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Best Practices Guidance for the Use of Anionic Polyacrylamide on Construction Sites in Ontario

Presented by: Lisa Rocha

STEP Water is a partnership between:

Toronto and Region Conservation for The Living City

Credit Valley Conservation inspired by nature

Lake Simcoe Region conservation authority

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What we'll cover

- Polymer basics (nature, safety, efficacy)
- Polymer literature review
- Field evaluation of anionic polyacrylamide (PAM)
  - Ditch application
  - Tank application
  - Results
- Anionic PAM Application Guide and Backgrounder

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What are polymers?

- Large molecules composed of many repeating units, known as monomers
- Polymers can be:
  - Anionic (negatively charged)
  - Cationic (positively charged)
  - Non-ionic (no charge)
  - Organic or inorganic
- Organic polymers can be:
  - Natural (e.g. starch, rubber, DNA, proteins)
  - Synthetic (e.g. nylon, teflon, PVC, polyacrylamide)
  - Semi-synthetic (e.g. vulcanized rubber, chitosan)

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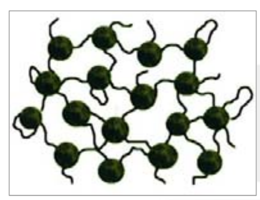
What are polymers?

- Polymers can also be flocculants and coagulants.
- A polymer ***flocculant*** adsorbs onto suspended particles and forms bridges between them, creating larger aggregates.
- A polymer ***coagulant*** neutralizes the negatively charged particle surface so that particles will no longer repel one another, making it easier for them to bind together.



Flocculation

Coagulation

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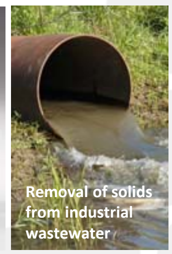
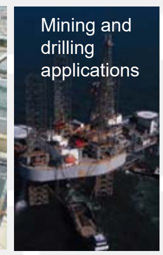
Uses of polymers

- Polymer flocculants and coagulants are widely used in industry to aid in solid liquid separations.





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Polymers for Construction Sediment Management

- Polymers that help bind soil particles together also have environmental applications (e.g. agriculture, mining, ESC)
- On construction sites, these types of polymers are used to:


Stabilize bare soils to prevent erosion


Remove suspended solids from sediment-laden water


Consolidate wet sediment during pond cleaning

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Polymers for Construction Sediment Management

- Polymers used for ESC or other environmental applications should be:
  - non-toxic to humans and other terrestrial and aquatic organisms
  - effective at reducing water turbidity and/or binding soil particles
  - practical for use in the outdoors
  - otherwise safe.
- Common polymers used for ESC applications:
  - Polyacrylamide (PAM)
  - Chitosan

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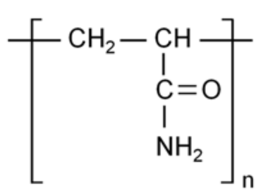
What is Anionic Polyacrylamide?



- High molecular weight, water soluble molecule formed by polymerization of negatively charged acrylamide co-monomer.
- PAM aids solid-liquid separation by causing suspended particles to bind and form larger aggregates.
- The process is known as ***polymer bridging***.

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What is Anionic Polyacrylamide?

- One of the most common polymer flocculants on the market
- Common uses of PAM as a flocculant:
  - reduction of sediment and nutrient loads to natural lakes and ponds
  - wastewater and drinking water treatment
  - clarification of effluents in industries like pulp & paper, aquaculture
- Also popular for erosion prevention in irrigation furrows and on construction sites.
- Promising performance and low toxicity findings in studies completed to date.

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Anionic vs. Cationic PAM

- Polyacrylamides can be anionic (negatively charged) or cationic (positively charged).
- Fish have a negative charge on their gill mucous.
- Anionic PAMs are repelled by the negative charge on fish gills, while cationic PAMs are attracted to it.
- As a result, the cationic PAM will attach to gills, causing suffocation of the organism.

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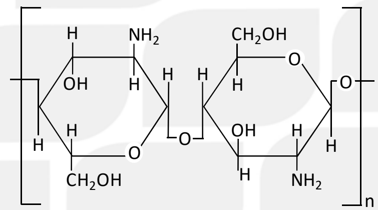
What is Chitosan?

- A cationic biopolymer derived from chitin, the major component of crustacean shells.
- Repeating unit (monomer) is glucosamine.
- Chitin is abundant in nature, biodegradable, biocompatible and derived from renewable materials



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Chitosan

- Used as a flocculant in many industries, including waste and drinking water treatment.
- Due to low water solubility, must be prepared by dissolving in slightly acidic solution.
- Common preparations include chitosan acetate (dissolved in acetic acid) and chitosan lactate (dissolved in lactic acid).
- Generally higher toxicity relative to anionic PAM due to its cationic nature
- Often used in active treatment systems
- Residual chitosan can be detected with test kits.

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Polymer Literature Review


FIELD RESULTS USING POLYACRYLAMIDE TO MANAGE FURROW EROSION AND INFILTRATION

ScienceDirect

Effects of chemical amendments on aquatic floc settling and strength

ScienceDirect

Chitin and chitosan: Properties and applications

Marguerite Rinaudo

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Literature Findings

Performance

- Both anionic and cationic PAMs and chitosan were effective in clarifying turbid waters.
- Turbidity reductions: PAMs: >85% and chitosan enhanced sand filtration: 94%.
- Anionic PAM is an effective erosion control.
- Reduces sediment, nutrients and metals in runoff from treated soil surfaces.

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Literature Findings

Toxicity

- Low toxicity of anionic PAM to aquatic invertebrates and fish.
- Cationic PAM and chitosan exhibited higher toxicity to fish than anionic PAM.
- Evidence of higher anionic PAM toxicity to aquatic invertebrates than to fish, with wide variation according to species.
- Oil-based emulsions of anionic PAM demonstrated higher toxicity than other forms PAM (*e.g.* gel blocks, powder)
- Higher emulsion toxicity attributable to additives (*e.g.* emulsifiers).

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Anionic PAM toxicity to invertebrates

Study	Anionic PAM form	LC50 (mg/L)	Comments
Weston et al., 2009	granular	Hyalella azteca: >100 Chironomus dilutus: >100 Ceriodaphnia dubia: 28.7	H. azteca and C. dilutus tested for 96 hrs, C. dubia for 6-8 days
	oil-based emulsion	Hyalella azteca: 0.8 and 2.1 Chironomus dilutus: 3.0 Ceriodaphnia dubia: 0.3	H. azteca and C. dilutus tested for 96 hrs, C. dubia for 6-8 days 2 different trials done for Hyalella azteca
	water-based liquid	Hyalella azteca: >100 Chironomus dilutus: >100 Ceriodaphnia dubia: >100	H. azteca and C. dilutus tested for 96 hrs, C. dubia for 6-8 days
Hall and Mirenda, 1991	emulsion	Daphnia pulex 0.09 – 0.66	96 hr test, range of anionic PAM emulsions tested
de Rosemond and Liber, 2004	granular	Ceriodaphnia dubia: 218	48 hr test
Biesinger et al., 1976	granular	Daphnia magna: 345, 17	48 hr test, 96 hr test
Biesinger and Stokes, 1986	granular	Daphnia magna: >100	48 hr test

***Hyalella azteca* – amphipod crustacean • *Daphnias* – Water fleas • *Chironomus dilutus* – Lake flies**

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Anionic PAM toxicity to fish

Study	Anionic PAM form	LC50 (mg/L)	Comments
Weston et al., 2009	granular	Fathead minnow: >100	Tested for 7 days
	oil-based emulsion	Fathead minnow: 16.6	Tested for 7 days
	water-based liquid	Fathead minnow: >100	Tested for 7 days
Hall and Mirenda, 1991	emulsions	Fathead minnow: 21 - 85	96 hr test, range of products tested
Kobunshi Gyoshuzai Konwakai (1986)	unknown	Rainbow trout: 53.2 and 75.2	96 hr test, two different PAM products tested
Biesinger & Stokes, 1986	granular	Fathead minnow: >100	48 hr test
Liber et al., 2005	granular	Lake trout: >600	96 hr test

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Literature Findings

Toxicity

- Some concerns regarding potential release of acrylamide (AMD) – a carcinogen and neurotoxin – from PAM products.
- PAMs are highly stable and do not readily degrade to AMD in natural environmental conditions.
- Properly selected and application of anionic PAM is key.
- Anionic PAM should be selected, applied and otherwise handled based on manufacturer recommendations.
- Residual AMD in manufactured PAMs should be below threshold set by the U.S. EPA for drinking water treatment: 0.05%

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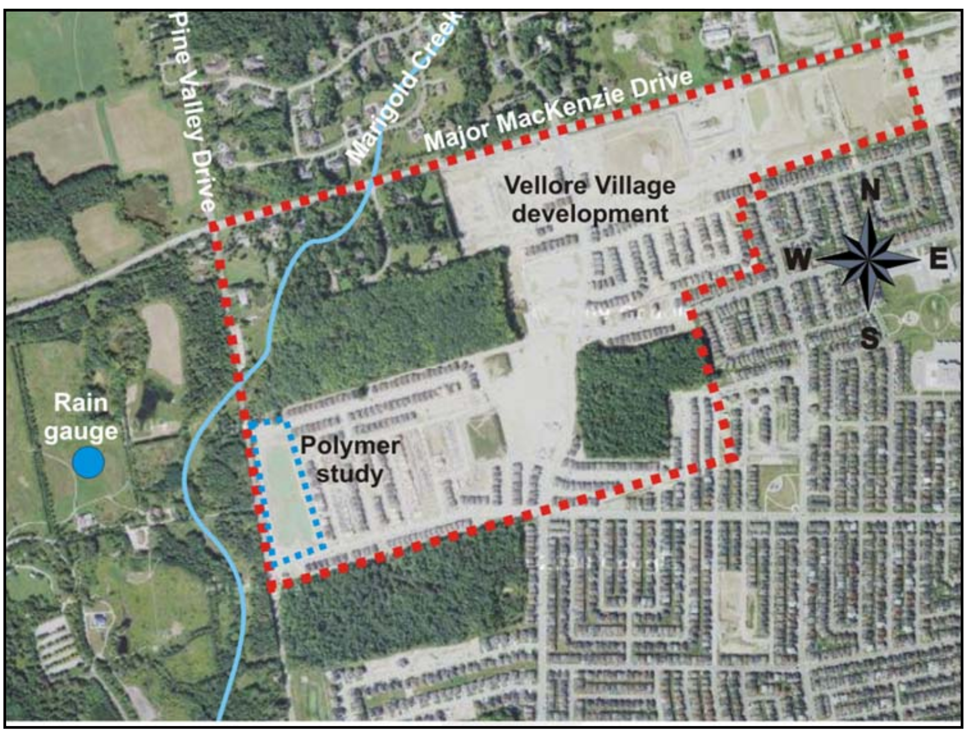
Field Evaluation of Anionic PAM

City of Vaughan, Ontario

- Objective: assess effectiveness of PAM for clarifying water pumped from the sediment control pond.
- Two applications tested:
  1. dewatering ditch
  2. PAM mixing tank and settling tank
- Demonstrate potential water clarification options during construction dewatering
- Using a controlled flow rate facilitated polymer dosing



Study Objectives

- Quantify performance of anionic PAM for sediment removal from construction runoff in two pond dewatering applications.
- Determine which application tested is the most effective.
- Identify the key factors that affected performance.
- Apply results to help determine best practices for anionic PAM use in Ontario

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Polymer Products

- Evaluated anionic PAM based products manufactured by Applied Polymer Systems (APS)
- Primary product used was the Floc Log®, a semi-solid block composed of drinking water chemicals and PAM
- In the ditch application an anionic PAM-based powder, sold by APS as Silt Stop®, was also used.

Ditch Application

- A south-draining 94 m stretch of the roadside ditch was retrofitted with a polyethylene liner, rock check dams, Floc Logs & jute netting coated with Silt Stop powder.
- Ditch received sediment laden water pumped from the sediment control pond.
- Experimental control: 52-metre long north-draining ditch retrofitted with everything except PAM products.
- Two separate experiments were carried out during periods of elevated pond turbidity in order to assess performance.

Ditch Application

- Experiment 1 – August 20, 2009
  - water pumped into ditch at 11 L/s
  - samplers set up at beginning and end of each ditch
  - samples collected hourly following a 60mm rainfall
- Experiment 2 – September 9, 2009
  - Logs re-positioned to improve contact with water
  - influent turbidity elevated through manual disturbance of pond bottom sediments near the pump intake.
  - Grab samples taken at different points in the ditches to measure the decline in turbidity along the flow path.
  - Samples were taken at two flow rates (8 L/s and 11 L/s) and at different influent turbidities

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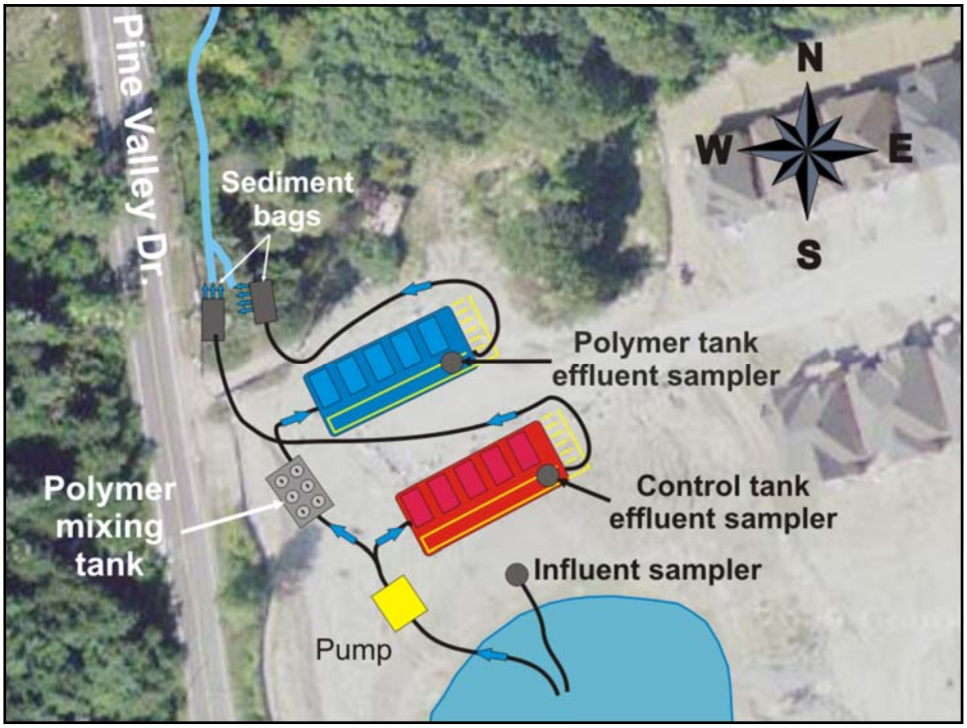
Tank Application

- Water pumped from the pond was dosed with anionic PAM Floc logs via a 1.8 m^3 mixing tank.
- Dosed water was pumped through to a large settling tank, followed by a sediment bag for final filtration and flow dispersion.
- Experimental control consisted of settling tank and downstream sediment bag.



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Tank Application

- Experiment 1: December 2, 2009
  - Sampling followed 17 mm rainfall
  - Influent and settling tank effluent samples collected
  - Handheld turbidity measurements showed samples were too clear for the test
- Experiment 2: December 4, 2009
  - Influent turbidity elevated through manual disturbance of pond bottom sediments
  - Samples collected included influent, settling tank effluent, and sediment bag (final) effluent
  - Log thawing was required due to freezing conditions

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Results

- For both applications, polymer systems resulted in greater TSS reductions than corresponding controls.
- Largest TSS reductions observed in polymer systems on Sept. 9 (88%) and Dec. 4 (95%).
- Polymer systems were capable of reducing TSS concentrations to below 25 mg/L.
- Polymer tank system with the sediment bag achieved largest TSS reduction (95%) and lowest effluent TSS concentration (13 mg/L).
- For controls, effluent TSS consistently >25 mg/L (ranging from 74 to 153 mg/L), even when percent TSS reduction was high.

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Factors influencing performance

Three functions governing effectiveness of PAM-based systems:

1. *Dosing*
   - Re-positioning of the Floc Logs improved ditch performance from 8% to 88% TSS reduction
   - Freezing of the logs resulted in decreased sediment removal performance.
2. *Mixing*
   - During the Sept. 9 ditch test, TSS levels progressively decreased from the inlet to the outlet.
   - Optimization of flow rate and system length and structure are essential to proper mixing.

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Factors influencing performance

3. *Final filtration*
   - Geotextile bag filtration decreased TSS in polymer tank effluent from 42 mg/L to 13 mg/L.

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Anionic Polyacrylamide Application Guide for Urban Construction in Ontario



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Product selection criteria

- Anionic PAM as the active ingredient
- Site specific performance testing
- Moderate charge density – 8 to 35% by weight
- High molecular weight – 6 to 24 mg/mol
- No emulsions
- Safe according to toxicity reports and MSDS, given the expected release rates
- Residual acrylamide <0.05%
- Appropriate product labels and use instructions

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General PAM Use Guidance

- Qualifications of professionals
  - Training + experience with polymers
- Appropriate documentation of PAM use
  - e.g. product details, site specific performance test, application date, rate and location
- Safety tips for product handling
  - PPE required, clean up procedures
- Spill response
  - Minor vs. significant spills
  - Reporting and documentation requirements

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Disposal considerations

- Settled sediment quality testing to determine disposal options.
- In Ontario, the Ministry's *Soil, Ground Water and Sediment Standards* (2011) provides contaminant thresholds for different land uses.
- Anionic PAM not listed in the Standards or classified as hazardous waste
- New excess soil guidance and regulation under development in Ontario.
- Approval for reuse of sediment containing anionic PAM is considered by MOECC on a case-by-case basis.

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Anionic PAM for erosion control

- Application methods:
  - Broadcast of granules
  - Sprayed as a water based solution
  - Incorporated into a hydroseeding mixture
- Construction site areas suitable for anionic PAM use:
  - soil stockpiles
  - low traffic sloped areas
  - stripped areas left inactive for extended periods of time
  - cut-off swales/ditches
  - other stripped areas where dust control is needed

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Anionic PAM for erosion control
Guidelines

- Applied >15m from wells or natural water features.
- Only applied alone (without other ground cover) to areas receiving non-concentrated flows.
- Prepare soil surface (i.e. fill rills, gullies).
- Preferred application is with seed or other ground cover rather than alone on bare soil.
- Apply at a rate based on manufacturer recommendations, avoiding excess that could wash into natural features.

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Anionic PAM for erosion control
Guidelines

- Surface wetting following application of granular PAM should be done through controlled watering (rather than awaiting rainfall).
- Re-apply according to manufacturer recommended frequency or sooner if erosion is observed (six week interval is recommended).
- The condition of the PAM-stabilized surface should be inspected weekly and before and after any rainfall event.
- Deficiencies observed during inspection of an anionic PAM treated surface should be ***rectified within 48 hours or sooner if critical environmental receptors are at risk of adverse impact.***

Construction runoff clarification

- When can anionic PAM be useful?
  - dewatering an area with highly turbid water
  - situations where conveyance of turbid water to a sediment control pond is not possible
  - available sediment retention measures can't provide long enough detention time
  - Ideally, for water with TSS >100 mg/L.
- Guidance on the maximum TSS concentration that is treatable should be obtained from the manufacturer.

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Construction runoff clarification

Dosing considerations

- **Polymer product formulation**
  based on site specific soil and water testing
- **Flow rate of water through the system**
  based on consultation with manufacturer, with consideration for intended use, system design/dimensions, site restrictions (e.g. space)
- **Polymer product amount**
  calculated from standard 'quantity per unit flow rate' value provided by the manufacturer
- **Physical structure of the system**
  designed for maximum contact with polymer, avoiding short circuiting

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Construction runoff clarification
Mixing

- Mixing increases opportunity for reaction between water and polymer
- Often passive, with water flowing through barriers to create turbulence.
- Importance of flow rate
  Higher flow rate requires longer mixing zone than a slower flow rate.
- Mixing time calculated based on manufacturer guidance.

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Construction runoff clarification
Settling

- Settling area allows gravitational settling of flocculated masses.
- Sized to hold a significant amount of sediment without requiring overly frequent clean out.

- Area may include a natural fibre (e.g. jute or coir) coated with anionic PAM powder.
- PAM-coated fibre has electrostatic affinity for flocculated sediment particles.

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Construction runoff clarification

Filtration

- PAM-based treatment system effluents should be filtered
- Filter should have AOS of 0.15mm (150 microns)
- Filtration options:
  - non-woven geotextile filter bags
  - non-woven geotextile curtains
  - non-woven geotextile fabric in another configuration
- Prevent erosion: flow path stabilization + dispersion of effluent

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Construction runoff clarification

System siting

- Never sited in natural areas, including woodlots and water features (e.g. streams, lakes, wetlands).
- >10m between system outlet and receiving natural feature
- Consider susceptibility to vandalism, or damage related to extreme weather or construction activities.
- More resilient and/or protected system designs are preferable to exposed systems.

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Construction runoff clarification

Inspection, monitoring and maintenance

- Base inspection frequency on extent to which system is actively used
- Recommended frequency of inspection:
  - Daily during active periods
  - Before and after wet weather events during inactive periods
- Monitoring and maintenance program should include:
  - Inspection of filters
  - Assessment of sediment accumulation and clean out as needed (i.e. at 30% accumulation or if re-suspension occurs)
  - Inspection and maintenance of anionic PAM blocks
  - General inspection and maintenance of system components
  - Periodic collection of effluent samples for suspended solids testing

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THANK YOU!

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Find STEP studies and guidance documents at:
www.sustainabletechnologies.ca

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