PHYSICAL OPTIMIZATION & TROUBLE SHOOTING STRATEGIES FOR RAPID SAND GRAVITY FILTERS

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Unlocking Your Filter's Performance Potential

- Configuration – Flexibility
- Underdrains
- Wash Water Troughs
- Filter Media
- Established Backwash Protocol
- Surveillance Components
- Seven Critical Filter Operation Parameters

Filter Configuration

- All filters are not created equally: Each functions only as well as its weakest component.
- Individual filter effluent discharge generally preferable to combined filter effluent discharge arrangements: greater flexibility and effectiveness in control, monitoring, backwash, and expansion/operation modifications.
- Critical components: underdrains, wash water troughs, media, backwash system and protocol, monitoring and rate control apparatus, and flexibility of operation strategy.

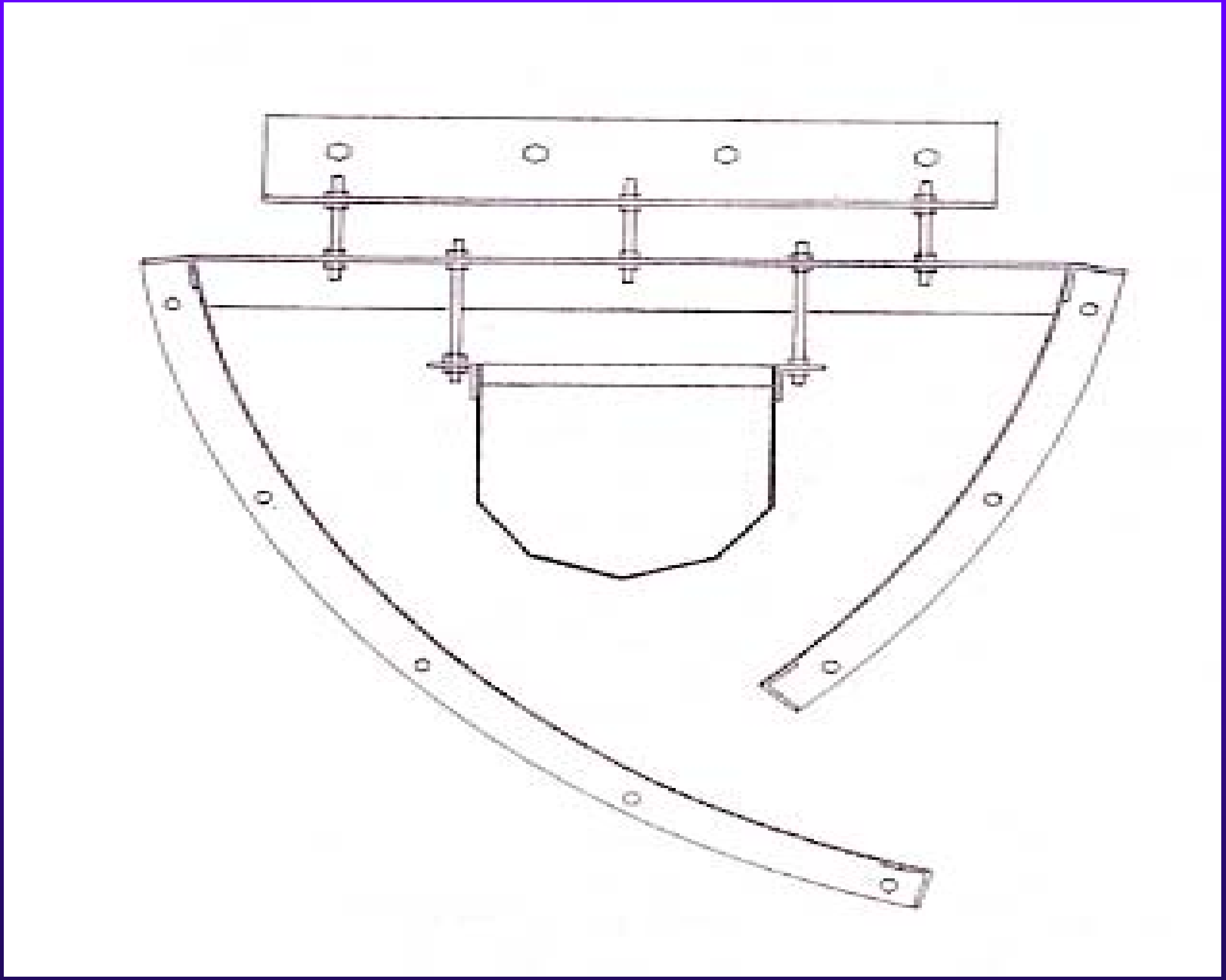
UNDERDRAINS

Style	*Distribution*	*Overpressure Resistance*	*Media Intrusion*
Pipe Laterals & Gravel	Poor to Good	Excellent	Low
False Bottom: Wheeler or Media-Ret. Nozzles	Good to Excellent	Good to Excellent (pressure relief pipe above BWL)	Variable
Block	Excellent	Low to Excellent (plastic w/o-ring design)	Low

WASHWATER TROUGHS

- Most common problems occur when located or leveled improperly and when air wash or air binding occur.
- Locate above expanded media bed.
- Ensure level installation.
- New media retaining styles offer advantages, especially for air scour applications.

MEDIA RETAINING WASHWATER TROUGHS



MEDIA

- Dual or Multi Media encourage particle/floc removal deeper in bed, reducing headloss.
- Larger (1 mm), low density media at surface, commonly anthracite or carbon.
- 12-inch minimum of smaller (o.45 to 0.55 mm) sand.
- Garnet or other high density media of small size at depth for multi media filters.

MEDIA ISSUES

- Media loss on backwash.
- Media abrasion.
- Effective size and/or uniformity coefficient non-compliance and other gradation issues.
- Excessive intermixing at media interfaces.
- Media fouling, mudballs, calcite deposition,
- Expansion during backwash: Clean media, but not excessively: ripening impacts.

BACKWASH SYSTEMS

- Elevated Storage Supply.
- Pumped Supply from Clearwell: VFD pumps add flow and head control flexibility. Beware of overpressurizing underdrain.
- Supply from Distribution Mains or High Service Pump Discharge: may have excessive pressure and potential for solids entrainment.
- Interfilter Supply: Supply is production of filters sharing common underdrain.

INTERFILTER BACKWASH

- Increasing backwash flows and head more difficult.
- Pre-wash drain down level and backwash head is limited by the elevations of the finished water weir and/or washwater trough.
- Expansion/operations modifications require weir, washwater troughs, and/or filter box depth change.
- Backwash distribution uniformity sometimes problematic.
- Terminal Subfluidization backwash and filter to waste/rewash not readily feasible.

BACKWASH PROTOCOL

- Standardized for all Operators?
- Prep for Backwash?
- Surface Wash?
- Air Scour?
- BW Rates & Rate Control?
- BW Waste Turbidity vs BW Time?
- Terminal Subfluidization Wash &/or Idle Period Incorporated?
- Filter to Waste or Rewash?

FILTER MONITORING AND RATE CONTROL

- Interfilter Backwash Supply: No direct rate control on individual filters. Requires increased loading (surge) on production filters to backwash off-line filter.
- Filters with individual effluent discharge piping offer most monitoring and rate control flexibility and most flexibility for future modifications.
- Monitoring: flows, turbidity, headloss.

FILTER MONITORING AND RATE CONTROL

- Filters with individual discharge pipes easily fitted with flow meters, actuated rate control valves, headloss instrumentation, and continuous or intermittent turbidity and particle counting instrumentation.
- Filters which share a common underdrain are suitable for combined filter rate control and effluent monitoring, but diagnosing individual filter performance difficult.

FILTER SURVEILLANCE COMPONENTS

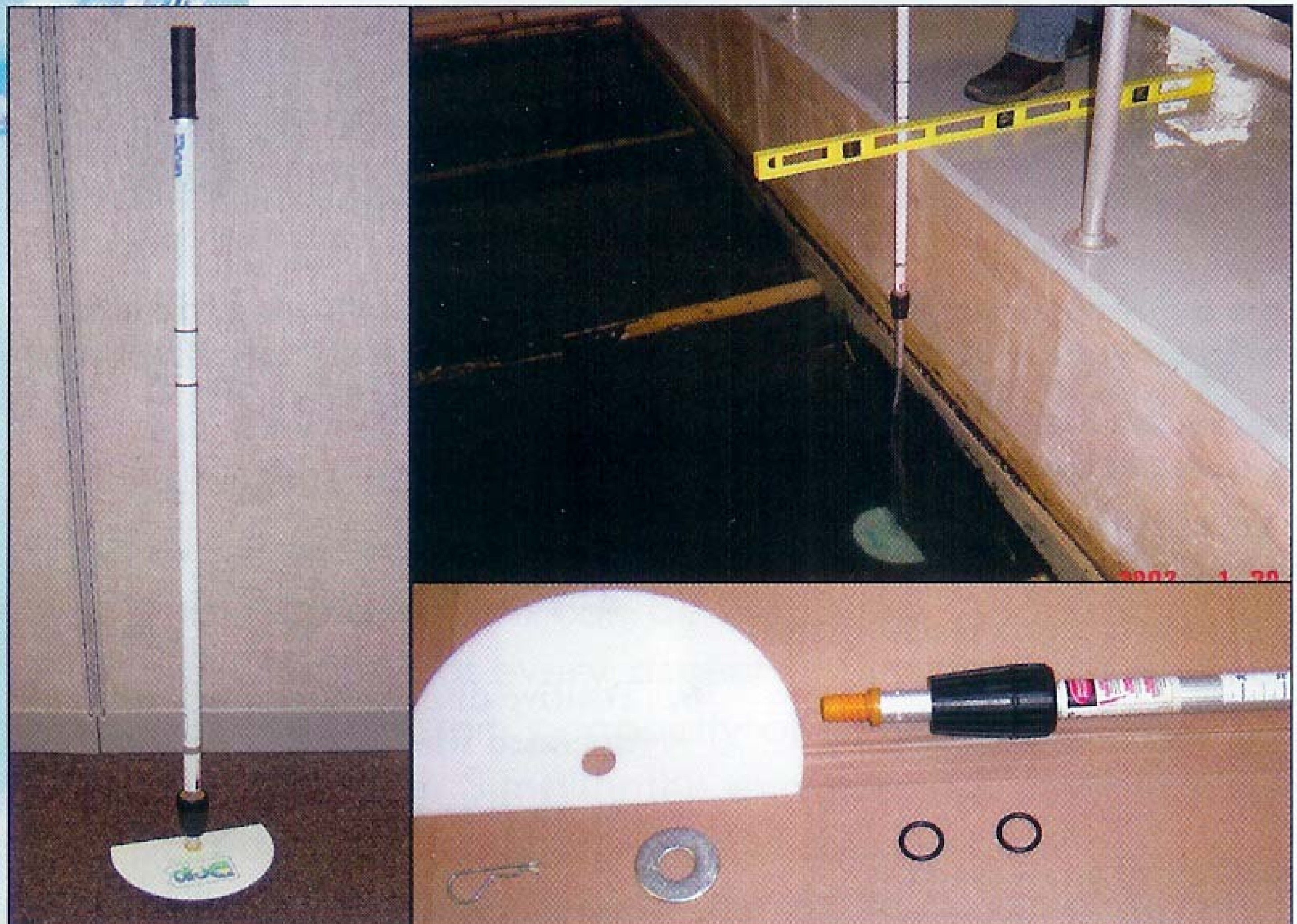
- Headloss Accumulation Rate
- Influent/Effluent Turbidities
- Filter Bed and Backwash Observations
- Influent, Effluent, and Backwash Waste Sampling and Evaluation
- Media Expansion, Coring, and Evaluation
- Optimized Filter Aid/Polymers and Dosage

SEVEN CRITICAL FILTER OPERATION PARAMETERS

- Bed Depth Changes.
- L/d_e ratio $\geq$ 1000 to 1100.
- D_{90} top layer/sand D_{10} ratios = 3 anthracite or 4 carbon.
- Filter Backwash Waste Turbidity vs Time: goal 10 ntu +/-.
- Unit Filter Run Volume (UFRV): 5000 to 6000 gal/sq. ft./run minimum.
- Bed Expansion of 20+ Percent During Backwash.
- Pre and Post Wash Solids Retention in Bed: Goal approx. 30 to 60 ntu/100 grams media (post wash).

MEDIA SURFACE & EXPANSION TOOL

- Telescoping paint pole, with ½-inch graduation increments (use a yard stick and perm. marker).
- 10-inch diameter white plastic disk (Cut one flat edge for access along filter walls & troughs. Drill center hole for threaded pole end to penetrate).
- Washer(s) and snap pin for locking plastic dish onto bottom of paint pole.
- Rubber o-rings for marking locations on the paint pole.



Bed expansion tool (left). Measuring the filter bed at rest (right). Material needed for assembling the tool (bottom).

PRE-WASH MEDIA BED CORING

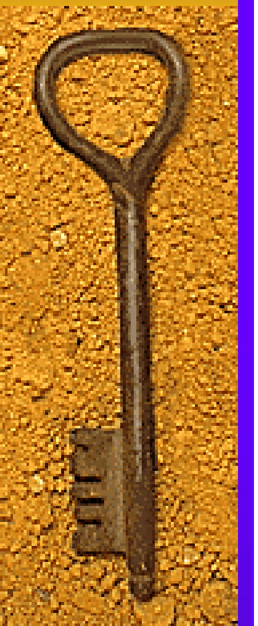
- **Purposes:**
  - Identify zones of greatest turbidity removal or solids retention within filter bed by depth.
  - Identify media type, gradation, condition, & min. fluidization velocity (with depth as appropriate).
  - Identify media concretions, mudballs or other indications of backwash problems.
  - Identify excessive intermixing at the interface of media types.

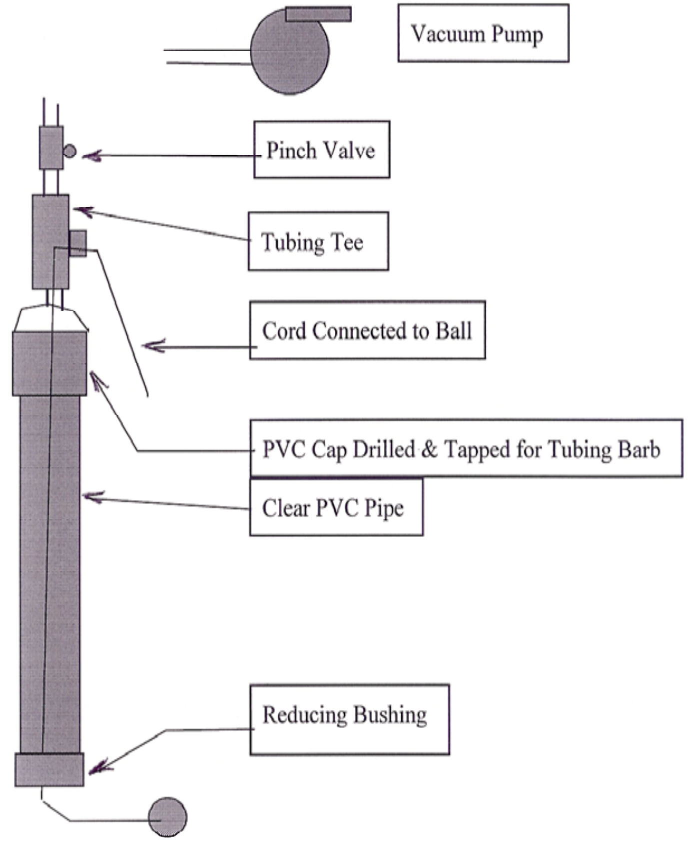
POST-WASH MEDIA BED CORING

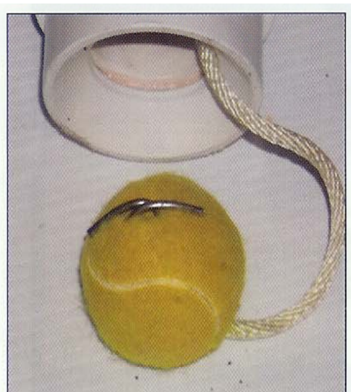
- Purposes:
  - To identify post-wash solids retention by depth in the media.
  - To identify media type, gradation, condition, specific gravity/density, & porosity with depth.
  - To identify media concretions, mudballs or other indications of backwash problems.
  - To identify excessive intermixing at the interface of media types

IMPROVED "WILSON" MEDIA CORING TOOLS

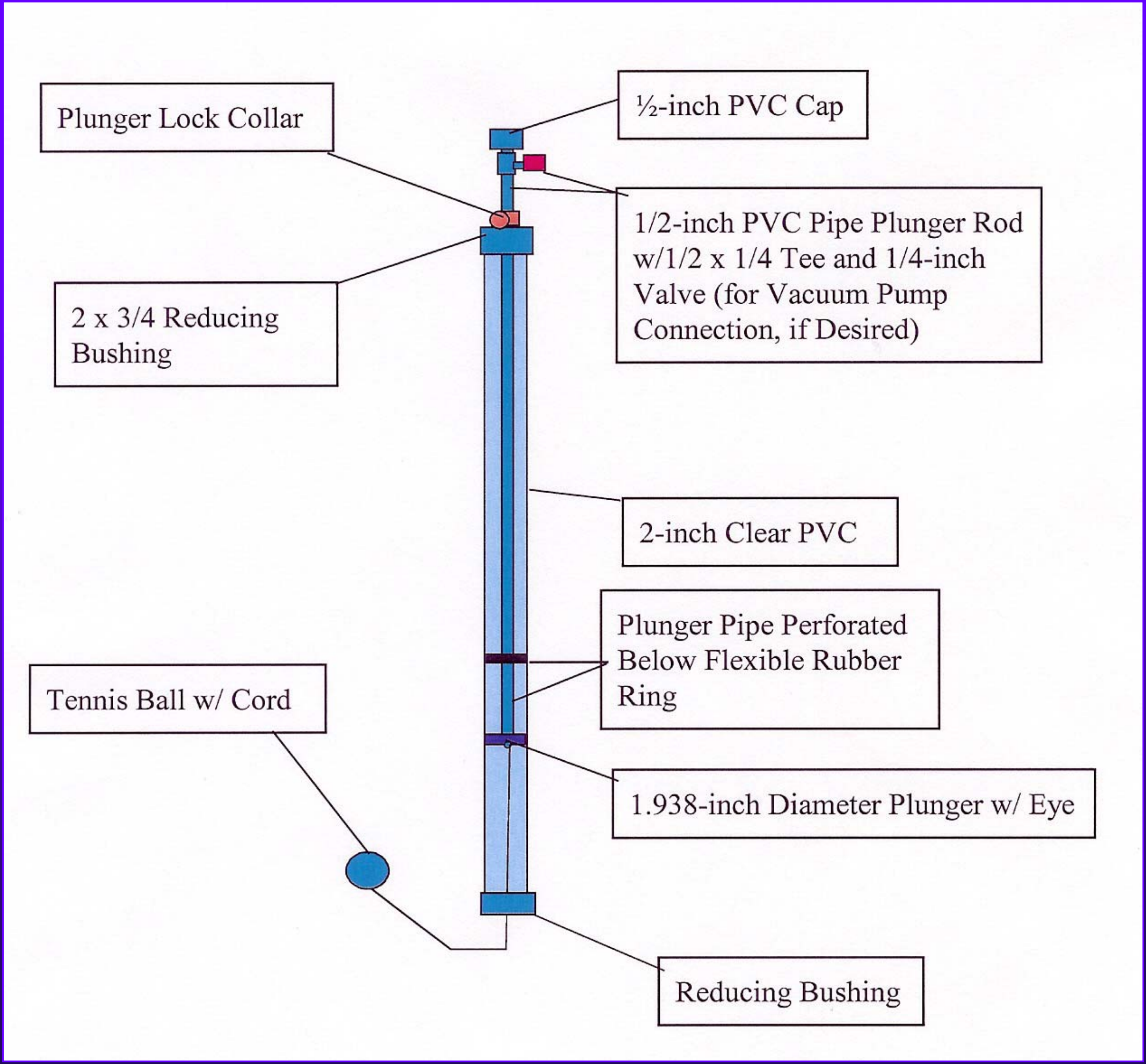
- PVC Pipe & Fittings Required: Appropriate length of 2-inch diameter schedule 40 pipe, 3-inch x 2-inch PVC bottom reducing bushing, and 2-inch top cap drilled and fitted with ¼-inch threaded air nipple.
- Vacuum pump, tubing, clamp, & tubing tee connector.
- Tennis/similar ball for resilient, stiff bottom seal.
- Stiff wire or 1/8-inch welding rod for ball loop, connected to suitable length of light nylon parachute cord or high-strength fishing line.




Vacuum Pump
Pinch Valve
Tubing Tee
Cord Connected to Ball
PVC Cap Drilled & Tapped for Tubing Barb
Clear PVC Pipe
Reducing Bushing



ALTERNATE CORE TOOL

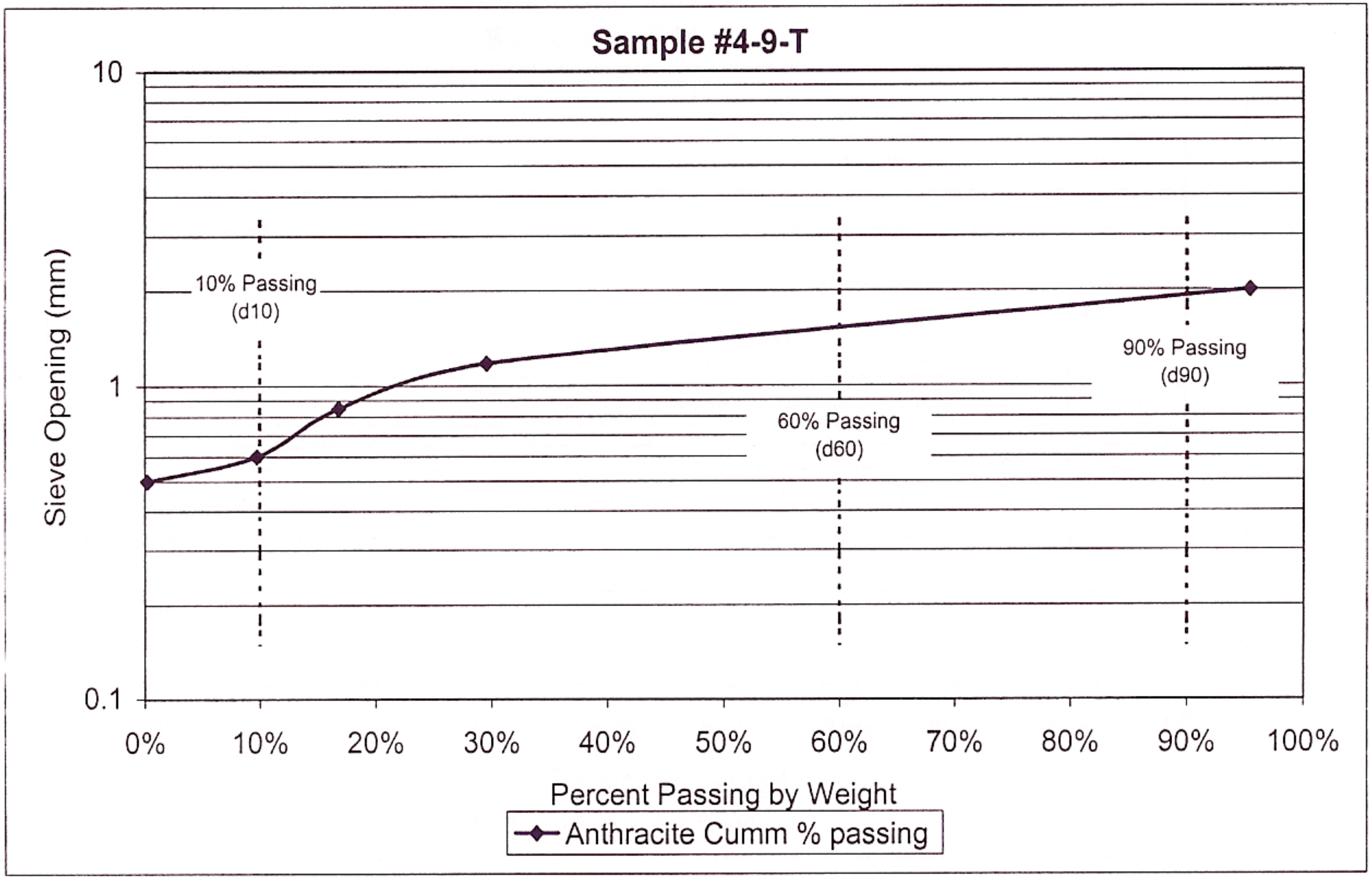


CORE SAMPLE TESTING

- Conduct Tests at Multiple Depths in Cores.
- Solids Retention Testing.
- Gradation Analyses:

  Effective size, uniformity coef., and 90% finer size. Sieves: No.4, 6, 8, 10 (2mm), 16, 20, 30, 35, 40, 50, 80, 100 (0.15mm), pan.
- Specific Gravity
- Porosity

GRADATION



Sample #4-9-T
10
1
0.1
Sieve Opening (mm)
10% Passing
(d10)
60% Passing
(d60)
90% Passing
(d90)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent Passing by Weight
Anthracite Cumm % passing

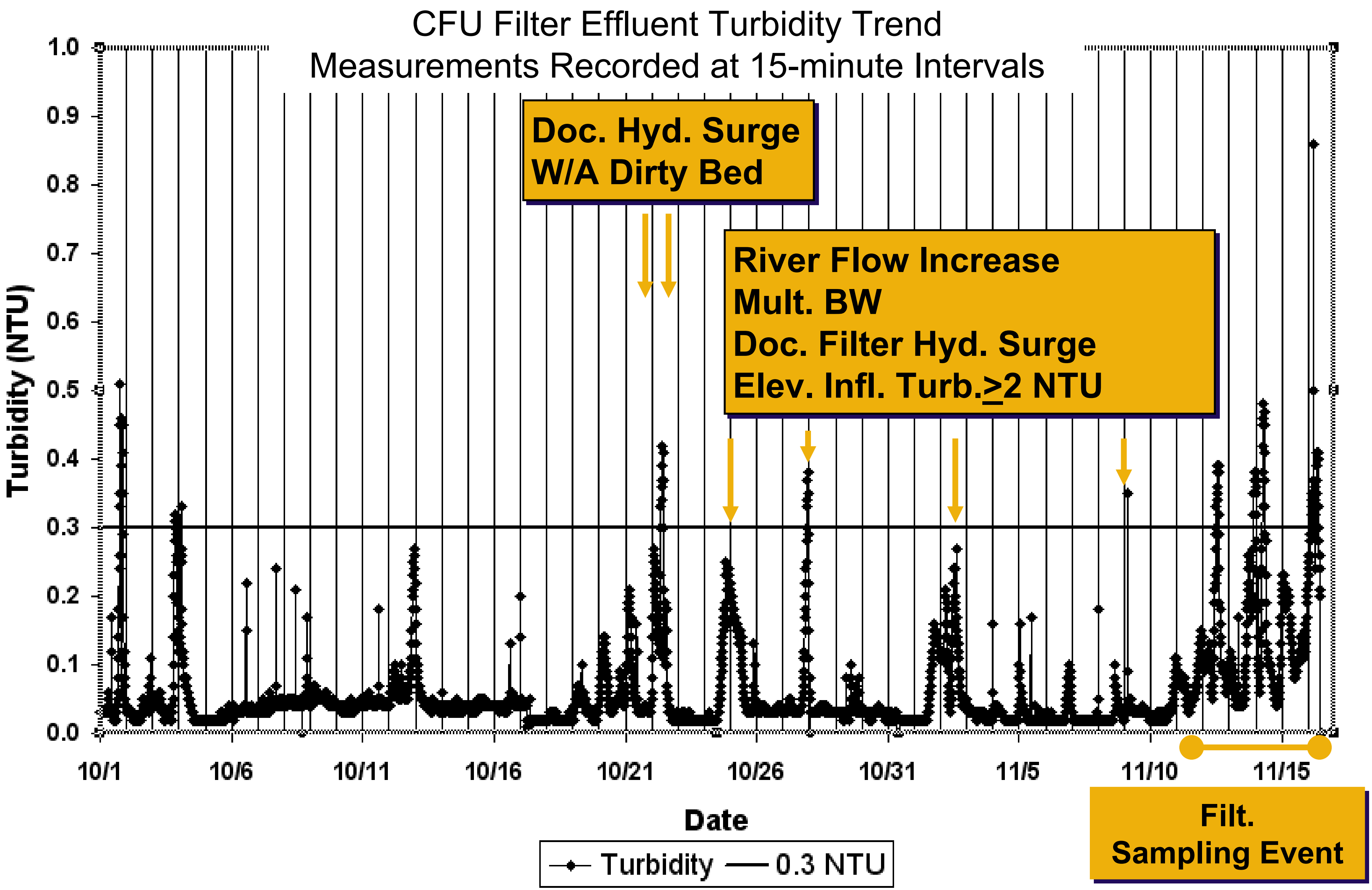
HEADLOSS ACCUMULATION RATE LOGS

Filter Run Lengths: Seasonal Long Term	**Compare Equiv. Conditions** UFRV Termination Reason: headloss vs. turbidity breakthrough vs. choice Trends
Hyd. Loading Rates Average Peak/Instant.	**Trends Compared with Influent Turbidity and Effluent Turbidity**
Post – Backwash Initial Headloss	**Trends Which May Indicate Backwash Problems**

INFLUENT & EFFLUENT TURBIDITIES

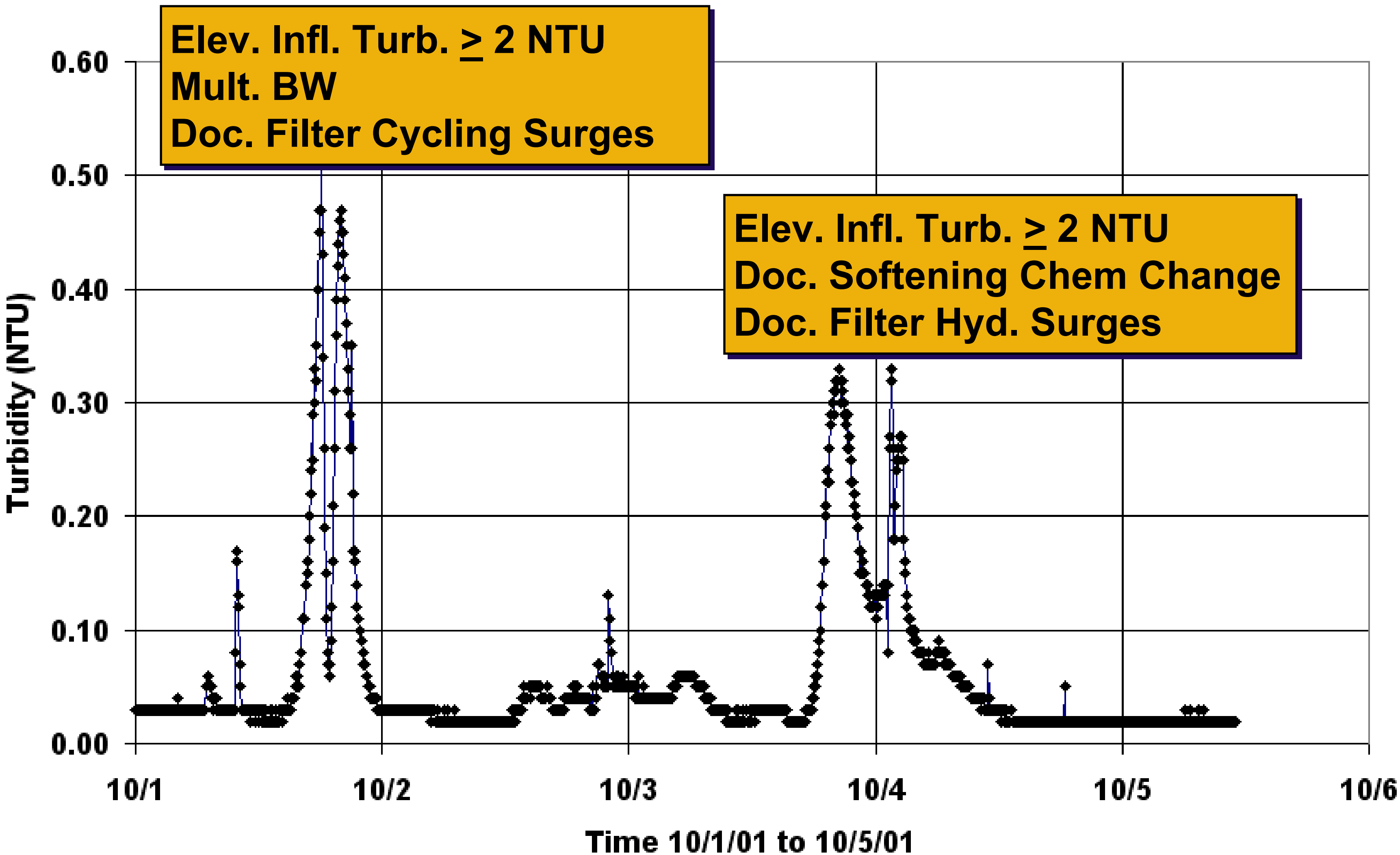
- Plots vs. Time identify breakthrough onset and bracket causal conditions for investigation. Often identifiable hydraulic surges, pretreatment effluent turbidity increase, or water chemistry changes.
- Plot Filter Aid/Polymer Dosage vs. Time.
- For Softening Plants: Plots of magnesium hardness removal and calcium carbonate saturation index may identify turbidity caused by inadequate sedimentation or recarbonation.

TURBIDITY CAUSAL CONDITIONS: SURFACE WATER SOFTENING PLANT

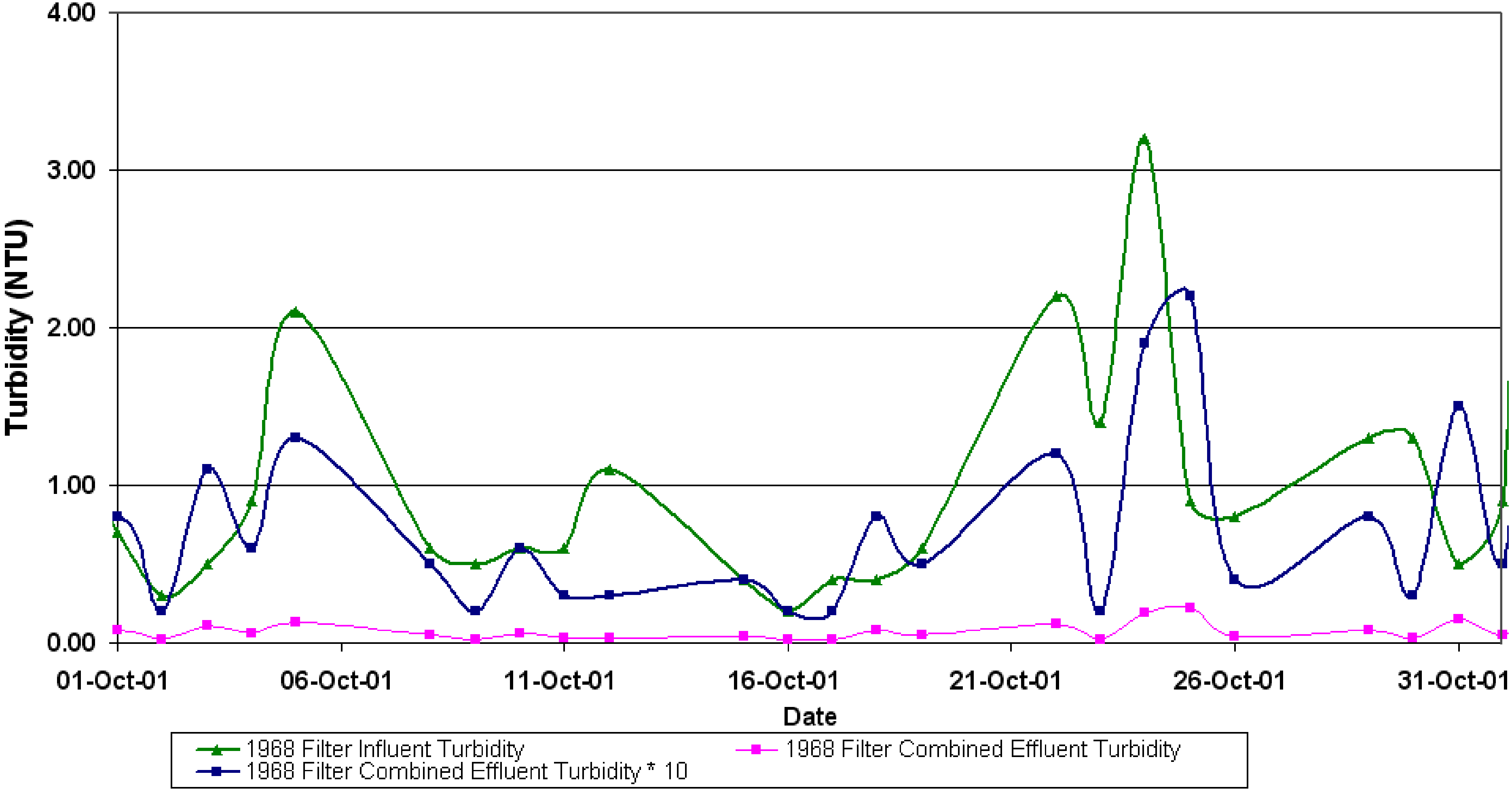


TURBIDITY CAUSAL CONDITIONS: SURFACE WATER SOFTENING PLANT

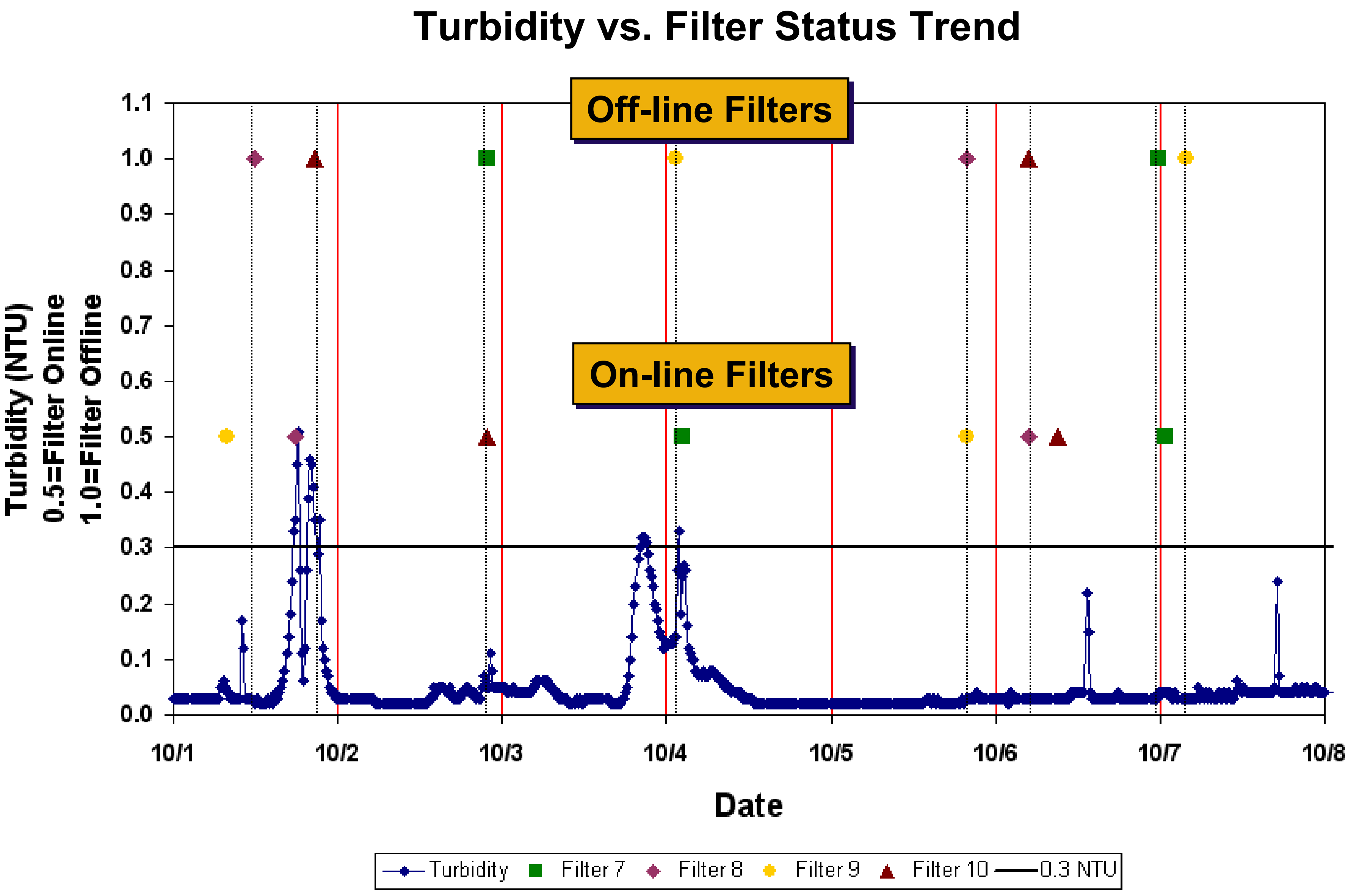
CFU Filter Effluent Turbidity Trend
Measurements Recorded at 5-minute Intervals



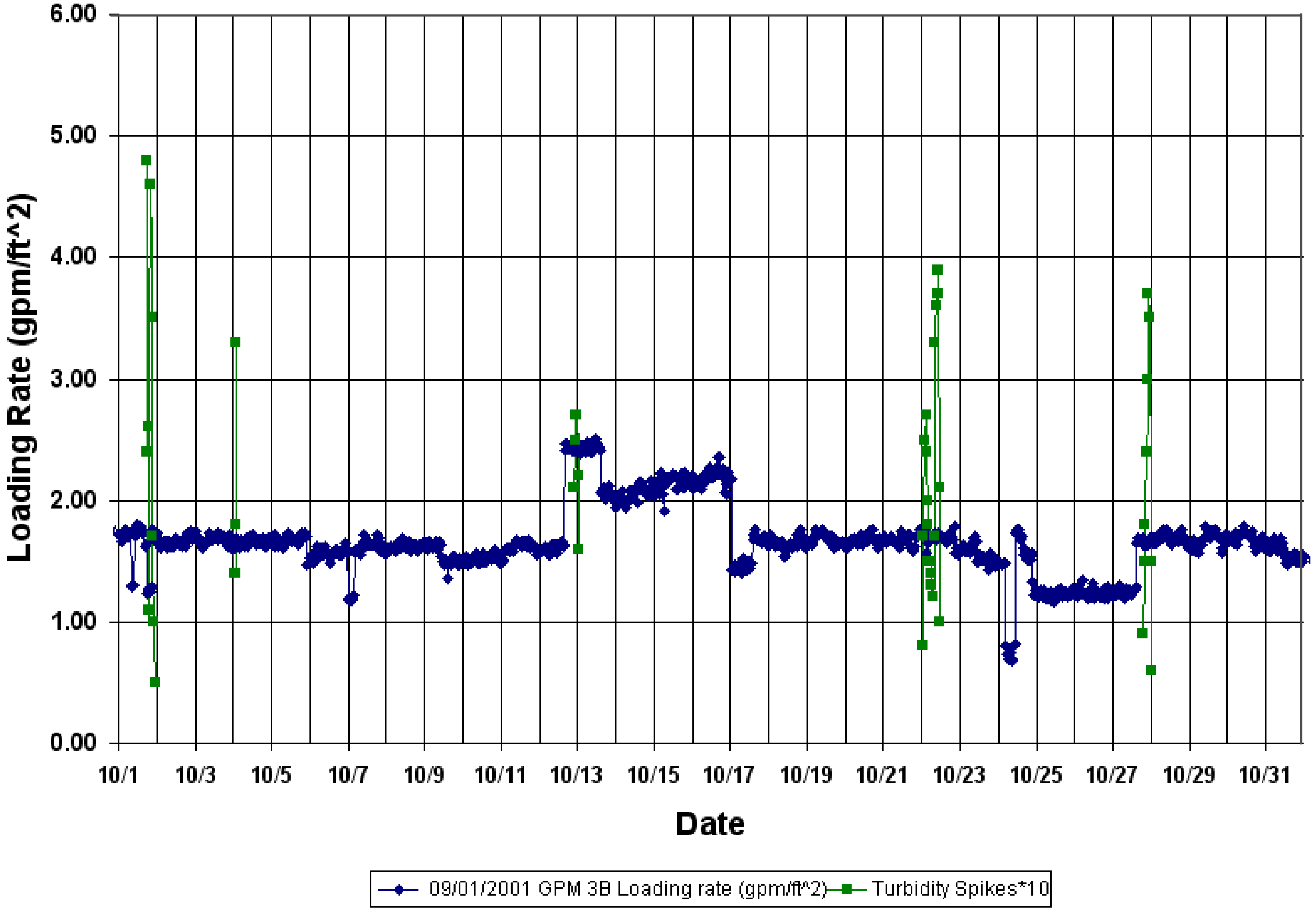
INFLUENT VS EFFLUENT TURBIDITY



FILTER OPERATION STATUS VS EFFLUENT TURBIDITY



HYDRAULIC LOADING RATE VS. EFFLUENT TURBIDITY



BED & BACKWASH OBSERVATIONS

- Pre and Post Wash Bed Surface: Level?, Cracks?, Holes?, Depressions?, Mounds?, Mudballs?, Mineralized Agglomerations?, Surface Elevation Measurements Changed? Document specific locations of abnormalities.
- Media or Excessive Calcium Carbonate Solids in Troughs?
- Troughs Level?

BED & BACKWASH OBSERVATIONS (CONT.)

- Drain Down Level: Below bottom of troughs, but above media bed?
- Surface Wash: Rate appropriate?, Condition of nozzles?, Effectiveness?
- Air Scour (if appl.): Rate?, Applied with simultaneous water backwash?, Water BW rate?, Causing media carryover into troughs?

BED & BACKWASH OBSERVATIONS (CONT.)

- Backwash Rate: Ramped up vs rapid surge?, Air release from bed?, BW supply pipe - air valves or leaking shutoff valves?
- Uniformity of Backwash: Turbulence uniform on initiation?, Turbidity development uniform above bed?, Air pocket releases?, Apparent zones of low or excessive expansion?, Turbidity disappearance uniform above bed?

BACKWASH RATE CONTROL

- Metered? Verify rise rate in filter box.
- Rate Ramped Up? VFD range if pumped. BW valve and actuator issues and delays if not pumped.
- Bed Expansion Optimized?
- Extended Terminal Subfluidization Wash?
- Post-Backwash Idle Period?

EXTENDED TERMINAL SUBFLUIDIZATION WASH

- Ref: Amburgey, Amirtharajah, Brouckaert, & Spivey, "An Enhanced Backwashing Technique for Improved Filter Ripening," pages 81- 94, JAWWA, Dec. 2003.
- Remove remnant particles normally left within & above the media bed at full high-rate fluidization BW termination
- Improve media restratification
- Reduce bed consolidation & effluent turbidity (ripening spike) on filter restart.

ETSW – WHAT IS IT

- Follows termination of full fluidization BW
- BW with upflow velocity = V_{mf} of d_{10} to d_{60} particle size (4 to 9 gpm/sq.ft.).
- BW volume = one filter volume = bed pore volume + volume above bed and below wash water troughs.
- Demonstrated reduced ripening spike effluent turbidity.

FILTER TO WASTE

- Rate Limitations?
- Time/Waste Storage Limitations?
- Are there control valve/actuator reliability issues?
- Is ramping of waste rate possible?

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TROUBLESHOOTING

- Avoid hydraulic surges of any type.
- Optimize BW protocols to reduce on-line ripening impacts & avoid media loss.
- Monitor source water, pretreatment and softening flow and turbidity trends. React to optimize chemical feed dosages quickly.
- Conduct periodic filter evaluations: components; performance; BW; media gradation & solids retention; operations (7 Critical Operation Parameters)

INFLUENT, EFFLUENT & BW WASTE SAMPLING & EVAL.

- Verify filter influent flow rate.
- Measure turbidities of influent & effluent prior to BW.
- During BW: collect BW waste flow turbidity samples at 30 second intervals for first 4 minutes and at one minute intervals for remainder of high-rate BW.

INFLUENT, EFFLUENT & BW WASTE SAMPLING & EVAL.

- Extended Terminal Subfluidization Wash: measure turbidity of BW waste at 2 minute intervals.

- Turbidity Sampling of Filter to Waste or Filter Effluent When Placed Back On Line -

  On-line turbidimeter w/ grab sample checks

  Otherwise: grab samples at 1-minute intervals first 25 minutes; then, grab samples at 5- minute intervals next 20 minutes, and 15-minute intervals thereafter.

MEDIA INTERMIXING

- For particles of equal settling velocity:

  $d_1/d_2 = [(p_2-p_w)/(p_1-p_w)]^{2/3}$

  d is diameter of particle 1 or 2

  p is spec. grav. of particle 1, 2, or water

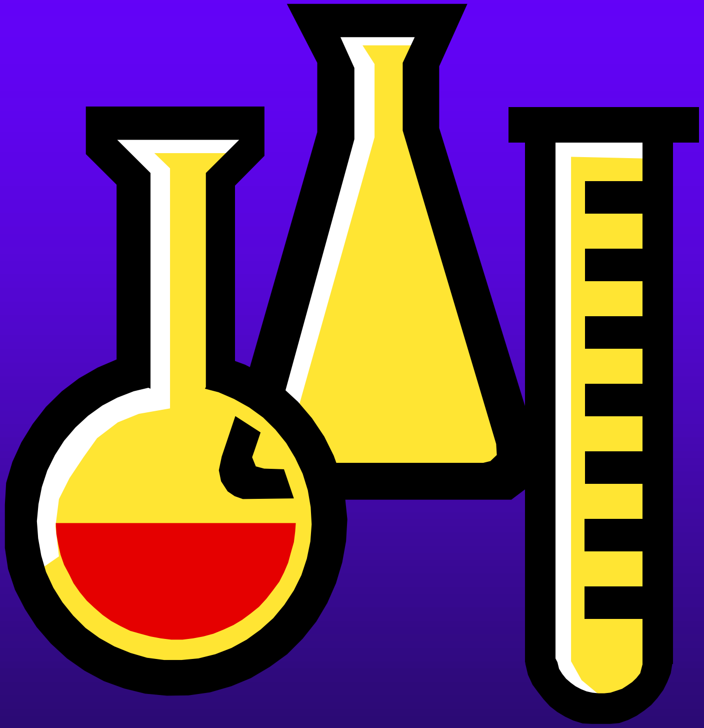
  subscripts (1,2,w): particle number or water

- Intermixing at interface prevented if: d_{90} upper media (i.e. d_1)/d_{10} lower media (i.e. d_2) ratio satisfies equation. Ratio $\leq$ 3 for anthracite cap, reasonable intermixing degree.

SPECIFIC GRAVITY (20 deg)

- Wt. Of Flask + Deaired, Distilled H_2O to mark = a
- Wt. Of Flask + Sat. Media + H_2O to mark = b
- Dry Wt. Of Media Only = c (dry & weigh after porosity test)
- G_s = Solids Mass/Solids Volume = c/(a+c-b)

POROSITY



- Transfer Specific Gravity media sample to graduated cylinder. Agitate in water and let settle.
- Record volume of media bed, d, (post BW, initial).
- Lightly tap to consolidate bed. Record consolidated media bed volume, e, (post-initiation of rewash or production).
- Porosity = ((d or e)-(a+c-b))/(d or e).

SOLIDS RETENTION PROCEDURES

- Remove media from PVC sample tube -discrete increments representing top, middle, & bottom bed segments.
- Air dry discrete increment samples, place 100 g +/- in glass jar, determine mass, & estimate relative mass of sand, anthracite, or garnet if mixture. Anthracite abrasion?
- Add 1 mL distilled, deionized water to glass jar/ gram dry media & thoroughly, but gently agitate for 90 seconds.
- Settle for 60 seconds & decant supernatant.
- Determine supernatant turbidity and suspended solids: compare results for pre-wash and post-wash at similar sample locations and depths. Post-wash Goals: 30-60 NTU/100 grams media and/or 0.05-0.2 mg SS/gram media.