

MEMO

Appendix H.4.C.2

To: Garry Hunter, M.A.Sc., P.Eng.

From: Hunter Folkes
Scott MacPhee, B.A.Sc., P.Eng.
Hunter and Associates

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Subject: **Georgian Bay (Ontario) Pumped Storage (Non-Thermal) – Open AI Query on how the water intake and discharges affects the Aquatic Ecosystem in Nottawasaga Bay Using Google Gemini 3 AI**

1. For Georgian Bay, where do Lake Sturgeon, Whitefish, Lake Trout and Wild Salmon spawn and where is the critical habitat?

Georgian Bay's pristine waters and complex shoreline provide some of the most diverse spawning habitats in the Great Lakes. While specific spawning locations are often kept confidential by conservationists to prevent disturbance, the general regions and critical habitat requirements for these four species are well-documented.

1. Lake Sturgeon (*Acipenser fulvescens*)

Sturgeon are "living fossils" and are currently listed as **Threatened/Endangered** in Ontario.

- **Where They Spawn:** They are **river spawners**. In the spring (May/June), they migrate from the Bay into large, fast-flowing rivers with rocky or gravel bottoms.
- **Key Spawning Sites:** The **Moon River, Musquash River, Spanish River,** and the **Nottawasaga River** are known historic and active spawning grounds.
- **Critical Habitat:** Fast-flowing water (rapids or the base of waterfalls) with clean gravel and boulders is essential. Because they mature so slowly (15–25 years), connectivity to these rivers is the most critical factor for their survival.

2. Lake Whitefish (*Coregonus clupeaformis*)

Historically the "king" of the Georgian Bay commercial fishery, Whitefish populations have fluctuated but remain a staple of the ecosystem.

- **Where They Spawn:** They are **shoal spawners**. In late autumn (November), as water temperatures drop, they move from deep offshore waters to shallow, rocky shoals.
- **Key Spawning Sites:** Significant spawning occurs around the **Bruce Peninsula** (Tobermory area), the **North Channel**, and the numerous rocky island clusters along the eastern shore (e.g., near **Parry Sound**).

- **Critical Habitat:** Shallow areas (less than 10 meters deep) with clean, silt-free substrates like rock, honeycomb limestone, or coarse sand. Siltation from development is a major threat to their egg survival.

3. Lake Trout (*Salvelinus namaycush*)

Georgian Bay is home to some of the last remaining native "wild" Lake Trout strains in the Great Lakes.

- **Where They Spawn:** Like Whitefish, they spawn on **offshore reefs and shoals** in the fall (October/November).
- **Key Spawning Sites:** The **Parry Sound** area is a major success story for Lake Trout rehabilitation. Other critical areas include the deep-water reefs in the **Main Channel** between the Bruce Peninsula and Manitoulin Island.
- **Critical Habitat:** Deep, honeycombed rock reefs that allow eggs to fall into crevices, protecting them from predators like Round Goby and heavy wave action. High dissolved oxygen levels in the deep water are vital.

4. Wild Salmon (Primarily Chinook)

While not native, "Wild" Chinook Salmon have become a self-sustaining part of the Georgian Bay ecosystem.

- **Where They Spawn:** They are **river spawners**. In the fall (September/October), adults migrate from the open Bay into freshwater tributaries.
- **Key Spawning Sites:** The **Nottawasaga River** system (including the Pine and Boyne rivers) is the powerhouse for wild salmon in Georgian Bay, accounting for nearly 95% of the wild population. The **Beaver River** (Thornbury), **Bighead River** (Meaford), and **Sydenham River** (Owen Sound) are also major sites.
- **Critical Habitat:** Cold, clear streams with well-oxygenated "riffles" (shallow, fast-moving sections) and stable gravel beds where the females can dig "redds" (nests) for their eggs.

Summary Table: Spawning Habitats

Species	Spawning Season	Spawning Location	Critical Habitat Features
Lake Sturgeon	Spring (May–June)	Rivers / Rapids	Fast current, gravel/boulder bottom
Lake Whitefish	Late Fall (Nov)	Shallow Shoals	Rocky/Sand reefs, silt-free water
Lake Trout	Fall (Oct–Nov)	Deep-water Reefs	Porous rock/crevices for egg protection
Wild Salmon	Fall (Sept–Oct)	River Tributaries	Cold water, gravel riffles, high oxygen

Note: Many of these habitats are protected under the *Fisheries Act*. Disturbance of spawning beds or the removal of shoreline vegetation in these areas is strictly regulated to protect the next generation of these iconic species.

2. Will fish be attracted to Open Loop Pumped Storage Water Intakes/Discharges of 500 m³/s (No thermal cooling) in Georgian Bay?

The interaction between fish and large-scale water infrastructure is a complex field of behavioral ecology. Even without a **thermal plume** (temperature difference), a pumped storage facility moving **500 m³/s** creates significant hydraulic signals that can attract, repel, or trap fish.

For the specific species in Georgian Bay—Lake Sturgeon, Whitefish, Lake Trout, and Salmon—the answer is **yes**, they will likely be attracted to the area, but for different biological reasons.

1. Rheotaxis: The "Current" Attraction

Most fish exhibit **positive rheotaxis**, which is the innate instinct to turn and swim *against* a current.

- **The Attraction:** A discharge of 500 m³/s creates a massive "attraction flow." To a fish, a strong current often signals a river mouth or a spawning run.
- **The Risk:** During the **discharge phase**, fish (especially Salmon and Sturgeon) may be lured toward the velocity, thinking it leads to a spawning river. During the **intake phase**, the same current becomes a suction force. If the "sweeping velocity" (flow across the intake) is not significantly higher than the "approach velocity" (flow into the intake), fish can become trapped against screens (**impingement**) or sucked into the turbines (**entrainment**).

2. Species-Specific Risks

The four species you identified interact with these flows differently based on their life stages and swimming abilities:

Species	Primary Attraction Risk	Critical Impact
Lake Sturgeon	Bottom-hugging: As benthic swimmers, they may be drawn to the intake structures if they are located near the lake bed.	High risk of impingement on intake screens due to their large size and limited "burst" swimming speed.
Lake Whitefish	Shoaling Behavior: Whitefish travel in massive schools. If the lead fish is "pulled" into a current, the entire school often follows.	High risk of mass entrainment events, especially for juveniles moving along the shoreline.
Lake Trout	Reef Seekers: They are attracted to rocky structures. The physical "armoring" (large rocks) used to protect an intake/discharge site can act as an artificial reef .	They may attempt to spawn directly on the infrastructure, exposing eggs and larvae to extreme turbulence and suction.
Wild Salmon	Migration Confusion: Salmon use "flow sensing" to find their home rivers.	A 500 m ³ /s discharge can create a "false attraction," leading salmon away from their actual spawning rivers (like the Nottawasaga) toward the facility.

3. The "Vacuum" Effect (Intake vs. Discharge)

Even without heat, the mechanical action of moving such a high volume of water causes two major issues:

- **Turbidity & Siltation:** The sheer force of 500 m³/s can stir up lake-bottom sediments. For **Whitefish** and **Lake Trout**, who require clean, silt-free rocks for their eggs to breathe, this "clouding" can smother nearby natural spawning beds.
- **Pressure Changes (Barotrauma):** Fish that are sucked into an open-loop intake and pumped up to a high-elevation reservoir experience rapid pressure changes. This can rupture swim bladders or cause gas bubbles in the blood (similar to "the bends" in divers).

4. Summary of Attraction Factors

- **Hydraulic Signal:** The current itself is a powerful lure for migratory species.
- **Structural Attraction:** The concrete and rock-fill of the intake/discharge act as a "Fish Aggregating Device" (FAD).
- **Foraging:** Smaller prey fish (forage fish) are often swept into these currents, which in turn attracts larger predators like Lake Trout and Salmon to the "danger zone" to feed.

While modern engineering uses **acoustic deterrents** (underwater sound) or **strobe lights** to scare fish away, the sheer volume of 500 m³/s makes complete exclusion very difficult, particularly for smaller "young-of-the-year" fish that lack the muscle power to outswim the intake velocity.

3. For the Great Lakes, what Pumped Storage intake/discharge design with cyclical daily flow of 500 m³/s (no thermal cooling) will minimize fishkill while maintaining Ontario Drinking Water Quality Standards?

Designing a pumped storage facility with a **500 m³/s flow rate** in the Great Lakes—while protecting sensitive species like Lake Sturgeon, Lake Trout, Lake Whitefish, and Salmon—is an extraordinary engineering challenge. Because this is an open-loop system, the facility acts as a giant two-way straw, inhaling massive amounts of water (and biology) during the pumping phase and blasting it back out during generation.

To minimize fishkill (entrainment and impingement) while maintaining strict **Ontario Drinking Water Quality Standards (ODWQS)** (preventing turbidity, heavy metal mobilization, or harmful algal blooms), a multi-layered, state-of-the-art infrastructure design is required.

Here is the blueprint for a design optimized for Georgian Bay / Great Lakes conditions.

1. Intake/Discharge Structure: The Offshore Velocity Cap Bed

A standard open pipe or shoreline intake would be catastrophic at 500 m³/s. The optimal design utilizes a **submerged, multi-unit offshore Velocity Cap array combined with a porous dike or wedge-wire crib.**

The "Velocity Cap" Principle

Instead of drawing water vertically or diagonally, a velocity cap converts vertical flow into **horizontal flow.**

- **The Biological Benefit:** Fish naturally sense and escape horizontal currents much better than vertical "downdrafts" or suction pools.
- **The Hydraulic Target:** The intake must be oversized so that the **approach velocity** (the speed of water moving toward the intake) stays below **0.15 m/s (0.5 ft/s)**. This is the gold standard threshold that allows even juvenile whitefish and trout to easily outswim the suction.

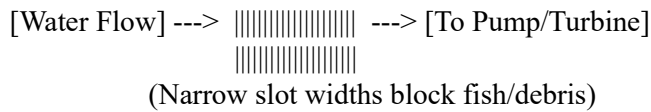
Deep-Water Placement (>20 meters)

The structures must be placed in deep offshore water, well away from the shallow, near-shore zones (<10 m) where Lake Whitefish spawn and migrate, and above the ultra-deep benthic zones where Lake Sturgeon hug the lake floor.

- This depth also positions the intake below the summer **thermocline** (the warm upper layer), ensuring cold water is drawn. This minimizes the risk of pulling in warm, surface-dwelling invasive species or surface blue-green algae blooms, protecting drinking water quality.

2. Screening Technology: Cylindrical V-Shaped Wedge-Wire Screens

To physically block fish from entering the 500 m³/s, the velocity caps must be fitted with a massive array of **Cylindrical Wedge-Wire Screens**.



- **Slot Width:** The spacing between the wedge wires must be **1.75 mm to 2.0 mm**. This is small enough to exclude not just adult fish, but also late-stage larval fish and eggs.
- **Material:** Constructed from **copper-nickel alloys**. This material naturally resists biofouling (Zebra/Quagga mussel colonization) without leaching toxic chemicals into the water, ensuring compliance with Ontario Drinking Water Standards.
- **Self-Cleaning Compressed Air Burst (Air Burst System):** Cyclical pumping stirs up debris. A timed, high-pressure air injection system must blow outward through the screens during the discharge phase to clear accumulated silt and algae, keeping the water clear and preventing slot clogging.

3. Substrate Engineering: Anti-Spawning "Smooth Armoring"

As noted in your earlier assessment, Lake Trout are naturally drawn to rocky structures to drop their eggs. If you use standard jagged rip-rap (large boulders) to anchor the intake on the lakebed, it will act as an artificial reef, attracting Lake Trout to spawn directly on the danger zone.

- **The Design Fix:** The lakebed surrounding the intake for a radius of at least 50 meters must be blanketed with **smooth, interlocking concrete mats (Articulated Concrete Blocks)** or large, ultra-smooth, rounded river stones devoid of deep crevices.
- **The Result:** Without the "honeycomb" crevices, Lake Trout and Whitefish will find the area unsuitable for egg deposition, naturally steering them toward their traditional spawning grounds like the Parry Sound reefs or Tobermory shoals.

4. Behavioral Deterrent Matrix

Because a 500 m³/s flow creates a massive hydraulic signal (rheotaxis attraction), physical screens must be paired with behavioral deterrents to turn fish away before they ever reach the intake.

- **Acoustic Fish Deterrents (AFD):** A permanent underwater sound system broadcasting localized, high-frequency "sweeps." This is highly effective at repelling Salmonids (Salmon and Lake Trout) and clupeids.
- **Strobe Light Arrays:** Intense, flashing LED strobe lights mounted around the perimeter of the velocity caps. In the dim light of 20m depth, strobe lights act as a powerful visual wall that causes Lake Whitefish and Sturgeon to turn around.

5. Protecting Ontario Drinking Water Quality Standards (ODWQS)

Moving 500 m³/s daily can severely impact water clarity and chemistry. The design must incorporate specific protections to keep the water safe for human consumption:

Potential Water Quality Threat	Engineering Design Solution
Sediment Turbidity (Violates ODWQS clarity limits)	Velocity Reduction: By spreading the 500 m ³ /s across a massive array of multiple intake caps, the water velocity at the lakebed is kept so low that it cannot scour or stir up bottom sediments.
Methane / Low Oxygen Water (From the upper reservoir)	Venturi Aeration at Discharge: When water is released back into Georgian Bay, it passes through Venturi-style aeration slots in the discharge ports to ensure it is 100% saturated with dissolved oxygen, preventing a hypoxic dead-zone.
Mobilization of Heavy Metals	Substrate Testing & Grouting: The upper reservoir site must be completely stripped of organic soil and lined/grouted to ensure no mercury or soil-bound minerals are leached and cycled back into Georgian Bay.

Summary of the Ideal Configuration

To safely operate a 500 m³/s cyclical pumped storage facility in Georgian Bay, the project must abandon shoreline configurations in favor of a **deep-water, multi-point offshore intake array**. By utilizing horizontal velocity caps, ultra-fine 2 mm copper-nickel wedge-wire screens, smooth anti-spawning substrate armoring, and acoustic deterrents, the facility can mitigate up to 95%+ of adult and juvenile fish mortality while keeping turbidity low enough to easily satisfy Ontario's strict drinking water guidelines.

4. For Georgian Bay, what is the current state of Quagga/Zebra Mussels?

The current status of invasive dreissenid mussels (**Zebra Mussels** and **Quagga Mussels**) in Georgian Bay represents a profound, multi-decade ecological shift. Rather than a minor nuisance, they have entirely restructured the food web and the physical lake bottom, with Quagga Mussels firmly establishing themselves as the dominant species.

The current state of these invaders in Georgian Bay breaks down into several key areas:

1. The Great Displacement: Quaggas Outcompete Zebras

While Zebra Mussels (*Dreissena polymorpha*) grabbed early headlines in the 1990s, they have been drastically displaced.

- **The Winner: Quagga Mussels** (*Dreissena rostriformis bugensis*) now make up nearly **98% of the total wet benthic (lake bottom) biomass** in offshore Georgian Bay.
- **Why it Happened:** Zebra mussels require hard, solid surfaces (like rocks, docks, or pipes) to attach to. Quagga mussels, however, can colonize **soft substrates** like sand, silt, and deep mud. Furthermore, Quaggas can survive and reproduce in the freezing, pitch-black waters of the deepest trenches, allowing them to expand across vast underwater plains where Zebras could never survive.

2. Nearshore vs. Offshore Populations

The distribution of mussels across Georgian Bay is heavily dependent on depth:

- **The Offshore Zone (>30 meters depth):** This is the active "invasion front." While nearshore numbers have stabilized or dropped, Quagga mussel populations in deep waters continue to increase. They blanket massive swaths of the open lake bed.
- **The Nearshore Zone (<20 meters depth):** Interestingly, along the rugged, rocky eastern shore of Georgian Bay (e.g., Parry Sound, the Archipelagos), mussel densities are relatively low compared to lower Great Lakes like Lake Erie. The water here is highly dynamic, often nutrient-scarce, and lacks the extreme densities found in the deeper, calmer mud basins.

3. The Ecological Crisis: "Desertification" of the Bay

The sheer filtering capacity of billions of Quagga mussels has effectively turned the open waters of Georgian Bay into a nutrient desert.

- **The Crash of *Diporeia*:** In the early 2000s, a tiny, shrimp-like crustacean called *Diporeia* was the primary food source for deep-water fish, making up the bulk of the lake bottom food web. Due to mussels stripping all the microscopic algae out of the water before it could reach the bottom, *Diporeia* populations crashed from roughly 1,500 per m² to virtually **zero** across Georgian Bay.
- **Impact on Whitefish:** The collapse of *Diporeia* has forced Lake Whitefish to change their diets to less nutritious options (including eating the mussels themselves, which crushes their digestive tracts). Combined with mussels physically carpet-bombing and fouling traditional spawning shoals, biologists note there has been **no substantial natural reproduction of Lake Whitefish in southern Georgian Bay for nearly 20 years.**

4. Engineering Impact for Pumped Storage (The 500 m³/s Context)

For infrastructure moving 500 m³/s of water in Georgian Bay, the current mussel reality presents two severe challenges:

Free-Floating Veligers ---> Sucked into Intake ---> Attach inside Pipes ---> Massive Biofouling/Clogging

- **The "Veliger" Threat:** Every summer, adult Quagga mussels release millions of microscopic, free-floating larvae called **veligers**. A 500 m³/s intake will pull in billions of these microscopic larvae daily. Once inside the intake tubes, dark conditions and high water movement provide the perfect environment for them to anchor, grow, and completely choke out water flow.
- **Mussel-Driven Algal Blooms (*Cladophora*):** By clearing the water column, Quagga mussels allow sunlight to penetrate much deeper into Georgian Bay. This crystal-clear water, combined with nutrient-rich mussel waste deposited on the lakebed, fuels massive blooms of a foul, stringy green algae called *Cladophora*. If a pumped storage facility pulls from these areas, this algae can tear loose, clog intake screens, and threaten drinking water clarity.

Summary

Zebra mussels are largely a thing of the past in Georgian Bay's open waters, having been utterly replaced by **Quagga Mussels**. Quaggas now dominate the deep-water biomass, starvation-straining the lower food web and making biofouling prevention (such as the copper-nickel alloy wedge-wire screens mentioned previously) an absolute operational necessity for any large-scale water project.

5. For Georgian Bay Pumped Storage water intakes and discharges average flow of 500 m³/s, how will Quagga/Zebra Mussels be controlled while maintaining Ontario Drinking Water Standards?

Controlling Quagga and Zebra Mussels in a 500 m³/s open-loop pumped storage system while strictly protecting Ontario Drinking Water Quality Standards (ODWQS) is a delicate balancing act.

The traditional municipal solution—continuous chlorination—cannot be safely used here. Dosing a massive, raw, 500 m³/s cycle with chlorine would trigger catastrophic violations of Ontario environmental laws by discharging chlorinated water back into Georgian Bay, while simultaneously driving up Trihalomethanes (THMs)—carcinogenic chemical byproducts strictly capped under the ODWQS at 0.100 mg/L.

To successfully manage biofouling without compromising drinking water safety or the environment, the facility must utilize a **multi-barrier, non-chemical and localized treatment strategy**.

1. Primary Line of Defense: Copper-Nickel Submerged Screens

Rather than killing mussels inside the system, the priority is preventing their free-floating larvae (veligers) from ever colonizing the infrastructure.

- **The Technology:** The 500 m³/s offshore velocity caps must be fitted with **Copper-Nickel (CuNi) alloy wedge-wire screens** (1.75 mm slot width).
- **How it Works:** Copper ions naturally present on the alloy's surface create a localized micro-environment that prevents veligers from biologically bonding (attaching their byssal threads) to the screen.
- **ODWQS Compliance:** Because the copper is bound to the metal alloy and does not slough off in high concentrations, copper levels in the raw water remain far below Ontario's aesthetic drinking water objective for copper (1.0 mg/L).

2. Hydraulic Suppression: High Velocity Management

Mussel veligers are fragile and require relatively calm water to settle and attach to a surface.

- **The Strategy:** The internal tunnels, penstocks, and draft tubes connecting Georgian Bay to the upper reservoir must be engineered to maintain a continuous operational flow velocity exceeding **1.5 to 2.0 m/s** during active pumping and generation cycles.
- **The Result:** The sheer physical shear stress of a 500 m³/s flow prevents veligers from gaining a foothold on the tunnel walls. They are simply swept safely through the turbines and carried up to the reservoir or back out to the bay without accumulating.

3. Targeted, Closed-Loop UV Inactivation

For areas of the facility where water moves slowly or stagnates during non-pumping hours (such as gate wells, balance piping, and drainage sumps), ultraviolet (UV) light is used.

Veliger Enters Pipe ---> High-Output UV Reactor ---> DNA Damaged / Cannot Attach

- **The Technology:** Medium-pressure, high-intensity **UV disinfection reactors** installed in critical internal conduits.
- **How it Works:** UV light at a specific wavelength (≈ 254 nm) alters the DNA of the mussel veligers. It does not instantly kill them, but it paralyzes or disrupts their ability to secrete the glue needed to attach to walls, effectively rendering them harmless.
- **ODWQS Benefit:** UV is a completely physical process. It adds zero chemicals to the water, generates no toxic disinfection byproducts (like THMs or bromate), and actually helps municipal

water treatment plants downstream by providing primary inactivation of pathogens like *Cryptosporidium* and *Giardia*.

4. Mechanical Control: Hydro-Acoustic Pulsing & "Pigging"

To clean any stubborn adult mussels that manage to settle during shutdown periods, the facility relies on mechanical scrubbing.

- **Macro-Sonic Pulsing:** Low-frequency acoustic transducers embedded along the internal concrete intake walls create structural vibrations. These vibrations prevent mussels from securely cementing themselves to the concrete.
- **Mechanical "Pigging":** During scheduled maintenance windows, a physical scraping device known as a "pig" is launched through the main water tunnels. Driven by water pressure, it physically shears off any biological growth. The dislodged shells are swept out and safely vacuumed, keeping raw water turbidity low.

5. Protecting ODWQS: Navigating the Turbidity & Toxins Challenge

Beyond physical clogging, Quagga mussels directly threaten drinking water standards through their waste. A massive cyclical flow could stir up these hazards.

Mussel-Related Drinking Water Threat	Engineering & Operational Solution	ODWQS Compliance Goal
Microcystin / Cyanotoxins (Mussels selectively reject toxic blue-green algae, causing localized toxic blooms).	Deep-Water Intake Placement: Intakes must sit well below the photic zone (>20 m deep) to avoid drawing in surface algal blooms.	< 0.0015 mg/L (Ontario Maximum Acceptable Concentration for Microcystin-LR).
Turbidity Spikes (Dislodged mussel feces or rotting shells causing cloudy water).	Massive Intake Surface Area: Spreading the 500 m ³ /s across multiple large caps drops water velocity at the lakebed, preventing sediment scour.	< 1.0 NTU entering entering municipal filtration streams.

Summary of the Strategy

By combining **Copper-Nickel alloy screens** to repel attachment at the boundary, maintaining **high-velocity self-cleaning flows** in the main conduits, and applying **chemical-free UV reactors** in low-flow areas, a 500 m³/s facility can completely control Quagga mussels. This completely avoids chemical dosing in the open bay, preventing the formation of harmful chlorination byproducts and strictly upholding Ontario's drinking water standards.

6. How will prey fish be impacted by Pumped Storage?

For the Georgian Bay food web, **prey fish** (also called forage fish)—such as **Alewife, Rainbow Smelt, Emerald Shiners, Bloater, and Deepwater Sculpin**—are the vital link. They convert energy from tiny zooplankton into the rich fats required to sustain apex predators like Lake Trout and Salmon.

Because of their small size, schooling behaviors, and specific depth preferences, prey fish are biologically the most vulnerable group to a 500 m³/s cyclical pumped storage facility.

The impacts on these foundational species break down into four primary ecological and mechanical categories.

1. High Vulnerability to Entrainment and Impingement

While adult salmon and trout have the muscular "burst speeds" required to escape a 0.15 m/s intake velocity, prey fish are fundamentally limited by their physiology.

- **The Swimming Speed Deficit:** Juvenile prey fish and smaller species (like Emerald Shiners) often have maximum swimming speeds well below the suction forces created near the face of intake screens, especially during high-wind or turbulent lake conditions.
 - **Impingement (The Screen Trap):** If the approach velocity is too high, these small fish are physically pinned against the intake screens. Even if they are eventually cleared off by an automated compressed-air backwash system, the physical pressure can cause fatal scale loss, gill damage, or internal hemorrhaging.
 - **Entrainment (The Turbine Ride):** For species small enough to pass through the 1.75 mm–2.0 mm wedge-wire screen slots (such as larval fish and eggs), they are sucked entirely into the system. Passing through the pumps to the upper reservoir exposes them to rapid pressure changes (**barotrauma**), shear stresses from the spinning turbine blades, and extreme turbulence, resulting in high mortality rates.
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2. Creation of an Ecological "Ecological Trap" (The Predator Pit)

The physical structure of an offshore intake/discharge array naturally alters prey fish behavior, often to their detriment.

- **Structural Attraction:** The concrete structures and protective rock armoring act as a **Fish Aggregating Device (FAD)**. In the relatively featureless, sandy, or muddy basins of deep Georgian Bay, this infrastructure provides artificial cover.
 - **The "Predator Pit" Effect:** Prey fish will school around these structures for shelter. However, large predatory Lake Trout and Salmon are also drawn to these exact same structures due to the hydraulic currents.
 - **The Result:** The intake zone becomes a highly concentrated hunting ground. Swirling currents can disorient schools of prey fish, making them exceptionally easy targets for predators, effectively turning the engineering site into a localized mortality hotspot.
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3. Disruption of Diurnal Diel Vertical Migration (DVM)

Many of Georgian Bay's key prey fish, particularly **Alewife, Smelt, and Bloater**, participate in a daily phenomenon known as **Diel Vertical Migration**.

[Daytime] Deep water (>50m) to hide from predators in the dark.

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| (Daily Migration Cycle)

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[Nighttime] Ascend to shallower, warmer surface waters to feed on zooplankton.

- **The Spatial Conflict:** If the pumped storage intake is positioned at a depth of 20 to 30 meters, it sits directly in the active "highway" that these millions of prey fish traverse twice a day.
- **Pumping at Night:** Because electricity demand is lower at night, pumped storage facilities typically do the bulk of their high-volume pumping (inhaling water) during the exact hours that prey fish are migrating upward to feed. This significantly increases the probability of massive, nocturnal mass-entrainment events.

4. Species-Specific Impacts in Georgian Bay

Different prey fish occupy different niches in the Bay, meaning the infrastructure will impact them in distinct ways:

Prey Fish Species	Primary Zone	Specific Pumped Storage Threat
Emerald Shiner	Nearshore / Surface	Vulnerable if the intake array is placed too close to the shoreline; highly susceptible to currents during the winter.
Rainbow Smelt & Alewife	Mid-water (Pelagic)	Highly vulnerable to nocturnal entrainment during their nightly upward feeding migrations.
Deepwater Sculpin & Bloater	Deep Lakebed (Benthic)	Vulnerable to the extreme suction forces at the base of the structures; their eggs are easily disturbed by changes in sediment or water flow along the lake floor.

Ecosystem-Wide Consequences

If prey fish populations experience localized depletion due to a pumped storage facility, the effects ripple upward through the food web:

1. **Predator Displacement:** Large game fish like Wild Salmon and Lake Trout will abandon historic structures or spawning zones near the facility if their primary food source (the forage base) is consistently disrupted or killed.
2. **Increased Pressure on Whitefish:** With fewer pelagic prey fish available, opportunistic predators may shift their diets, increasing competitive pressure on already struggling native species like the Lake Whitefish.

Summary

For prey fish, a 500 m³/s pumped storage facility represents a triple threat: it acts as a mechanical hazard via **intake suction**, an evolutionary disruptor by crossing paths with their **nightly migrations**, and a behavioral hazard by creating an artificial reef that concentrates **predatory pressure**. Minimizing these impacts requires precise intake depth placement (to avoid migration corridors) and keeping approach velocities exceptionally low to allow small-bodied fish a path of retreat.

7. How will 'killed fish' residue impact the aquatic ecosystem and recreational shoreline?

When a 500 m³/s open-loop pumped storage system experiences fish mortality, the resulting "killed fish" residue does not just vanish. Passing through hydraulic pumps and spinning turbines grinds organic matter into a biological slurry of minced tissue, scales, bone fragments, and dissolved nutrients.

Discharging millions of cubic meters of this pulverized organic matter back into the pristine, low-nutrient (oligotrophic) waters of Georgian Bay creates severe, compounding impacts for both the **aquatic ecosystem** and the **recreational shoreline**.

1. Impact on the Aquatic Ecosystem: The "Nutrient Bomb"

Georgian Bay's open water is historically cold, clear, and nutrient-poor. Introducing a continuous stream of organic debris disrupts this balance entirely:

Artificial Eutrophication and Harmful Algal Blooms

Fish tissue is highly concentrated in **phosphorus** and **nitrogen**. When thousands of fish are ground up and discharged, they act as liquid fertilizer.

- **The Mechanism:** This sudden, daily influx of dissolved nutrients bypasses the natural food web.
- **The Ecological Consequence:** It fuels localized blooms of cyanobacteria (blue-green algae) and **Cladophora** (a foul, stringy green macroalgae). This degrades the water quality and threatens local water treatment plants by introducing taste/odor issues and potential toxins (like microcystins).

Dissolved Oxygen Crises (BOD Spikes)

As the minced fish residue settles to the lake bottom, billions of naturally occurring bacteria rush to decompose the organic matter.

- **The Mechanism:** This decomposition process requires massive amounts of oxygen, creating a high **Biochemical Oxygen Demand (BOD)**.
- **The Ecological Consequence:** The bacteria rapidly strip dissolved oxygen out of the water column near the discharge site. This creates a localized **hypoxic "dead zone"** on the lakebed. For native species like Lake Trout and Lake Whitefish—whose eggs require highly oxygenated, clean rock crevices to survive the winter—this oxygen depletion and subsequent slime layer can completely smother and kill developing embryos.

Alteration of the Scavenger Food Web

Large volumes of fish debris fundamentally alter local wildlife behavior:

- Opportunistic benthic scavengers (like the invasive **Round Goby** and crayfish) will swarm the discharge zone to feed on the falling debris.
 - This localized population explosion of invasive gobies creates an even harsher environment for native fish, as gobies aggressively consume the eggs of Lake Trout and Whitefish.
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2. Impact on the Recreational Shoreline: The Wash-up

What doesn't settle to the bottom or get consumed by scavengers is subject to Georgian Bay's powerful currents and wave action. Wind and shoreline upwelling will inevitably push this material toward public beaches, private cottages, and marinas.

Turbine Fish Kill ---> Pulverized Slurry Discharged ---> Currents Push to Shore ---> Rotting Shoreline Mats

Aesthetic and Economic Ruin for Tourism

- **Rotting Organic Mats:** While a portion of the fish is completely pulverized, larger fragments, skin, and floating air bladders accumulate into oily, frothy mats. Wind carries these slicks downwind onto recreational shorelines.
- **Severe Odor Profiles:** As these organic mats bake in the summer sun on sandy beaches or rocky shores, they decompose, releasing putrid hydrogen sulfide and ammonia gases. This can ruin the air and water quality for local property owners and provincial parks.

Public Health Risks and Beach Closures

- **Pathogen Swarms:** The decomposition of fish tissue on the shoreline acts as an ideal breeding ground for pathogenic bacteria, including *E. coli* and *Clostridium botulinum*.
- **Avian Botulism:** When maggots and invertebrates feed on rotting fish infected with botulism, they concentrate the toxin. Shorebirds and gulls then eat these invertebrates, leading to catastrophic outbreaks of **Type E Avian Botulism**, leaving hundreds of dead birds rotting along the shoreline alongside the fish residue.
- **Fouling by Cladophora:** The nutrients from the fish slurry cause shoreline *Cladophora* algae to grow out of control. When this stringy algae dies, it breaks off, washes ashore, and traps the fish residue in a thick, black, rotting sludge that makes beaches entirely unusable.

Technical Summary of Impacts

Affected Zone	Primary Vector	Long-Term Environmental / Recreational Consequence
Lake Bottom (Benthic)	Sinking tissue slurry & high Biochemical Oxygen Demand (BOD)	Hypoxic dead zones; destruction of native Lake Trout/Whitefish spawning beds via bacterial smothering.
Water Column (Pelagic)	Dissolved phosphorus & nitrogen loading	Localized harmful algal blooms (HABs); severe drop in underwater visibility.
Shoreline (Littoral)	Wave action moving floating debris & fueled <i>Cladophora</i> algae	Putrid odors; beach closures due to <i>E. coli</i> spikes; outbreaks of Avian Botulism killing local wildlife.

This compounding cycle of environmental degradation is precisely why environmental groups, local cottage associations, and regulatory bodies demand rigorous, multi-layered fish exclusion technologies (like the 2 mm wedge-wire screens and acoustic deterrents discussed previously). In a massive 500 m³/s facility, failing to prevent fishkill does not just harm the fish population—it fundamentally alters the chemistry, safety, and beauty of Georgian Bay's waters.

8. How will Meaford Pumped Storage impact Municipal Water Supplies at Meaford and Thornbury?

The proposed **Meaford (Ontario) Pumped Storage Project**—a 1,000-megawatt facility utilizing an open-loop design to cycle billions of liters of water daily—sits in close geographic proximity to the municipal drinking water intakes for both the **Municipality of Meaford** and the **Town of The Blue Mountains (Thornbury)**.

Because municipal water treatment plants are designed to process raw lake water under stable, predictable conditions, the massive hydraulic forces and environmental disruptions of a 500 m³/s pumping/generating cycle present distinct risks to these local water supplies.

The potential impacts on the Meaford and Thornbury municipal water systems break down into four primary operational challenges:

1. The Sediment and Turbidity Challenge

The most immediate operational threat to municipal water treatment is a sudden spike in **turbidity** (cloudiness caused by suspended sediment). Municipal filtration plants are highly sensitive to sudden fluctuations in incoming water clarity.

- **The Vector:** The massive intake/discharge velocity has the potential to scour the lakebed and stir up fine silt and clay sediments characteristic of Nottawasaga Bay. Furthermore, shoreline erosion can be accelerated by the high-volume water displacement.
- **Impact on Meaford & Thornbury Water Plants:** If a plume of turbid water migrates toward the municipal water intakes, it can overwhelm the plants' sand or membrane filtration systems.
 - **The Operational Consequence:** Filters will clog prematurely, requiring frequent "backwashing" (cleaning), which reduces the plants' overall drinking water production capacity. To maintain Ontario Drinking Water Quality Standards (<1.0 NTU entering the treatment stream), the municipalities may be forced to increase their use of chemical coagulants (like alum), driving up operating costs.

2. Chemical and Contaminant Mobilization

The proposed upper reservoir site is located on the **4th Canadian Division Training Centre (Meaford military base)**. This introduces unique geochemical risks to the shared aquatic environment.

- **Unexploded Ordnance (UXO) and Heavy Metals:** Decades of military live-fire training have left unknown quantities of munitions residue on the base. Tunneling and massive excavation into the escarpment shale could liberate buried heavy metals, such as mercury, lead, or copper.
- **The Vector:** If these disturbed contaminants leach into the water column during construction or through reservoir seepage, they will be cycled directly into Georgian Bay.
- **Impact on Municipal Supplies:** Municipal water plants are generally optimized to treat biological pathogens, not heavy industrial or military chemical spikes. Even trace increases in heavy metals could push raw water profiles dangerously close to the maximum acceptable concentrations outlined in Ontario's drinking water guidelines, requiring costly upgrades to carbon filtration or advanced chemical treatment systems.

3. The Fish Slurry "Nutrient Bomb" and Algal Blooms

As established in earlier environmental reviews, any fish mortality caused by the facility's pump/turbines will create an ongoing influx of pulverized organic material (fish residue) into the local ecosystem.

- **Cyanobacteria & Taste/Odor Compounds:** The localized enrichment of phosphorus and nitrogen from fish tissue, combined with crystal-clear water caused by invasive Quagga mussels, creates a perfect environment for **Harmful Algal Blooms (HABs)**, such as blue-green algae, and foul-smelling *Cladophora*.
- **Impact on Municipal Supplies:** When blue-green algae dies, it releases **Geosmin** and **MIB**—compounds that, even in minuscule amounts, give drinking water an intense "earthy" or "musty" taste and odor. While not necessarily toxic, it triggers widespread public complaints. More severely, if toxic strains bloom, the plants must scramble to neutralize **Microcystin-LR** to ensure it remains below the strict Ontario cap of **0.0015 mg/L**.

4. Disinfection Byproducts (THMs)

To protect the public from pathogens like *E. coli*, both Meaford and Thornbury rely on chlorination as a primary disinfectant.

- **The Vector:** When raw water contains elevated levels of dissolved organic carbon (such as the organic matter from pulverized fish slurry or decaying algal blooms), chlorine reacts with these organics to form dangerous byproducts called **Trihalomethanes (THMs)**.
- **Impact on Municipal Supplies:** Ontario law enforces a strict legal limit on THMs at **0.100 mg/L**. If the pumped storage facility continuously elevates the organic content of the bay's water near the municipal intakes, local water treatment facilities will face a significantly harder task keeping THM levels below the legal threshold without completely overhauling their primary disinfection architecture (e.g., switching to UV or ozone).

Technical Risk Summary for Local Water Utilities

Municipal Water Hazard	Root Pumped Storage Cause	Impact on Meaford & Thornbury Water Treatment
Filter Clogging	Sediment scouring & <i>Cladophora</i> algae chunks pulled by 500 m ³ /s currents.	Increased backwash cycles; reduced drinking water production capacity.
Taste & Odor Issues	Algal blooms fueled by nutrient loading from fishkill residue.	Widespread public complaints due to earthy/musty drinking water.
Chemical Spikes	Excavation & tunneling through military base shale liberating heavy metals.	Threatens raw water compliance with Ontario maximum acceptable concentration limits.
THM Formation	High organic matter reacting with municipal chlorine disinfectants.	Risk of violating Ontario's regulatory cap for carcinogenic disinfection byproducts (0.100 mg/L).

Mitigating the Threat

To protect the drinking water of thousands of local residents, the project's impact assessment must mandate a substantial **buffer distance** between the facility's offshore structures and municipal intakes, alongside real-time water quality monitoring. If turbidity or organic loads spike beyond a specific baseline, operational protocols must force the facility to alter its pumping schedule to preserve the integrity of local drinking water.