Optimizing Oxic Limestone Treatment of AMD using Automated Flushing Technologies

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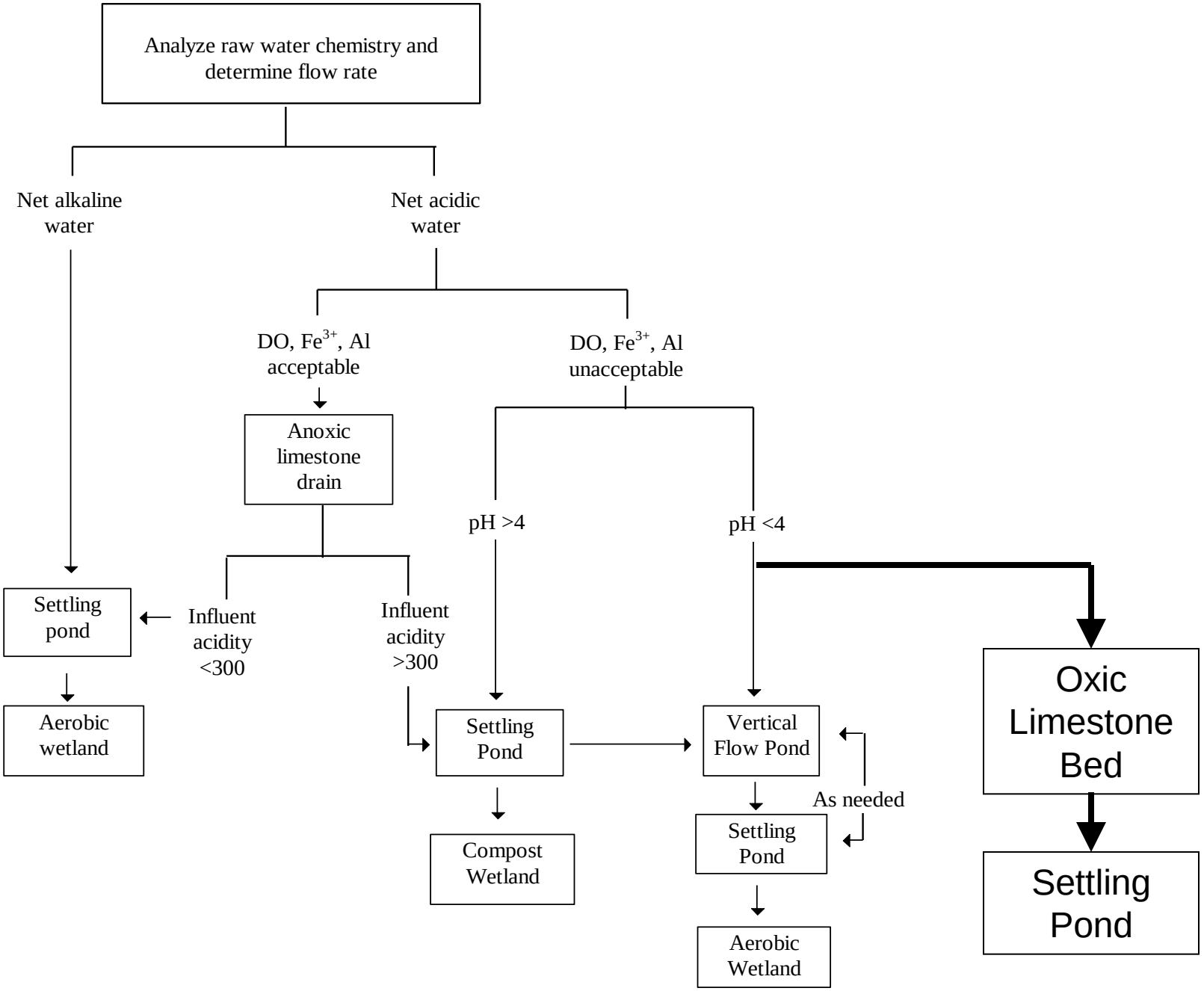
Grant administered by WPCAMR

Technical components of project by Hedin Environmental

Passive Treatment of Mine Drainage



Plugging is a Problem with Oxic Limestone Systems

And everyone blames Al!

Plugging:

Don’t blame the water, design a better system!

The spectrum of design philosophies:

Flush hard, flush often

- Sophisticated design
- Up flow, down flow, horizontal flow
- Siphons, automated valves
- Pipe, pipe everywhere

“Design to fail”

- K.I.S.S.
- Let it plug then deal with it
- No valves
- No pipes

Finding a Design Balance

Goals and Objectives

Quantify flushing effectiveness

- Does it remove solids?
- Does it prevent plugging?

Improve chemical performance

- Produce compliant effluent
- Improve efficiency

Reduce treatment cost

- Is flushing capability worth the cost?
- Limestone is the cheapest treatment chemical

Evaluation of Existing Self-flushing Systems

- Installed previously by Hedin Environmental
- Jonathan Run (Beech Creek, Centre County)
- Mitchell (Babb Creek, Tioga County)

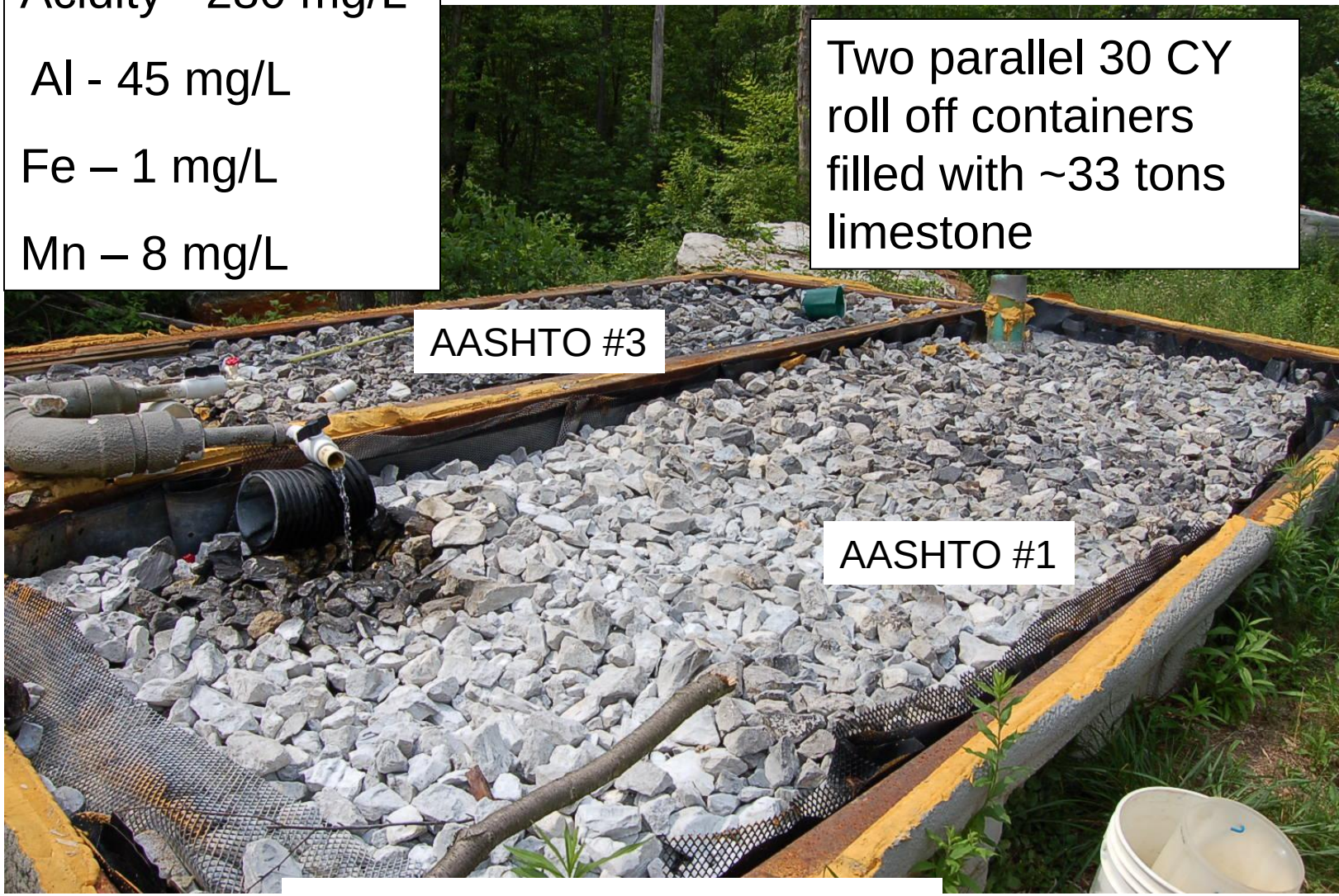
Jonathan Run Flushing Study

Acidity - 280 mg/L

Al - 45 mg/L

Fe – 1 mg/L

Mn – 8 mg/L



8” dosing siphons empty the containers in 3.6 minutes

Mitchell Self-Flushing System

Acidity - 230 mg/L

Al - 26 mg/L

Mitchell Tank

50’ diameter concrete

Construction of Experimental Flush Units

<u>Mitchell Site</u>

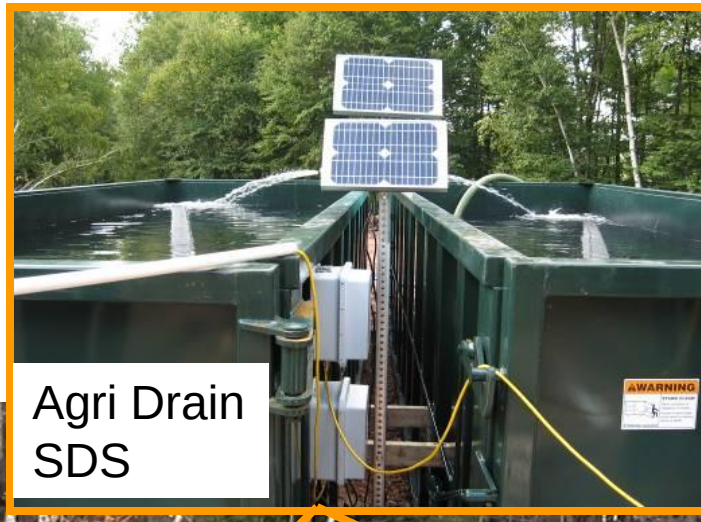
Two parallel 30 CY roll off containers filled with ~33 tons limestone

Acidity - 230 mg/L

Al - 26 mg/L

Fe – 9 mg/L

Mn – 13 mg/L



Agri Drain SDS

East Box

West Box

“Small” limestone

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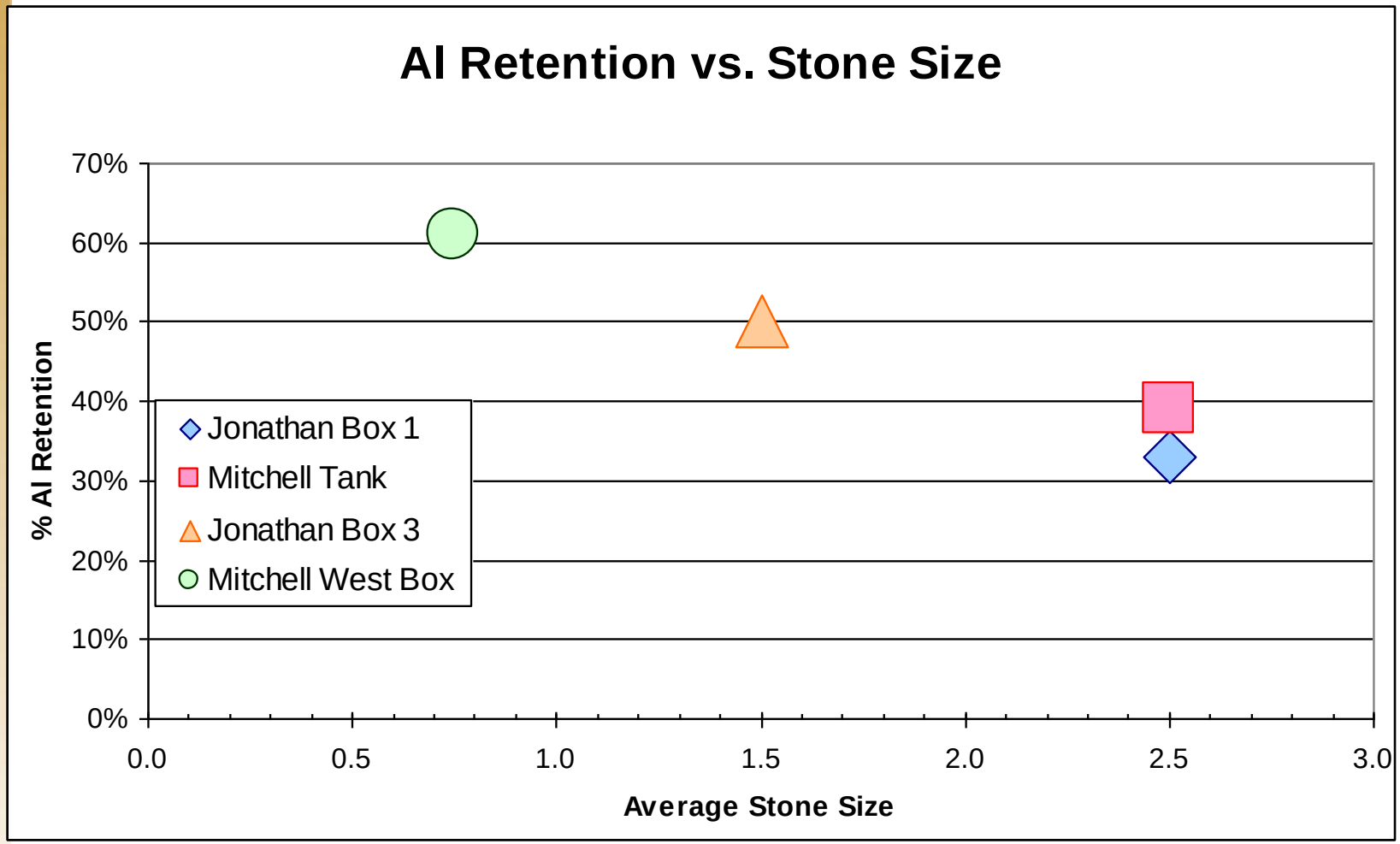
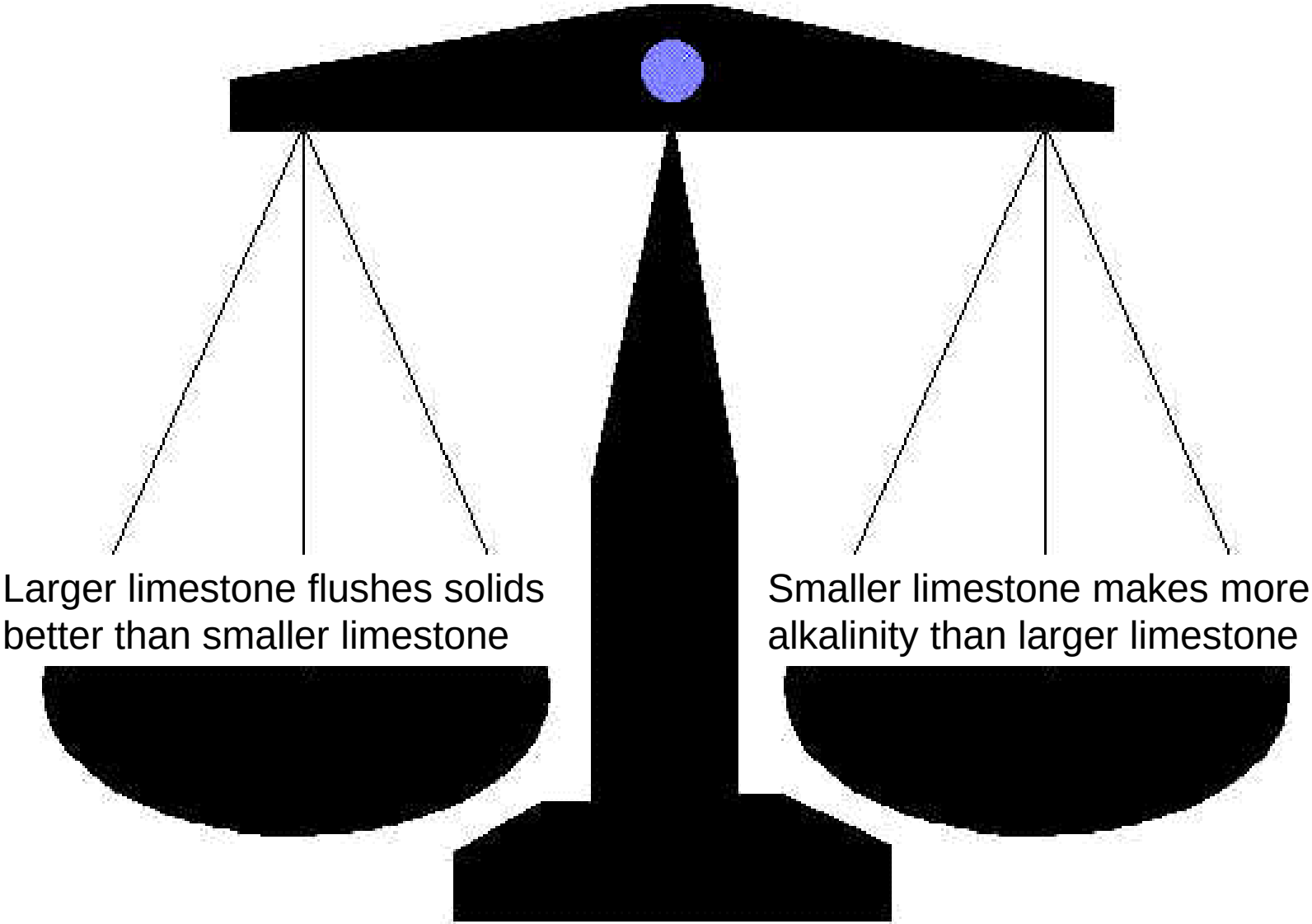
Flushing Removes only Some of the Solids

Site	Al Retained	Al Flush (TSS)	Total Al Removal
Jonathan 1	33%	16%	51%
Mitchell Tank	39%	26%	65%
Jonathan 3	50%	5%	45%
Mitchell West Box	61%	37%	100%

Stone Size Influences Flushing



Aggregate Size Influences Flushing Effectiveness



Goals and Objectives

Quantify flushing effectiveness

- Does it remove solids? – Yes*
- Does it prevent plugging?

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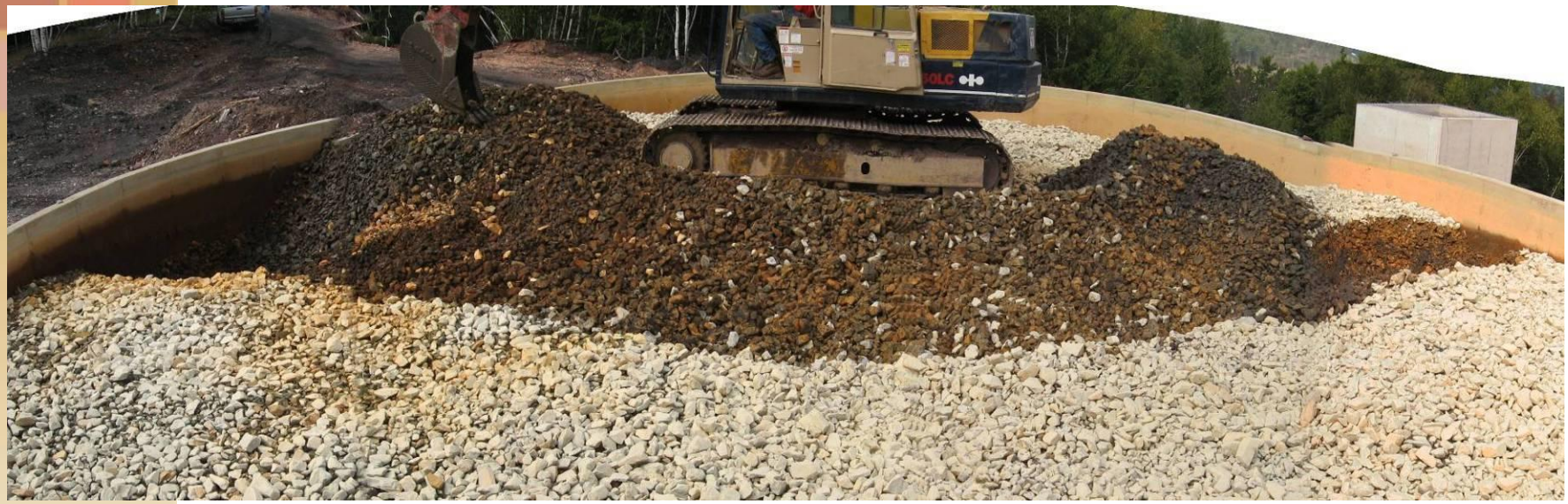
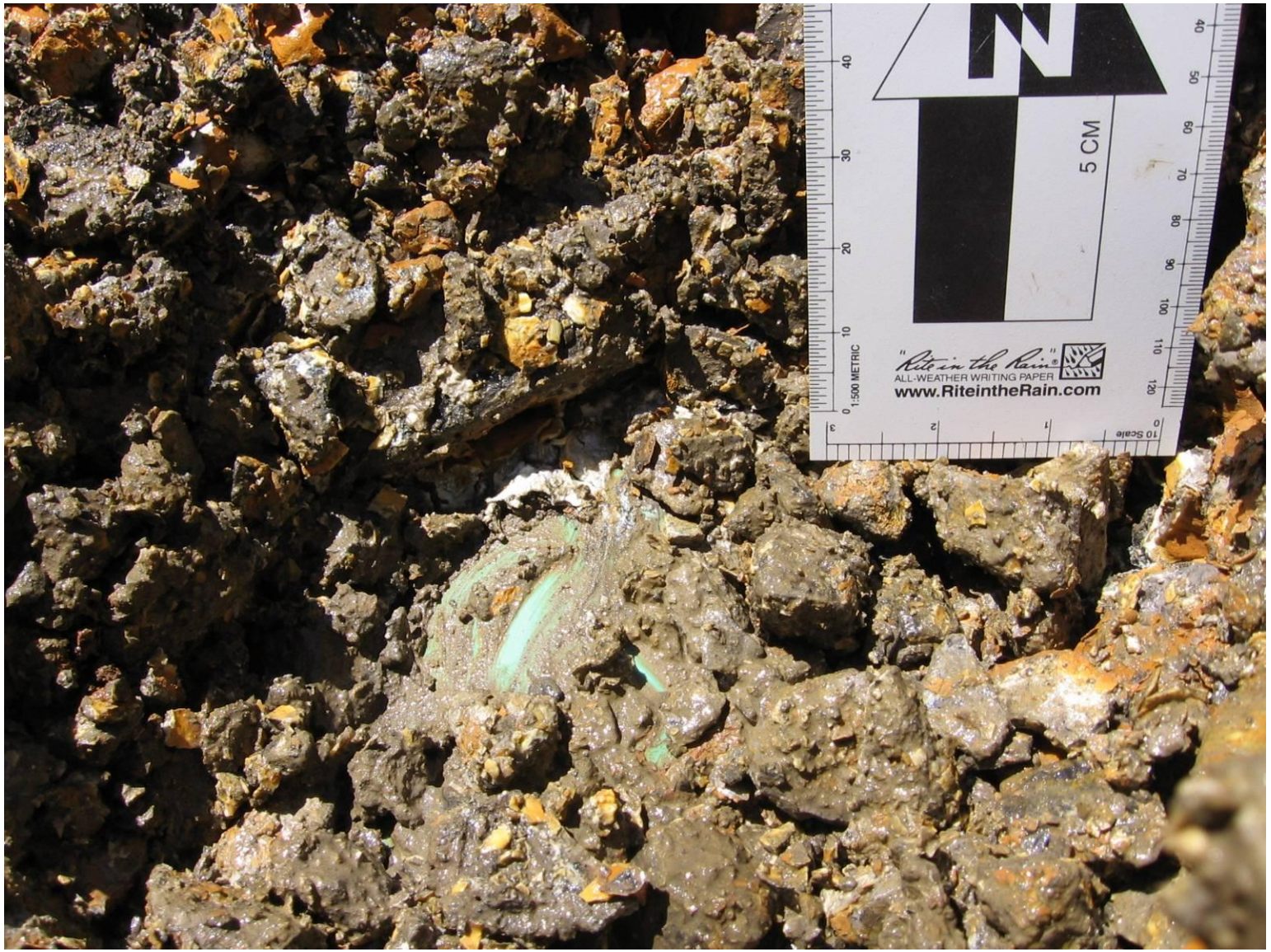
Excavations of “fouled” limestone



Flushing maintains permeability

Solids next to perforation



Pore velocity doesn’t remove scale

Flushing Distributes Solids
Flush to Empty!

Goals and Objectives

Quantify flushing effectiveness

- Does it remove solids? – Yes*
- Does it prevent plugging? – Yes*

Improve chemical performance

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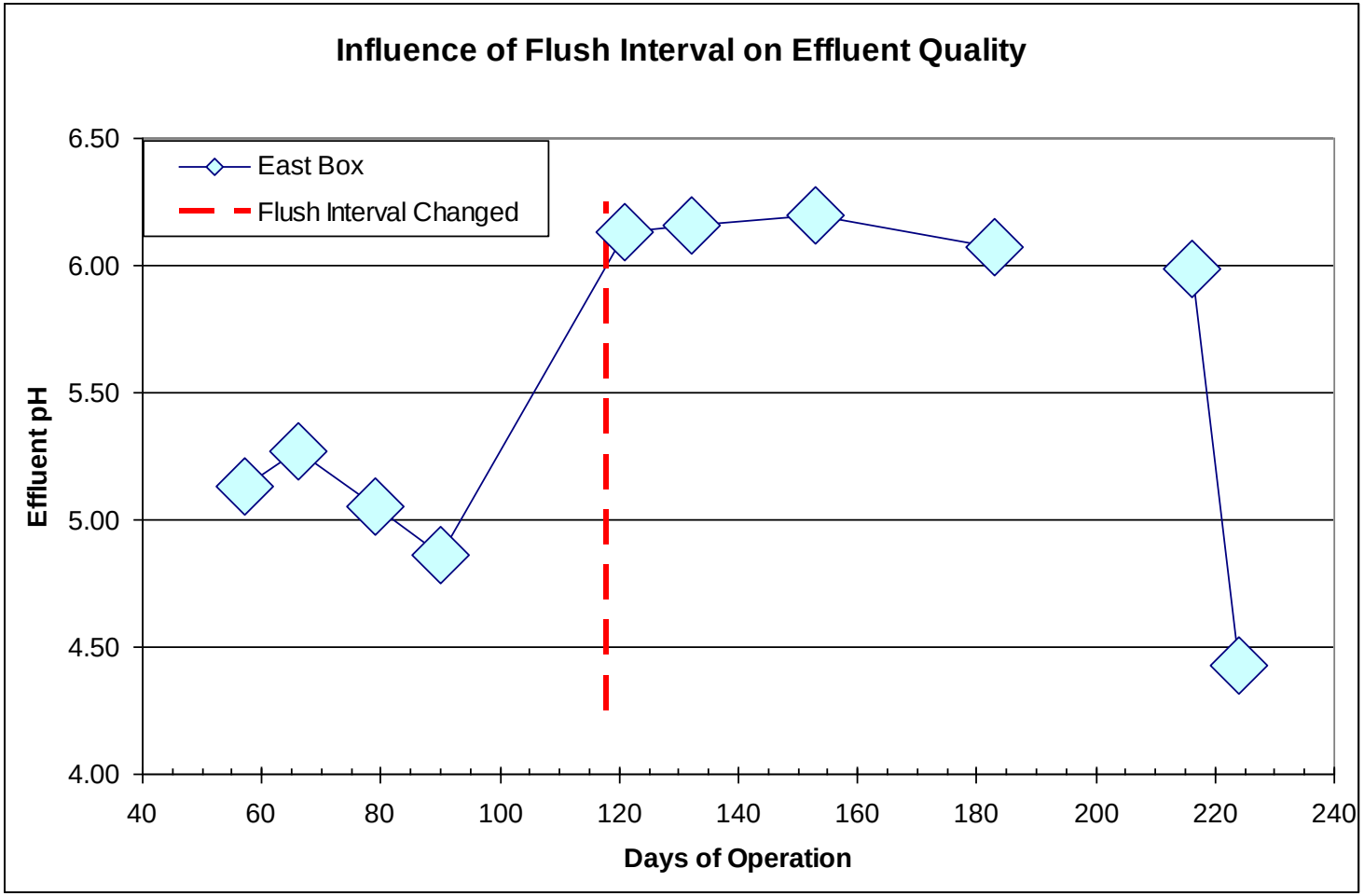
Let the Fun Begin

Manipulate the experimental systems

- Flush interval
- Flush duration
- Flow distribution
- Flow rate (Loading)

Too Much of a Good Thing

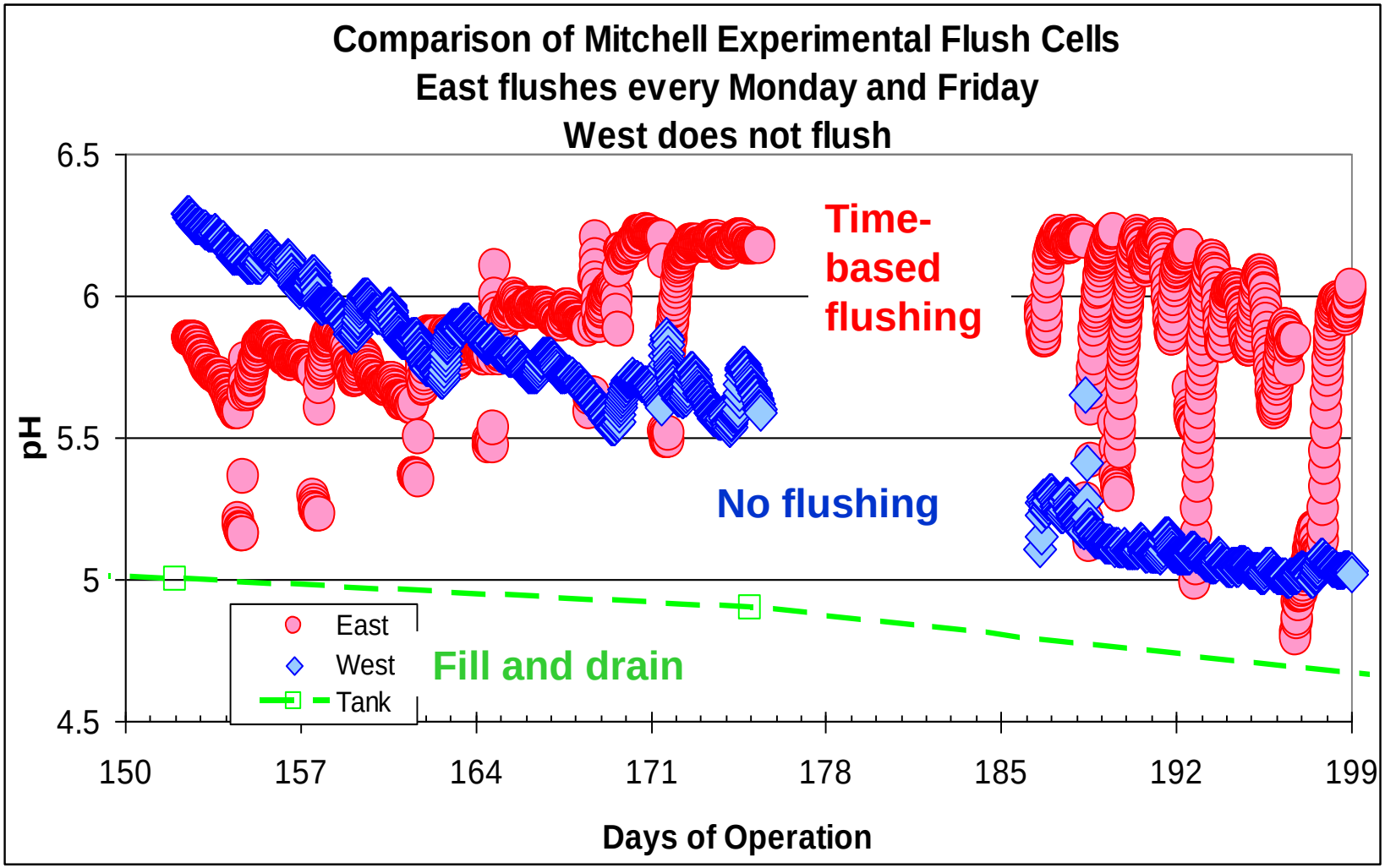
Fill-and-drain systems are half empty



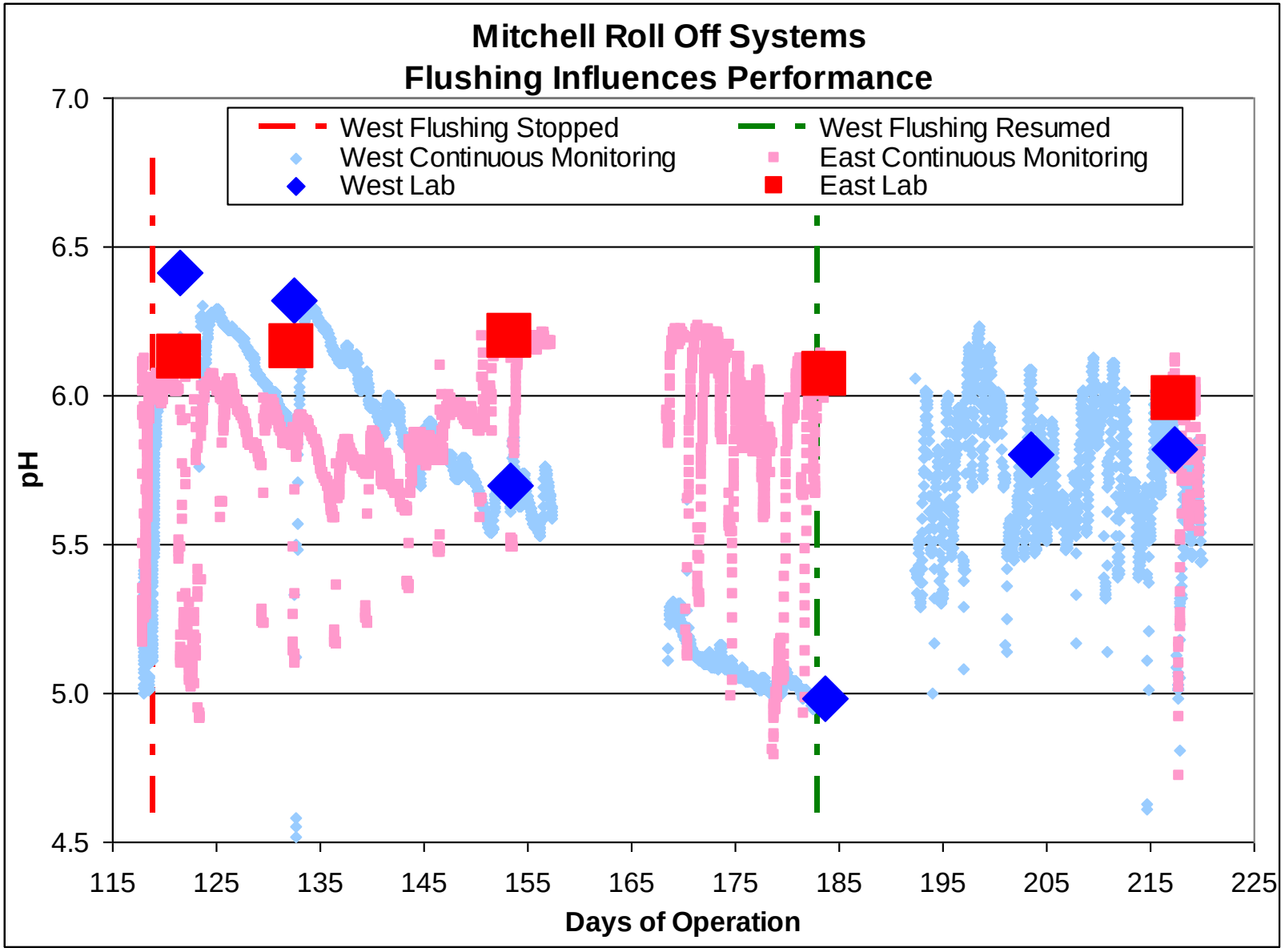
Flush Based on Time Not Level

Flush Mode	Days	n	gpm		pH	Acid mg/L	Acid Rem g m^{-2} day^{-1}	% Acidity Removal
Level Based	61	4	5.5	In	3.02	244		84%
				Out	5.05	38	417	
Time Based	98	5	5.5	In	3.06	185		100%
				Out	6.11	0	374	

Time Based Flushing is Better than No Flushing



Return from the Dead



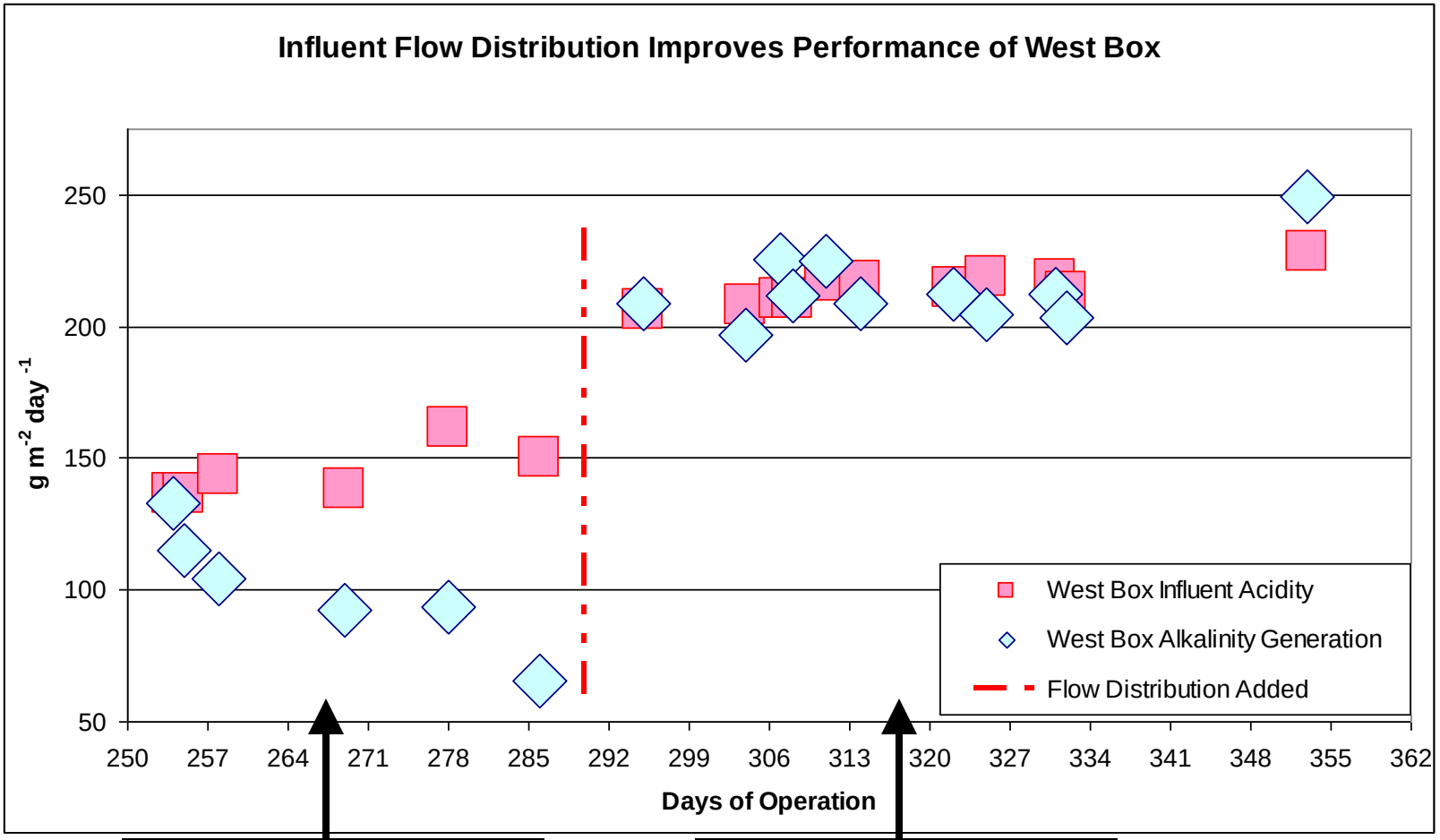
What's Going On Here?

Theory – Pore spaces with slower velocities fill with suspended solid-rich water leading to a density gradient (very small resistance to flow, not plugging). Eventually a column of acidic flow forms directly between influent and effluent plumbing (i.e. short-circuiting). Flushing to empty removes this "interstitial goo".

Interstitial Goo

Flow Distribution is Awesome

Like I Said, Awesome



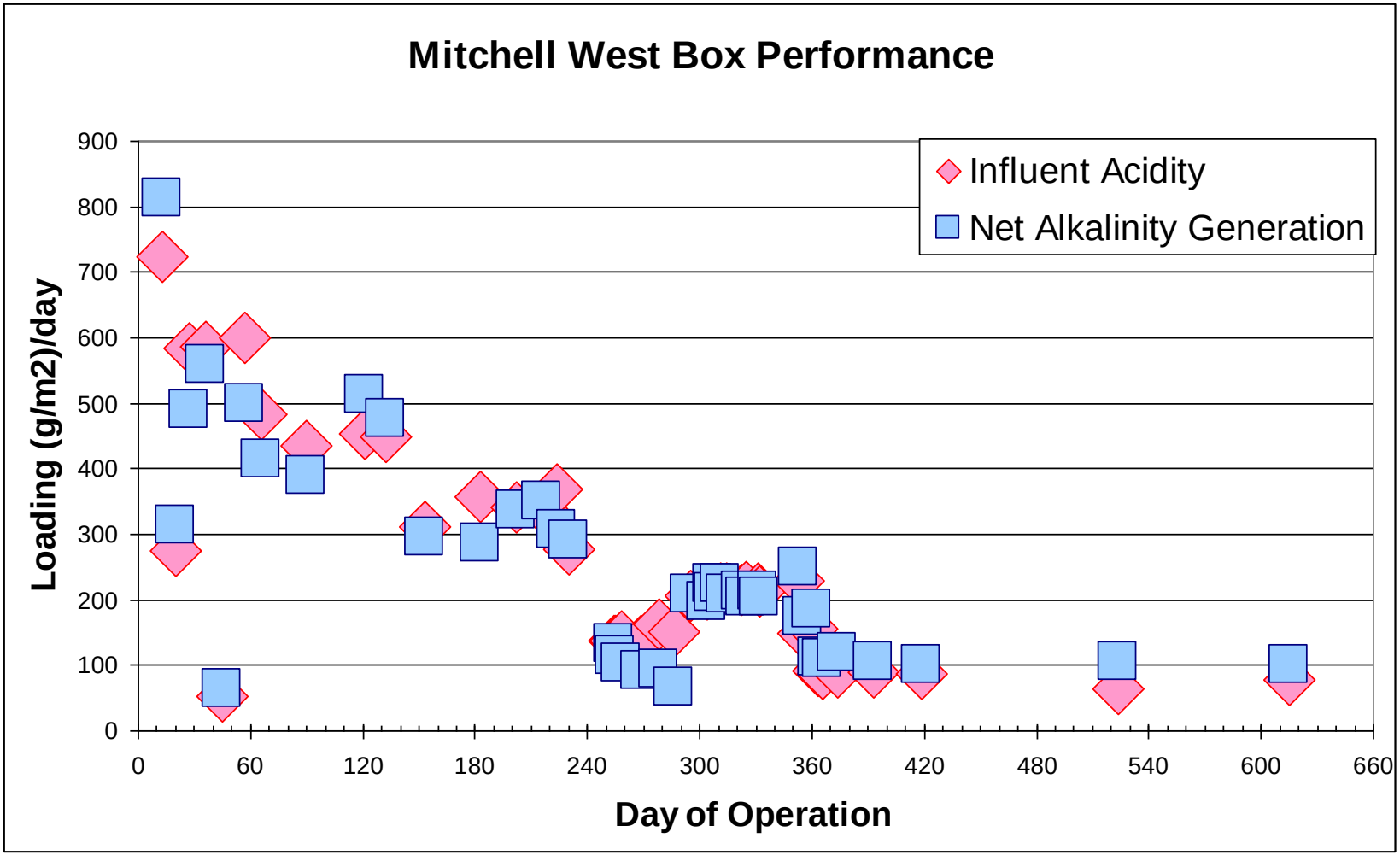
1.9 gpm,

Effluent pH 4.75

2.5 gpm,

Effluent pH 5.95

The West Box Lives On!



Permit Compliant Effluent for 277 Days and Counting…

Location	pH	Acid mg/L	Fe mg/L	Al mg/L	Mn mg/L
Avg. Influent	2.95	270	11.4	30.8	**18.1**
Avg. Effluent	6.73	-71	0.9	1.4	**2.0**
6/22/09 Influent	2.95	233	7.8	24.9	**11.9**
6/22/09 Effluent	7.24	-73	0.7	2.4	**2.4**

O&M

Nothing lasts forever so how do you keep it going?

Problem – Limestone consumed

Solution – Buy more limestone (Now or later?)

Problem – Limestone effectiveness diminished by solids coating

Solution – Wash off the solids coating

Scale is Brittle

“Fouled” limestone can be cleaned: The hose and excavator method

“Fouled” limestone can be cleaned: Excavator only method

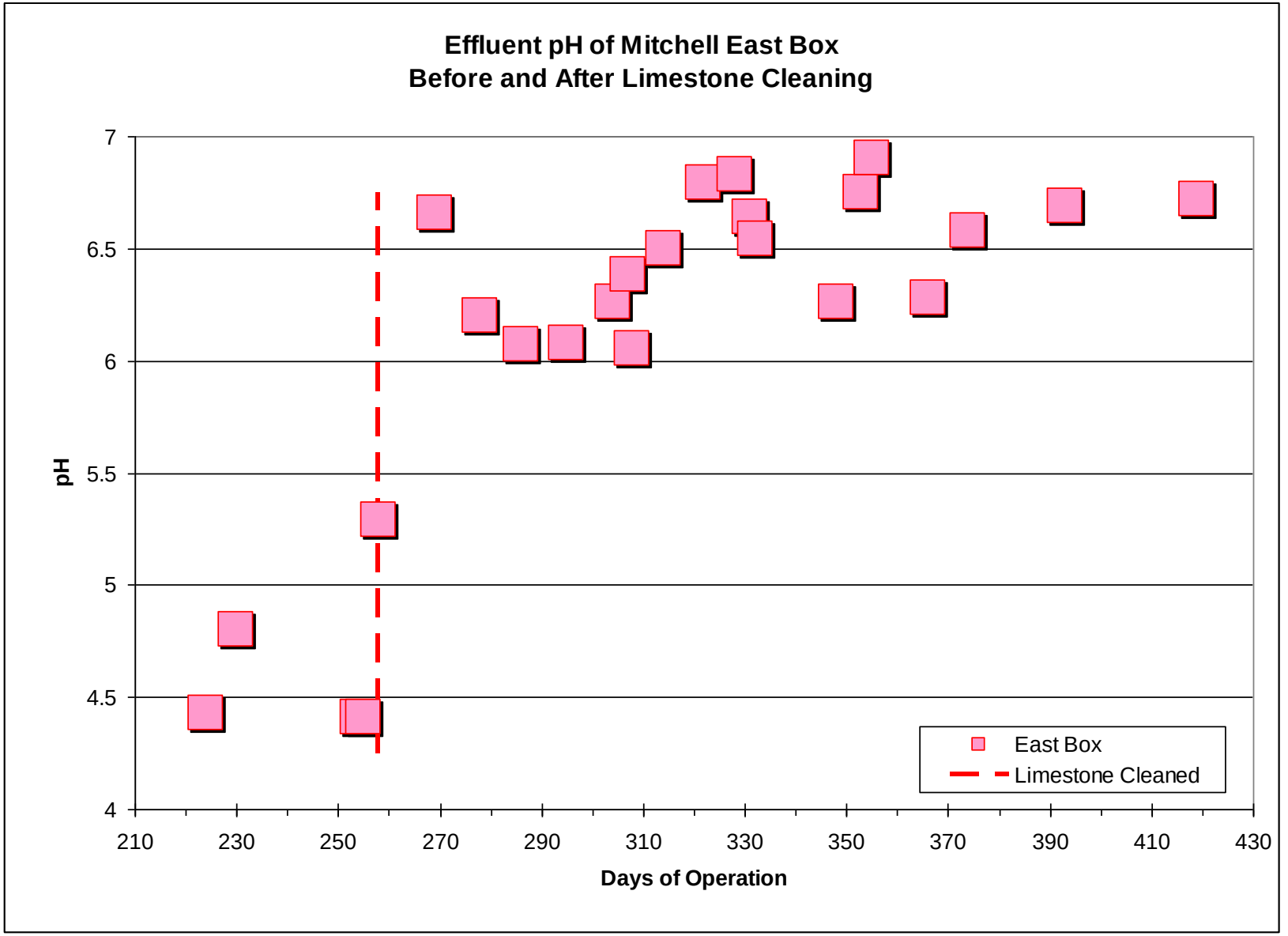
“Fouled” limestone can be cleaned: Stone box method

Chemical cleaning

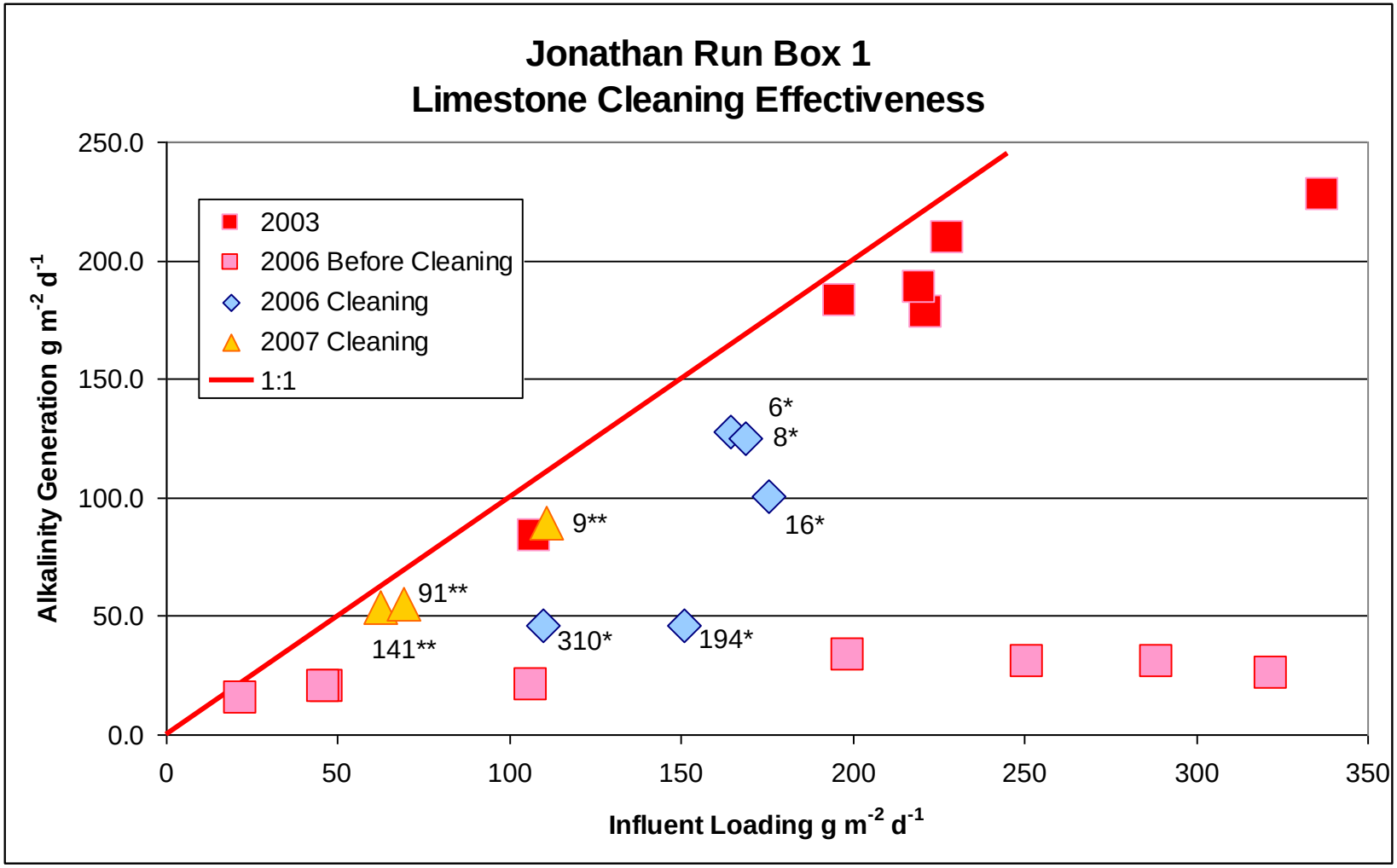
Cleaning Limestone Works

- Cleaned limestone performance similar to that of new limestone
- Performance decline mirrors that of new limestone as well
- Remember to replace what has dissolved
- We cleaned 600 tons of limestone for as little as $2.50/ton

Clean Off the Gunk and Voila!



Starting Over



**days since 5/24/06 limestone cleaning event*

***days since 4/3/07 limestone cleaning event*

Plumbing Makes Cleaning Limestone Difficult

Cost Factors

Costs

- Build the system (capital cost)
  - Excavation
  - Limestone
  - Automated flusher
  - Pipe and misc.
- Maintain the system (annual cost)
  - Routine – samples, flows, clear debris, rodent control, etc.
  - Major – clean and add limestone

Loading rate dictates cost

- Lower loading rate = higher capital cost but lower annual costs
- Opposite for higher loading

Limestone-Based Treatment is Cheap

Costs projected over 25 years

$0.12 per thousand gallons (O,M & R)

$0.31- per thousand gallons (design & construct)

$0.43 per thousand gallons (total cost)

$341 per ton acidity removed (total cost)

What you get

Al, Fe and Mn removal, net-alkaline effluent

For comparison

Ziemkiewicz cites a cost of $291/ton acidity removed for in-stream lime dosing

Take Home Messages

- Use small but UNIFORM aggregate -
  - AASHTO #5 is very good,
  - AASHTO #57 is very bad
- Minimize or eliminate underdrain plumbing
- Flush to empty
- Flush once or twice per week max.
  - Discharge like a VFP between flushes
- “Fouled” limestone can be cleaned cheaply and easily – design with this in mind
- Limestone-based treatment is cheap

“Four score and seven

mg/L aluminum is not too much for passive treatment.”

Abraham Lincoln

Personal communication, June 2009

Questions?