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IJC 2009-2011 PRIORITY: EFFECTIVENESS OF WASTEWATER TREATMENT PLANTS FOR REMOVAL OF CHEMICALS OF EMERGING CONCERN

UPDATE FOR GREAT LAKES BINATIONAL TOXICS STRATEGY MEETING

December 1, 2010

IJC Multi-board Workgroup on CECs

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Charge from Commission

The IJC Multi-board Work Group on Chemicals of Emerging Concern (CEC) is addressing two topics during 2009-2011 priority cycle

- Assessment of the performance of wastewater treatment plants for removal of CECs
  - To provide the Parties with a sampling of the information which might be derived if a more fulsome evaluation was undertaken, the performance of a subset of the WWTPs in the Great Lakes basin will be examined
  - A literature review of the effectiveness of CEC removal technologies is expected to provide an opportunity to consider an array of potential WWTP upgrades

- Assessment of human and ecosystem health effects from exposure to CECs
  - The assessment of human and ecosystem health effects due to exposure to CECs will be accomplished through a literature review and an expert consultation workshop

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Assessment of the WWTP Performance: Outline of Approach

1. Develop inventory of facilities
2. Detailed survey of operating parameters for selected facilities
3. Literature search of the effectiveness of CEC removal technologies
4. Analysis of field studies of the performance of full scale facilities
5. Integration of steps (1-4)

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Team Members

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Bob Arnold (Univ AZ)

Saad Jasim (IJC)
Doug Alley (IJC)
Nick Hotz, Matt Kerwin (IJC)
Michael Laitta (IJC-Washington)

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Develop Inventory of Facilities

- Define total number of facilities which discharge into the Great Lakes basin
- Differentiate based on type of treatment operations (lagoon, primary, secondary, tertiary)
- Deliverables
  - Databases for both U.S. and Canadian municipal facilities
  - Summary statistics – total number by country, distribution by type
  - Overview map to illustrate locations within the watershed

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Canadian Facilities

- Ontario Ministry of the Environment/ Environment Canada have an existing database of municipal facilities and a map showing locations/type
  - Michelle Heyens provided recent (2009) update
- Database contains information for 470 facilities in Ontario

Location	Region, district, area names
Description	Name, plant works number, Plant address, owner, operating authority
Coordinates	Map coordinates
Receiving Water	Watershed name, conservation authority
Facility Information	Treatment type, Population, capacity (rated), average daily flow, Sludge disposal practice, disinfection method

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Summary Statistics - Canada

Treatment Type	# Facilities	Percentage
Primary	8	1.7
Communal Septic	7	1.5
Lagoon	174	37.1
Secondary	212	45.2
Tertiary	68	14.5

Total of 470 Facilities

} 59.7%

Not included in our analysis of municipal facilities:

- Wastewater treatment plants operated by First Nations
- Industrial treatment facilities

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General Findings - Canada

- Primary facilities – serve communities ranging from 1000 to 46000
  - Locations – Cornwall, Owen Sound, Timmins, Brockville, South Dundas, Nipigon, Amherstburg, Red Rock
- Lagoons – typically serve smaller communities; populations range from 50 to 15500
- Secondary plants – typical of the larger communities; all cities > 100000 employ secondary treatment, typically with chlorine disinfection

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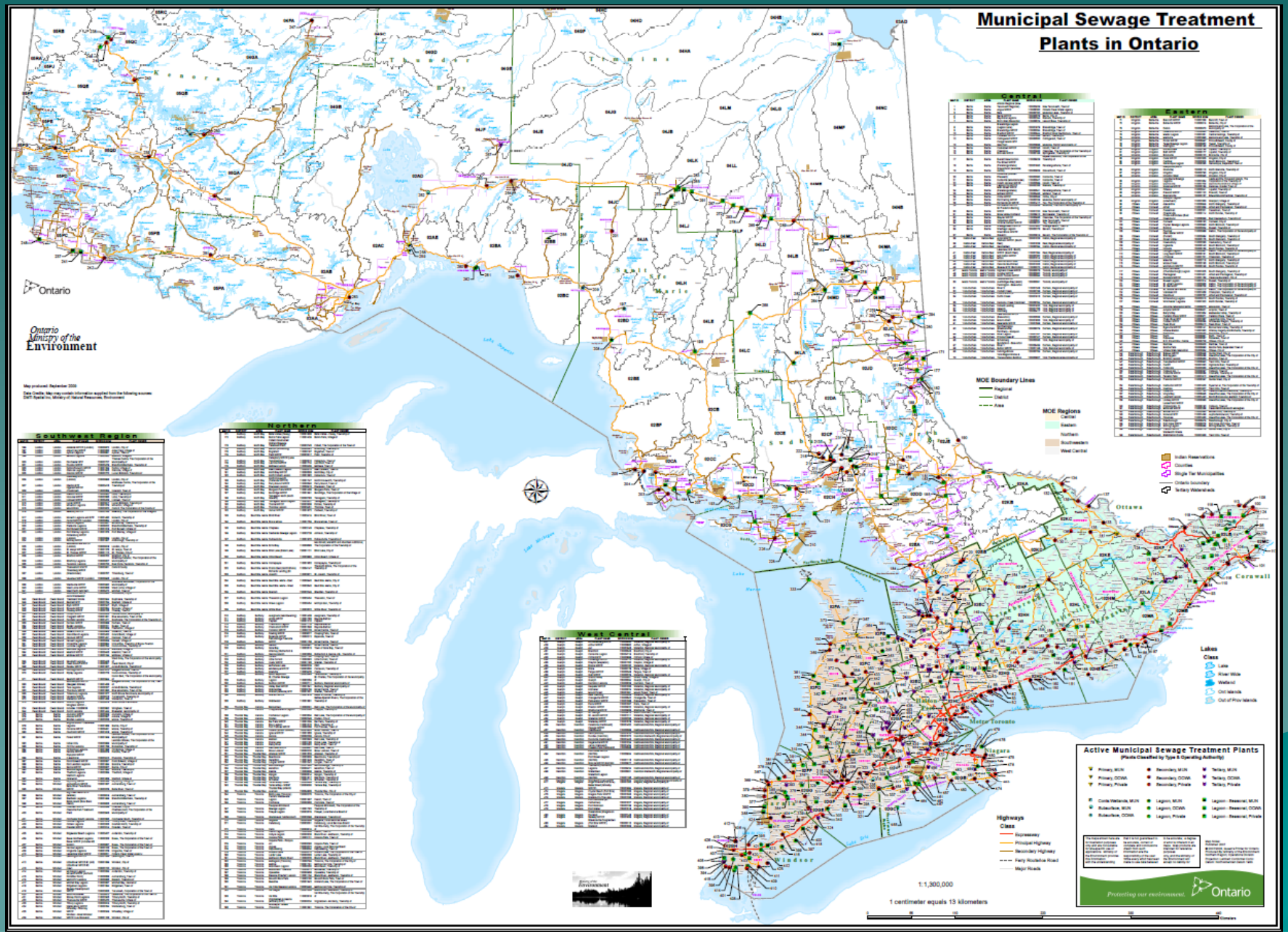
Location Map - Canadian STPs



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US Facilities

- Working with Michael Laitta (IJC-Washington) and Nick Hotz to develop a similar database and map for U.S. facilities which discharge into the Great Lakes basin
  - Build on recently completed 1:24,000 scale map of the Great Lakes drainage basin

- Challenge was to identify data sources for facilities in (8) States bordering the Great Lakes
  - Located USEPA Clean Watersheds Needs Survey
  - Database contains much of the same information as available for Canada

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Summary Statistics - US

Treatment Type	# Facilities	%
Primary	4	0.3
Communal Septic	4	0.3
Lagoons	104	6.5
Secondary	470	29.5
Tertiary	61	3.8
Advanced	567	35.5
Not Assignable	376	23.6

Total of 1595 Facilities

} 68.8%

- Database is still draft at this point – work continues to refine
- Development of GIS map also in progress

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Detailed Survey of Operating Parameters for Selected Facilities

- Project contracted to Veronica Loete and Dave Bennett of Brown and Caldwell, WI
- Criteria for selection of facilities included: geographic distribution, size, facility type, hydraulic loading, disinfection technology
- Surveys submitted to facilities to obtain detailed information on key operating parameters
- High response rate
  - Of 33 plants solicited, 25 responded to the request for information

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Selection Criteria

- Geographic Distribution
  - All 5 lakes included
- Plant size
  - Small < 10 MGD (10)
  - Med 10 - 50 MGD (14)
  - Large > 50 MGD (9)
- Treatment Type
  - Primary (2)
  - Lagoons (2)
  - Fixed Film 6)
  - Activated Sludge (22)
  - BNR (4)
  - Tertiary (6)
- Disinfection Technology
  - Chlorine (23)
  - UV (8)
  - None (2)

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Operating Parameters

- Various data were solicited from the candidate WWTPs

Readily accessible (reporting required)

- Flow rate
- Temperature
- Influent/Effluent
  - BOD_5
  - TSS
  - Ammonia, NH_3-N
  - Total P

Key Operating Parameters

- Organic Loading
- MLSS
- SRT
- HRT
- F/M

Requested data from monthly (avg, min, max) and annual (past 3 years) measurements

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General Observations

- Activated sludge is the most common secondary treatment technology used by the selected facilities (17 plants)
  - Within this group are different modes of operation:
    - Nitrification only
    - Biological nutrient removal (BNR)
    - Membrane bioreactor.
  - Chemical precipitation of phosphorus (or BPR) is practiced at all
- Biological fixed-film technology is second most common technology (4 plants)
  - Three of which use biological aerated filtration technology
  - One uses the trickling filter/solids contact process.
  - These fixed film processes are more advanced than the historically more common trickling filter (generally less effective in removal of CECs)
- Of the remaining plants:
  - Two are lagoon-based systems
  - Two have no secondary treatment process, employing only primary treatment (Nipigon) or activated carbon and chemical oxidation (Niagara Falls).

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CEC Removal

- One critical parameter that has been identified with high CEC removal (i.e., those biodegradable) is a high SRT
  - Some CECs are difficult to biodegrade since the microorganisms that have adapted to degrade them grow slowly
- SRT is related to the microorganism growth rate; serves as a surrogate measure of the ability of the activated sludge to retain slower growing organisms
- BNR systems are typically operated at higher SRTs than those that are designed to remove BOD only
  - Are able to retain the slower growing organisms that can degrade some CECs
- BNR systems often remove some CECs more efficiently than activated sludge systems operated at lower SRTs

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Insight into CEC Removals

- In the absence of CEC data, it is useful to compare the efficiency of the plants to remove ammonia
- Plants reporting SRT data can be divided into two groups
  - SRT < 5 days
  - SRT > 5 days
- Hamilton, Napanee and Detroit operate at SRT < 5 days
  - Effluent NH_3-N concs are in the 4-10 mg/L range
- Buffalo, Green Bay, Michigan City, both the Milwaukee plants, and Toledo operate at higher SRT, typically, > 10 days
  - Effluent NH_3-N concs for these plants are typically < 1.0 mg/L
- The lowest of effluent ammonia concentrations (< 0.2 mg/L) occur at Michigan City and the two Milwaukee plants
  - These plants operate at long SRT and higher HRT, likely conservatively designed for year-round nitrification

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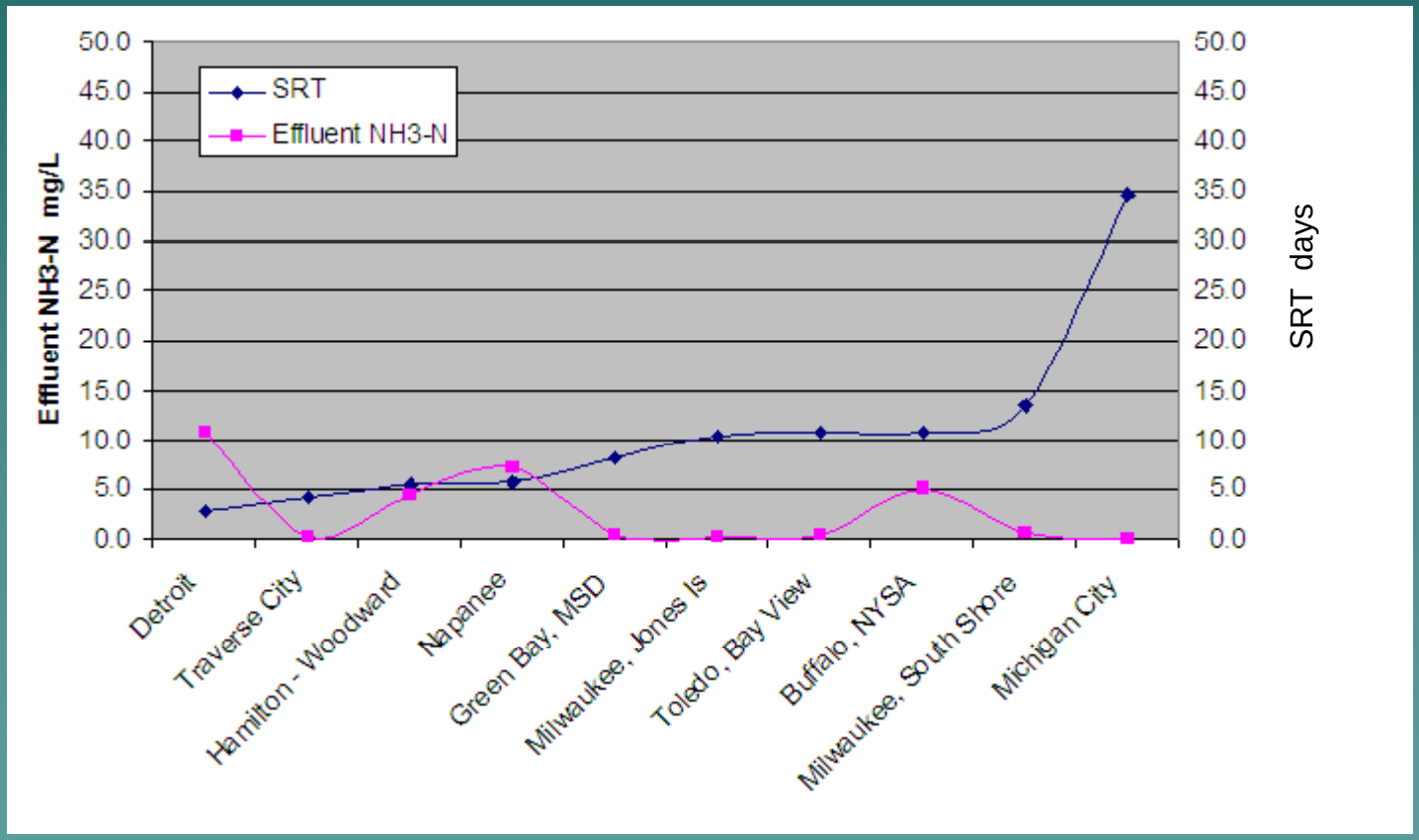
SRT vs Effluent NH_3-N



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Insight into CEC Removals

- Traverse City plant also produces a very high quality effluent with <0.2 mg/L ammonia as well as very low BOD and TSS concentrations
  - Attributed to the membrane bioreactor design for this plant
  - MBR facilities have higher level of control over sludge inventory
- However, advanced technologies may not always be required to achieve high quality effluent
- For example, the lagoon system at Muskegon achieved the lowest effluent ammonia concentrations of all 25 plants (<0.1 mg/L)
  - The effluent BOD and TSS concentrations were also very low (2 and 6 mg/L, respectively).
  - Performance suggests the plant was designed conservatively and is operated well

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Literature Search of the Effectiveness of CEC Removal Technologies

- Project contracted to Eduardo Saez, Mario Rojas, Bob Arnold (University of Arizona)
  - In addition to literature search, leveraging related prior work (e.g., WERF projects)
  - CEC substances/categories as defined under 2007-2009 priority
  - Additional substances included as they are identified in the search
  - Treatment technologies defined as those which are proven (AOP, membranes, chlorination, bank infiltration) and commercially available (vs. research)

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Literature Search of the Effectiveness of CEC Removal Technologies

- Status
  - Bibliography and summary table have been prepared
  - Over 700 citations addressing ~288 different chemicals
- Approach to Analysis/Interpretation
  - Weight of Evidence, based on consideration of
    - Physical-chemical properties (propensity for adsorption, volatilization)
    - Biodegradability
    - Laboratory studies under controlled conditions
    - Pilot plant results
    - Full scale observations (typically “snapshot” samples of influent/effluent)
- Final report expected end of Dec

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Analysis of Field Studies of the Performance of Full Scale Facilities

- WWT Team is collecting USEPA, Environment Canada, and WERF reports which summarize the performance of full scale facilities (not necessarily in the basin), e.g.,
  - USEPA 9 POTW Study
  - OMOE Study of 48 Ontario STPs
  - Numerous WERF reports
    - Contributions of Household Chemicals to Sewage and Relevance to Municipal WWTS
    - Fate of PPCP in WWT
    - Removal of EDCs in Water Reclamation Processes
- As noted, studies at full scale facilities are often “snapshots” based on limited influent/effluent analysis
  - Plan to combine with weight of evidence

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Integration – Final Report

- Henryk Melcer (Brown & Caldwell) will work with team members to prepare a draft report
- Jan 25, 26 – Team meeting to review progress, identify key conclusions, and develop strategy for final report
- Draft report will be reviewed and commented by the IJC multi-board workgroup, and provide the basis for the report submitted to the IJC by June 2011

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Appendix/Backup Slides

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Definitions of Treatment Types

- ***Primary treatment*** consists of temporarily holding the sewage in a quiescent basin where heavy solids can settle to the bottom while oil, grease and lighter solids float to the surface. The settled and floating materials are removed and the remaining liquid may be discharged or subjected to secondary treatment.
- ***Secondary treatment*** removes dissolved and suspended biological matter. Secondary treatment is typically performed by indigenous, water-borne micro-organisms in a managed habitat. Secondary treatment may require a separation process to remove the micro-organisms from the treated water prior to discharge or tertiary treatment.
- ***Tertiary treatment*** is sometimes defined as anything more than primary and secondary treatment in order to allow rejection into a highly sensitive or fragile ecosystem (estuaries, low-flow rivers, coral reefs,...). Treated water is sometimes disinfected chemically or physically (for example, by lagoons and microfiltration) prior to discharge into a stream, river, bay, lagoon or wetland, or it can be used for the irrigation of a golf course, green way or park. If it is sufficiently clean, it can also be used for groundwater recharge or agricultural purposes.
- ***Advanced Treatment*** waste water treatment process designed to produce an effluent of higher quality than normally achieved by secondary process or containing unit operations not found in secondary processing (in the U.S. sense). Advanced processing usually includes the total removal of nutrients (Nitrogen and Phosphorus). Advanced wastewater treatment can be applied to any level of treatment…usually to produce effluent of potable quality. These facilities are relatively few and very expensive.
- ***Lagoon-*** a pond designed to accelerate the settlement of solids (generic definition)
- ***Exfiltration Lagoon-*** (Canadian Term) used interchangeably with Lagoon.
- ***Tertiary with lagoon with emergency storage:*** see above definition for tertiary- the associated lagoon is designed for 'over-max' flow or emergency event control. These tertiary types are usually associated with highly sensitive areas.
- ***Tertiary with seasonal lagoons:*** see above definition for tertiary – seasonal lagoons are usually associated with facilities that are located in a 'highly responsive' (flashy) hyd area, or for tertiary facilities that deal with highly variable inputs.