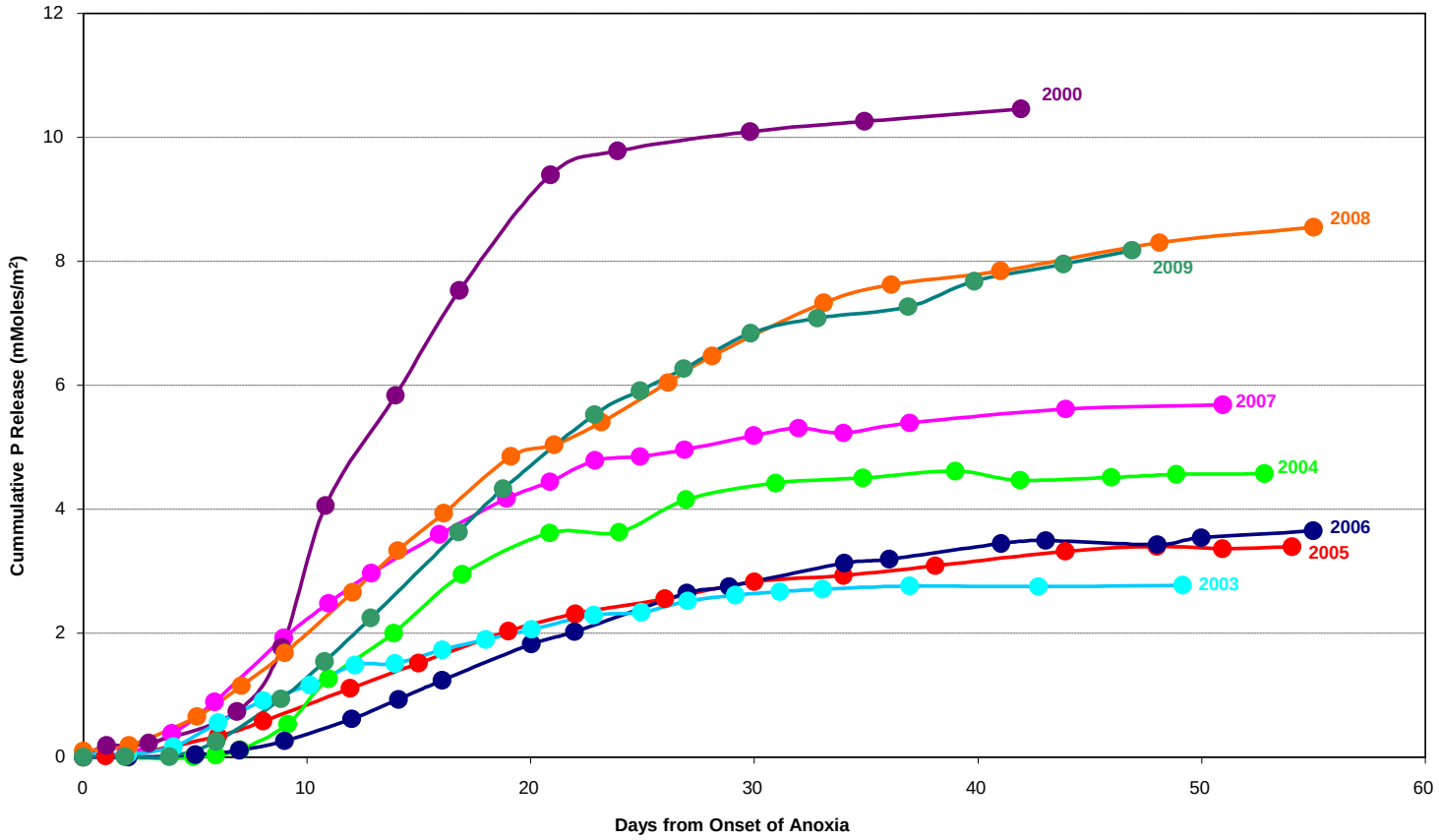



Average Total Phosphorus in Epilimnion (Trophogenic Zone)
0 - 26 Feet
Average Trophogenic TP (mg/L)
60
50
40
30
20
10
0
Pre-Alum
Post-Alum
Post-Barrier
4/29/1999
7/20/1999
10/12/1999
5/25/2000
9/28/2000
6/7/2001
12/3/2001
8/15/2002
11/4/2002
7/30/2003
10/30/2003
7/19/2004
11/1/2004
5/26/2005
10/11/2005
5/18/2006
11/15/2006
7/16/2007
3/31/2008
10/15/2008
6/30/2009
12/2/2009
Sampling Date

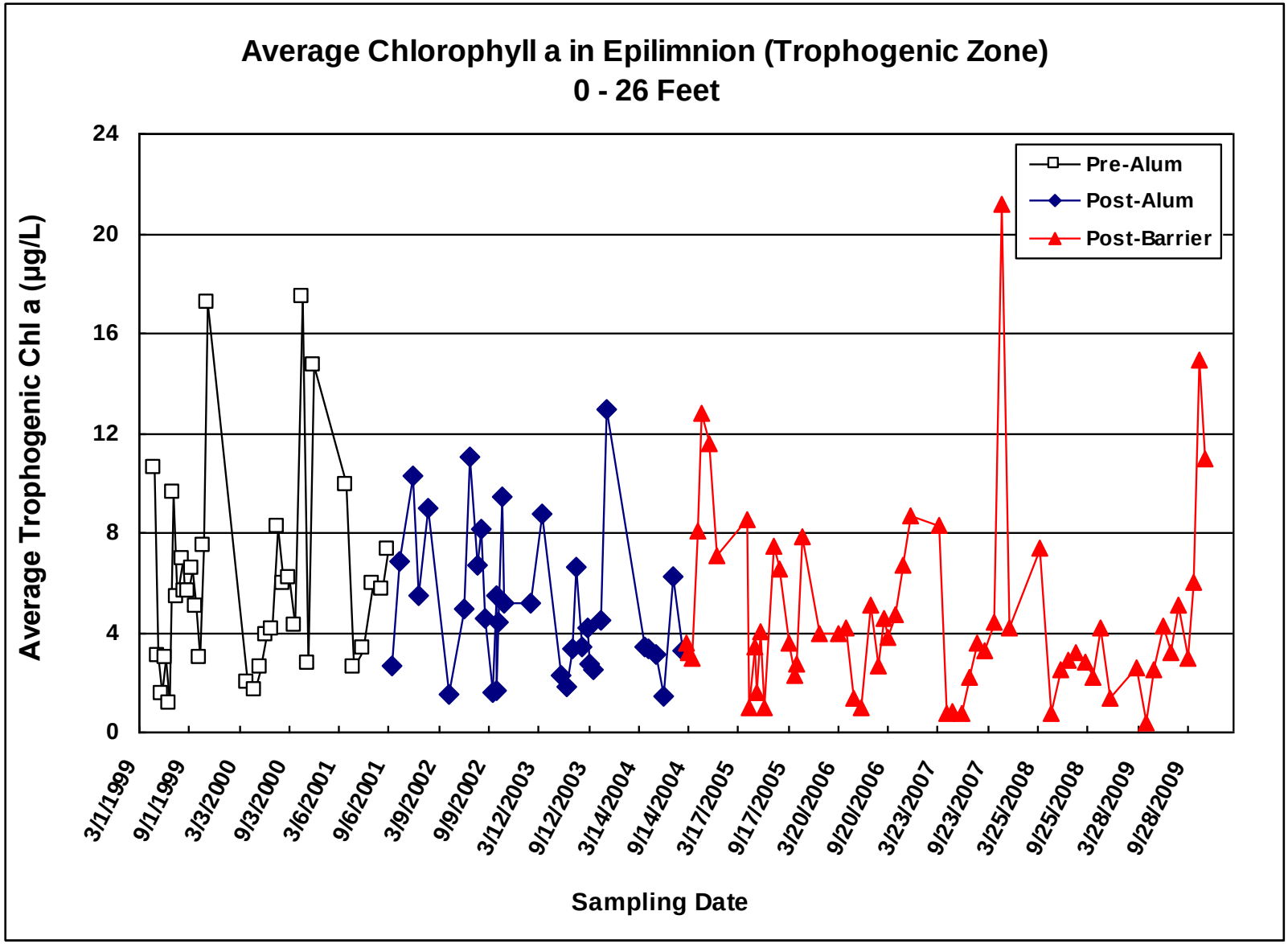

Average Total Phosphorous in Hypolimnion (Tropholytic Zone)
32 - 63 Feet
Average Tropholytic TP (mg/L)
700
600
500
400
300
200
100
0
Pre-Alum
Post-Alum
Post-Barrier
4/29/1999
7/7/1999
9/14/1999
3/16/2000
7/6/2000
10/23/2000
6/7/2001
10/17/2001
7/1/2002
10/10/2002
3/25/2003
8/18/2003
10/30/2003
6/15/2004
9/30/2004
4/19/2005
6/21/2005
10/18/2005
5/18/2006
10/16/2006
5/14/2007
10/16/2007
6/18/2008
11/12/2008
6/30/2009
11/10/2009
Sampling Date

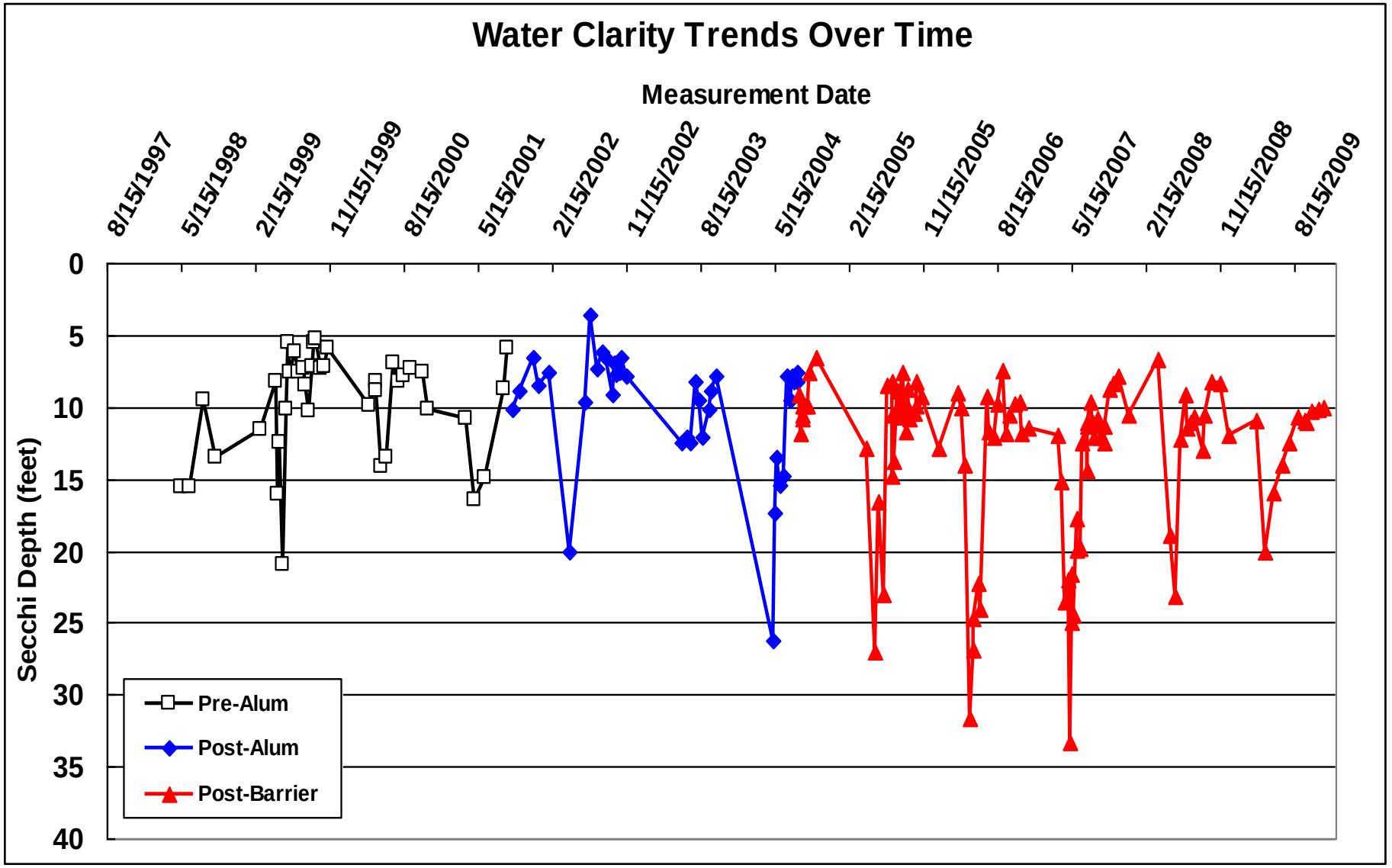
Anaerobic Sediment Release of Phosphorus

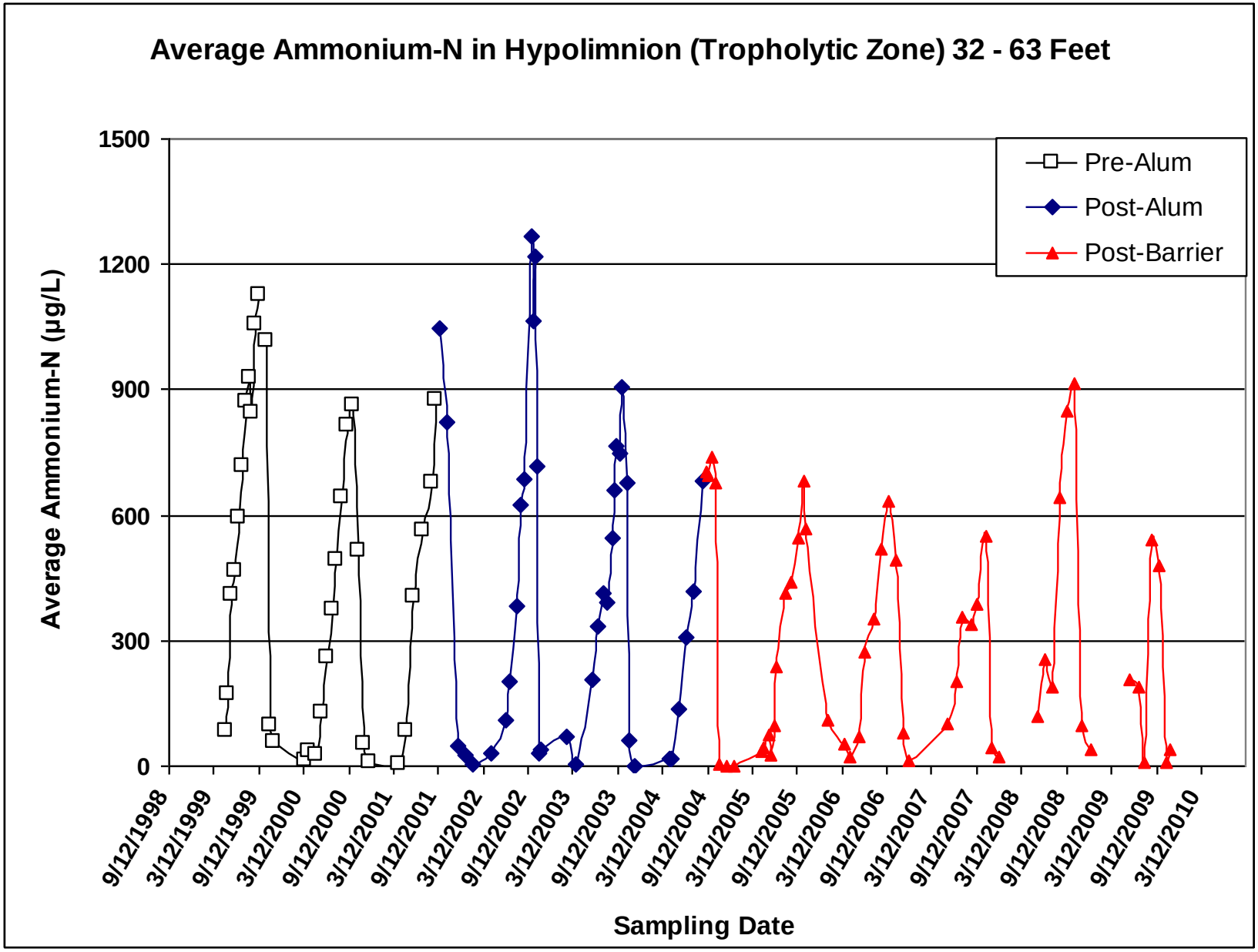
Ashumet Pond Deep Basin ~ 18.0 m depth

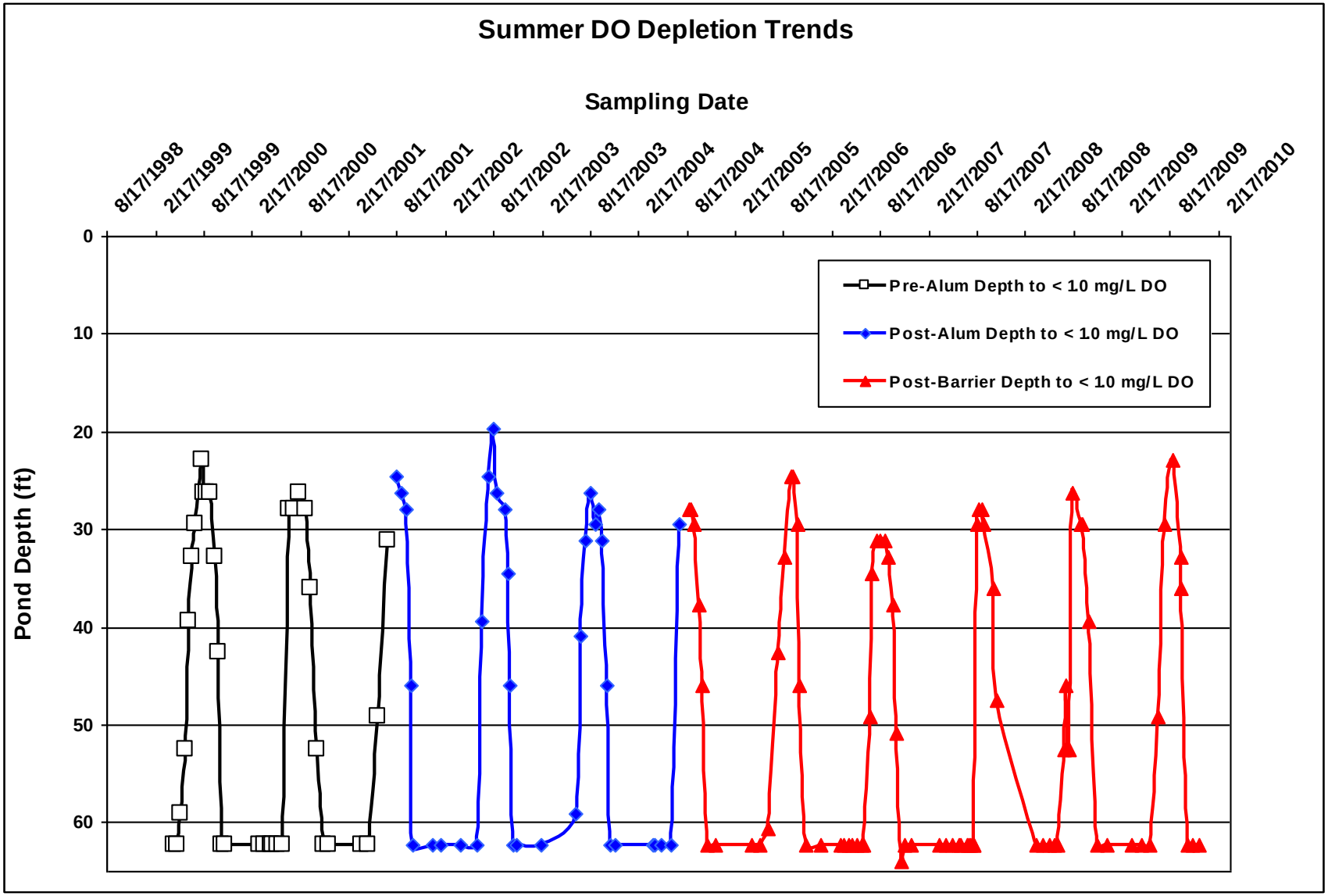


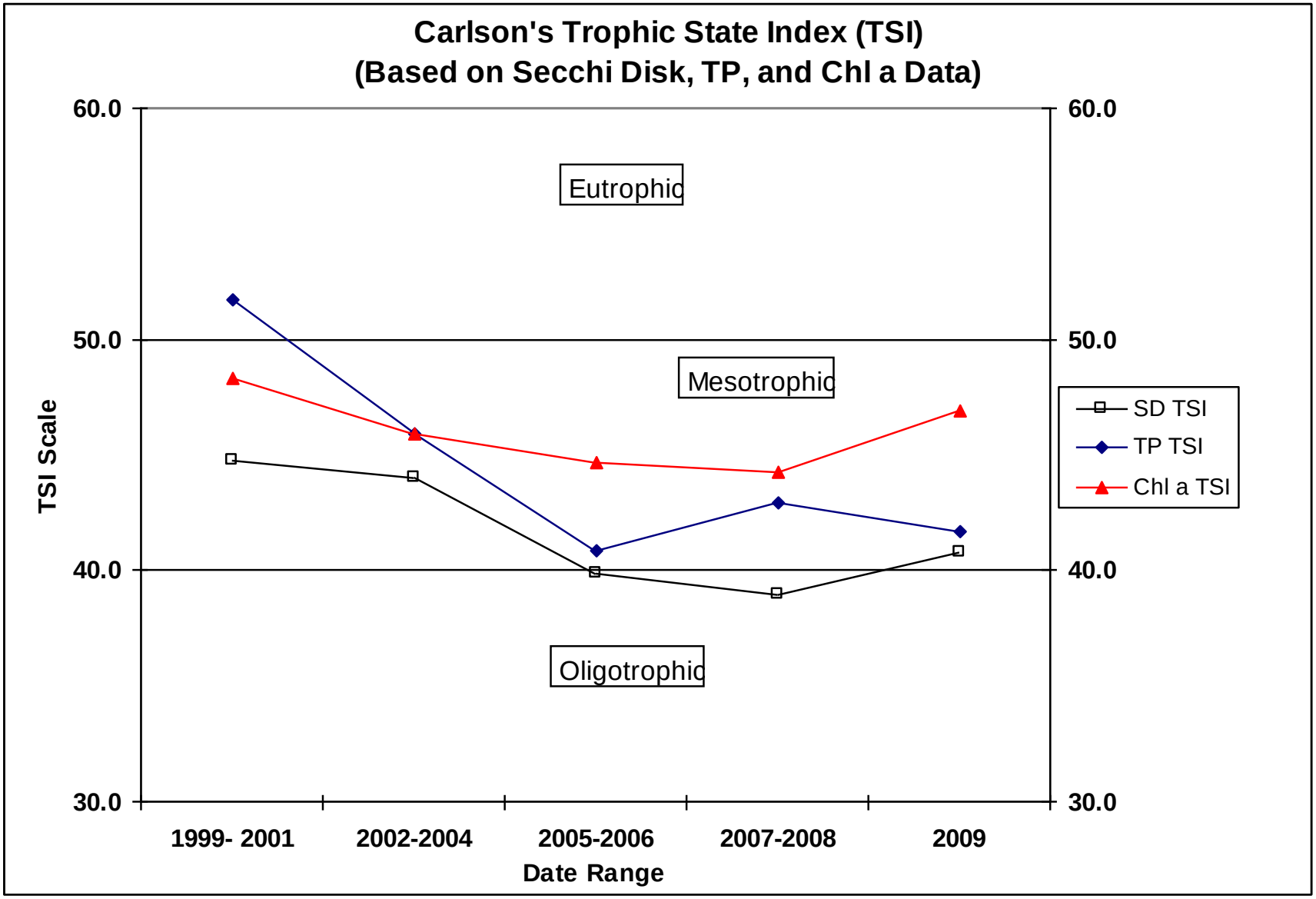
Laboratory tests of 2008 pond sediment core samples produced the highest release of phosphorus observed since the alum treatment.


Average Chlorophyll a in Epilimnion (Trophogenic Zone)
0 - 26 Feet
Average Trophogenic Chl a (µg/L)
24
20
16
12
8
4
0
Pre-Alum
Post-Alum
Post-Barrier
3/1/1999
9/1/1999
3/3/2000
9/3/2000
3/6/2001
9/6/2001
3/9/2002
9/9/2002
3/12/2003
9/12/2003
3/14/2004
9/14/2004
3/17/2005
9/17/2005
3/20/2006
9/20/2006
3/23/2007
9/23/2007
3/25/2008
9/25/2008
3/28/2009
9/28/2009
Sampling Date


Water Clarity Trends Over Time
Measurement Date
8/15/1997
5/15/1998
2/15/1999
11/15/1999
8/15/2000
5/15/2001
2/15/2002
11/15/2002
8/15/2003
5/15/2004
2/15/2005
11/15/2005
8/15/2006
5/15/2007
2/15/2008
11/15/2008
8/15/2009
Secchi Depth (feet)
0
5
10
15
20
25
30
35
40
Pre-Alum
Post-Alum
Post-Barrier


Average Ammonium-N in Hypolimnion (Tropholytic Zone) 32 - 63 Feet
Average Ammonium-N (µg/L)
1500
1200
900
600
300
0
Pre-Alum
Post-Alum
Post-Barrier
9/12/1998
3/12/1999
9/12/1999
3/12/2000
9/12/2000
3/12/2001
9/12/2001
3/12/2002
9/12/2002
3/12/2003
9/12/2003
3/12/2004
9/12/2004
3/12/2005
9/12/2005
3/12/2006
9/12/2006
3/12/2007
9/12/2007
3/12/2008
9/12/2008
3/12/2009
9/12/2009
3/12/2010
Sampling Date


Summer DO Depletion Trends
Sampling Date
8/17/1998
2/17/1999
8/17/1999
2/17/2000
8/17/2000
2/17/2001
8/17/2001
2/17/2002
8/17/2002
2/17/2003
8/17/2003
2/17/2004
8/17/2004
2/17/2005
8/17/2005
2/17/2006
8/17/2006
2/17/2007
8/17/2007
2/17/2008
8/17/2008
2/17/2009
8/17/2009
2/17/2010
Pond Depth (ft)
0
10
20
30
40
50
60
Pre-Alum Depth to < 10 mg/L DO
Post-Alum Depth to < 10 mg/L DO
Post-Barrier Depth to < 10 mg/L DO


Carlson's Trophic State Index (TSI)
(Based on Secchi Disk, TP, and Chl a Data)
60.0
50.0
40.0
30.0
Eutrophic
Mesotrophic
Oligotrophic
TSI Scale
SD TSI
TP TSI
Chl a TSI
1999- 2001
2002-2004
2005-2006
2007-2008
2009
Date Range

Summary

- Phosphorus concentrations in the epilimnion (where most algae growth occurs) have increased slightly since 2006.
- Phosphorus concentrations in the hypolimnion have generally increased since 2007.
- Overall Chlorophyll a concentrations have remained low, although major algae blooms occurred in November of 2007 and 2009.
- Early Summer Secchi depths decreased substantially in 2008 and 2009.
- Ammonium concentrations in the hypolimnion have generally increased since 2007
- Summer oxygen depletion reached a minimum in 2006 and has progressively increased in 2007, 2008, and 2009.
- The Trophic State Index points toward increased eutrophication in 2008 and 2009.

Findings/Conclusions

- The alum treatment and the geochemical barrier have produced substantial and steady improvement in the health of the pond between 1999 and 2007.
- AFCEE core sampling in 2008 and USGS barrier pore water sampling in 2009, indicate that the barrier continues to remove substantial amounts of phosphorus from groundwater, preventing it from discharging to the pond.
- The concentrations of phosphorus in the groundwater plume discharging to the pond have substantially decreased since 1999.
- Based on the current barrier effectiveness and mineralogy, it is anticipated that the barrier will remain effective for at least the next five to ten years – barrier evaluation will continue.
- Relatively large Fall algae blooms in 2007 and in 2009, decreasing water clarity, increasing TP and Chl a, suggest that the health of the pond is starting to decline.
- A new alum treatment is being considered for the summer of 2010.


Questions?