STITCHING LANDSCAPES:
Architecture for Rehabilitating Abandoned Aggregate Quarries in Southern Ontario

by

Bilal Khan

Submitted in partial fulfillment of the requirements
for the degree of Master of Architecture

at

Dalhousie University
Halifax, Nova Scotia
March 2019

To my mother, Dr. Yasmeen Khan.

Contents

Abstract

Milton Quarry, located along the Niagara escarpment, is Ontario's largest resource for aggregate raw materials such as sand, gravel and limestone and is rapidly coming close to the end of its life-cycle, which raises questions about the manufactured landscape it will leave behind. This thesis questions whether these post-industrial landscapes on the Niagara Escarpment be re-imagined to actively rehabilitate the site through water, while simultaneously provide opportunities for recreation, education and research? The thesis aims to propose a design strategy that addresses the prototypical nature of quarry abandonment on the Niagara Escarpment and uses the site as a case study to create infrastructure for recreation, landscape rehabilitation, education and research.

Acknowledgements

Thank you my supervisor Susan Fitzgerald, for your immeasurable support, encouragement, and unwavering belief in my ideas throughout this process. You have been a wonderful mentor and an inspiration throughout my time at the school. Thank you to my advisor Steve Mannell for your thoughtful insights that nudged the project in the right direction.

Thank you, Alexa Desjarlais, for your help and encouragement near the end. Thank you to Ken Kam for your patience during stressful printing sessions. Thank you Regan Southcott for your guidance during the model building process.

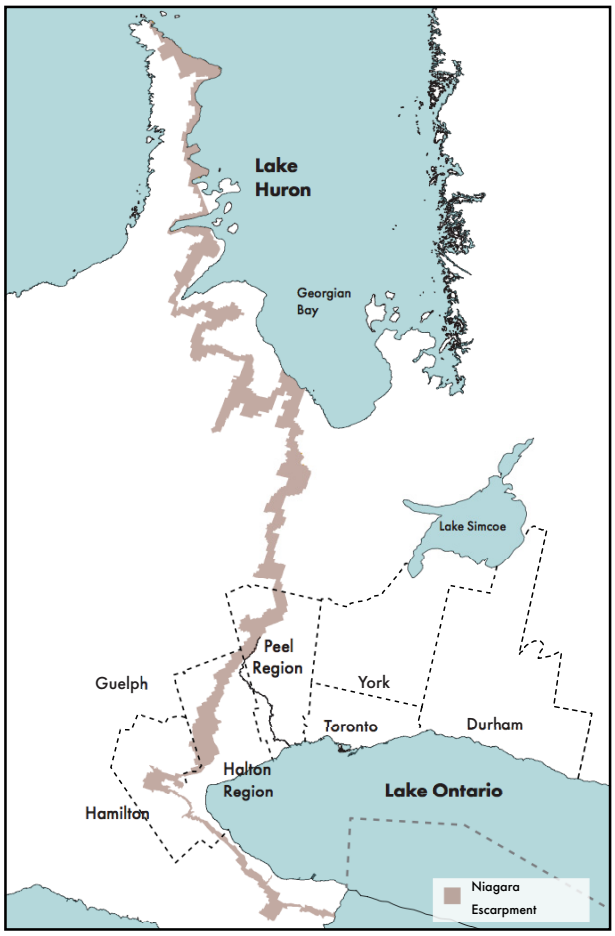
Thank you Brookes Roche for your last minute help in assembling the model. Thank you Luca Di Gregorio, without your expertise the model would not have been possible. Thank you Myles Burry and Chelsea Kinnee for lending your knowledge when I needed it the most. A very special thanks to Morgan Anna Kerber for the meticulous detail that only you could have accomplished. The defense of this project could not have been possible without the help of Ryan Swirsky. Ryan, I am immensely grateful for your friendship and your contribution to this project. Thank you to my class for sharing so many good times over the past four years, in and out of the studio.

Thank you to my father and sister for your love and support throughout the four years of architecture school. Finally, a huge thank you to my wife, Khadija Ghazi, for being there through it all, and taking on the world while I was working away in the studio. And of course, thank you Barakh Khan for being the greatest joy of my life. I cannot imagine these past four years...and my life without you guys!

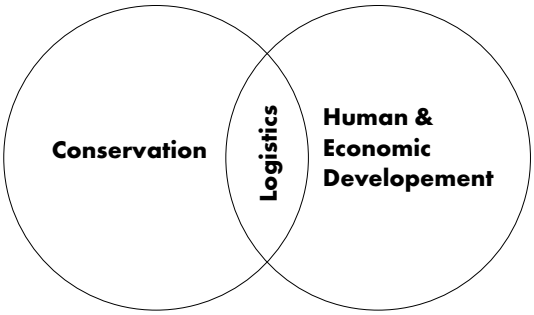
Chapter 1: Introduction

The Niagara Escarpment is part of the 686 UNESCO World Network of biosphere Reserves (WNBR) spread across 122 countries. Niagara Escarpment, Located in Ontario, is one of Canada's 18 Biosphere reserves. Designated in 1990, It stretches 725 Kilometers from the foot of Niagara Falls to the edge of Georgian Bay and Lake Huron.

WNBR has three main functions: Conservation of cultural diversity and biodiversity; human and economic development; and logistics support through facilitating demonstrations projects environmental and sustainable development education; training research and monitoring (Unesco.org 2017).



Location of Niagara Escarpment in Ontario (data from ArcGIS 2018)



Interpretive diagram of UNESCO Biosphere functions (UNESCO 2017)

Ecological Value of Niagara Escarpment

Niagara escarpment supports a wide variety of habitats that are home to over 300 species of birds, 53 types of mammals, 36 species of reptiles and amphibians, 90 types of fish and over 1500 plants (Niagara Escarpment Commission 2019). The Niagara Escarpment is home to roughly a quarter of Canada's endangered or threatened species such as the Jefferson Salamander, the Eastern Mississauga Rattlesnake, the vulnerable Southern Flying-squirrel and the rare Eastern Pipistrelle bat. It contains 50 species of ferns, more than 300 species of birds, 55 mammal species and 34 species of reptiles and amphibians, and more than 1500 species of vascular plants (Giants Rib Escarpment Education Network 2014).

Danaus plexippus

Falco peregrinus

Ixobrychus exilis

Pseudacris triseriatc

Graptemys geographica

Ambystoma Jeffersonianum

Parkesia motacilla

Sample of At risk species of Niagara Escarpment Ecological System (Conservation Halton 2019)

Geological Value

Rock formations of the Niagara Escarpment are as old as 450 million years. Niagara Escarpment is located along the Michigan Basin. Around 450 million years ago this region was a small ocean with thriving marine life. East of this large water-body, along the edge of North America was a large mountain range that eroded and weathered by rain, wind and ice. The eroded material moved towards the Michigan Basin and after settling formed sedimentary rocks. Layers of Mud turned into red shale while layers of sand turned into sandstone (Giants Rib Education Network 2014).

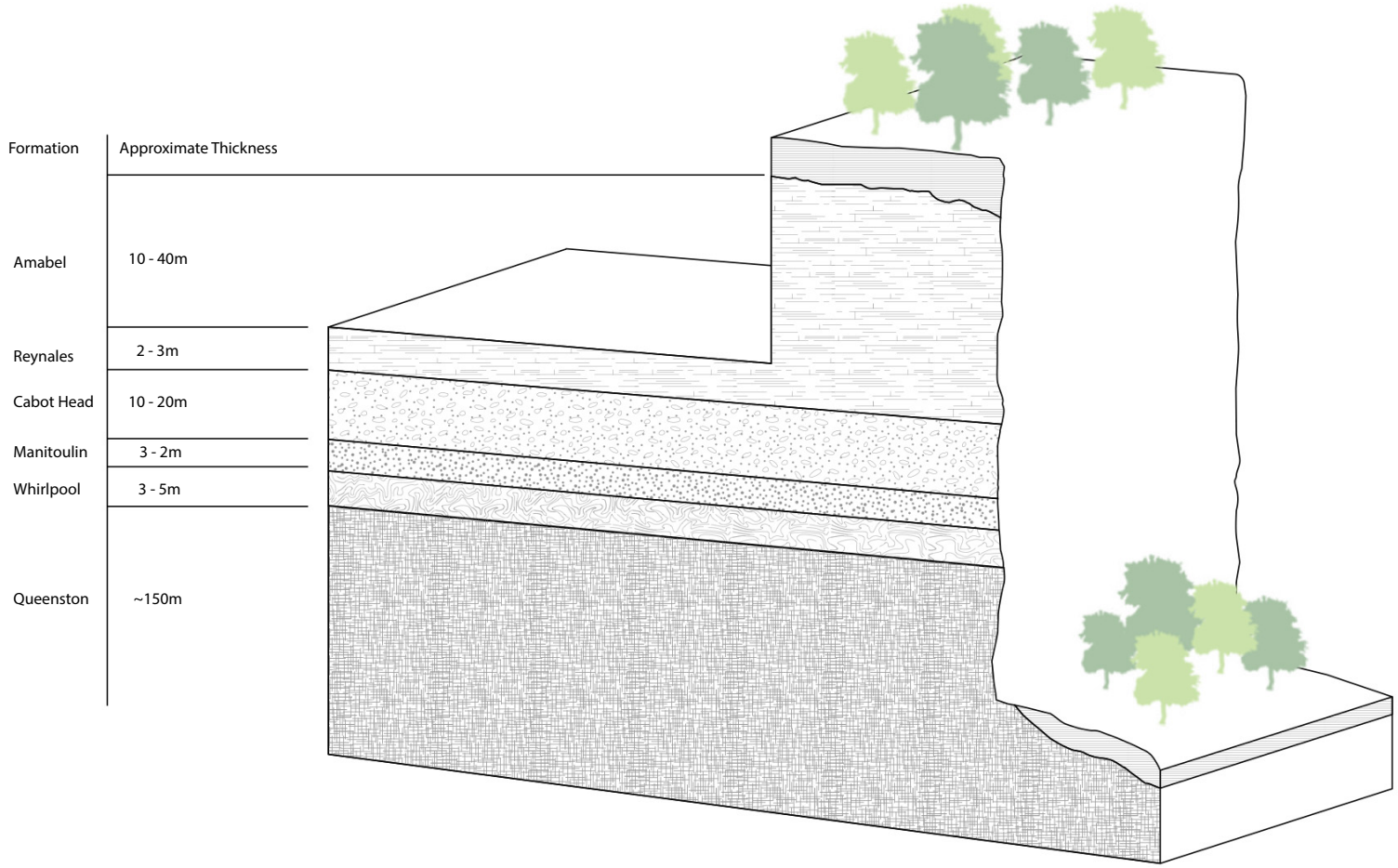
As the basin increased in size, it became warmer supporting a variety of animal life. As these animals died, their bones, containing calcium, fell to the bottom of the ocean floor. Eventually, all of this calcium was compressed into layers of limestone (Giants Rib Education Network 2014) that form the Niagara Escarpment (Canadian Geoscience Education Network 2018).

As landforms continued to change, the vast water body of the Michigan Basin gradually became shallower. The concentration of salt and magnesium from the ocean water seeped into the porous limestone and the chemical reaction created dolostone, a hard erosion resistant rock. Today dolostone forms the cap rock of the Niagara Escarpment (Giants Rib Education Network 2014). This stone formation is the back bone of the aggregate industry of Ontario.

Aggregate industry has caused a significant Human Impact on the Escarpment environment. The Escarpment area is the site of the large mineral aggregate industry.

Thesis Question

This thesis therefore questions as the life-cycle of a quarry comes to an end, can these post-industrial landscapes on the Niagara Escarpment be re imagined to actively rehabilitate their site through water, while simultaneously provide opportunities for recreation, education and research?



Interpretive look at the type and depth of rock formation of Niagara Escarpment ((Duffrin Aggregates 2012)

Chapter 2: Ontario Aggregate Industry

Ontario's Aggregate Resources Act defines "aggregates" as gravel, sand, clay, earth, shale, stone, limestone, dolostone, sandstone, marble, granite, rock or other prescribed material (Ontario Aggregate Resources Act 1990). Aggregates are used primarily for the construction and maintenance of numerous types of infrastructure, including highways, bridges and sewer mains. Aggregates are also used in the manufacturing of products such as pharmaceuticals and cosmetics.

Operational Model

Aggregate operations are strategically located near major transportation networks and the industry operates on a close-to-market business model (Ontario Ministry of Natural Resources 2010), therefore they are always situated near the urban areas, that they service. What's even more interesting is that a majority of quarrying occurs within the ecological areas of the Niagara escarpment and Oak ridge's morainethat forms part of the hinterlands surrounding the project known as the Ontario Greenbelt (Toronto Environmental Alliance 2009, 4).

Quarries in GTA

A more interesting pattern can be seen through GTA where aggregate quarries are situated along the edge of the escarpment, in close proximity to adjoining urban areas and almost adjacent to conservation lands. The Escarpment's natural features, include watercourses, hiking trails, and ski hills account for many of Ontario's outdoor recreational opportunities. Hiking, caving, skiing, mountain biking and kayaking are a few of the tourism and recreational opportunities in this landscape (Niagara Escarpment Commission 2012).

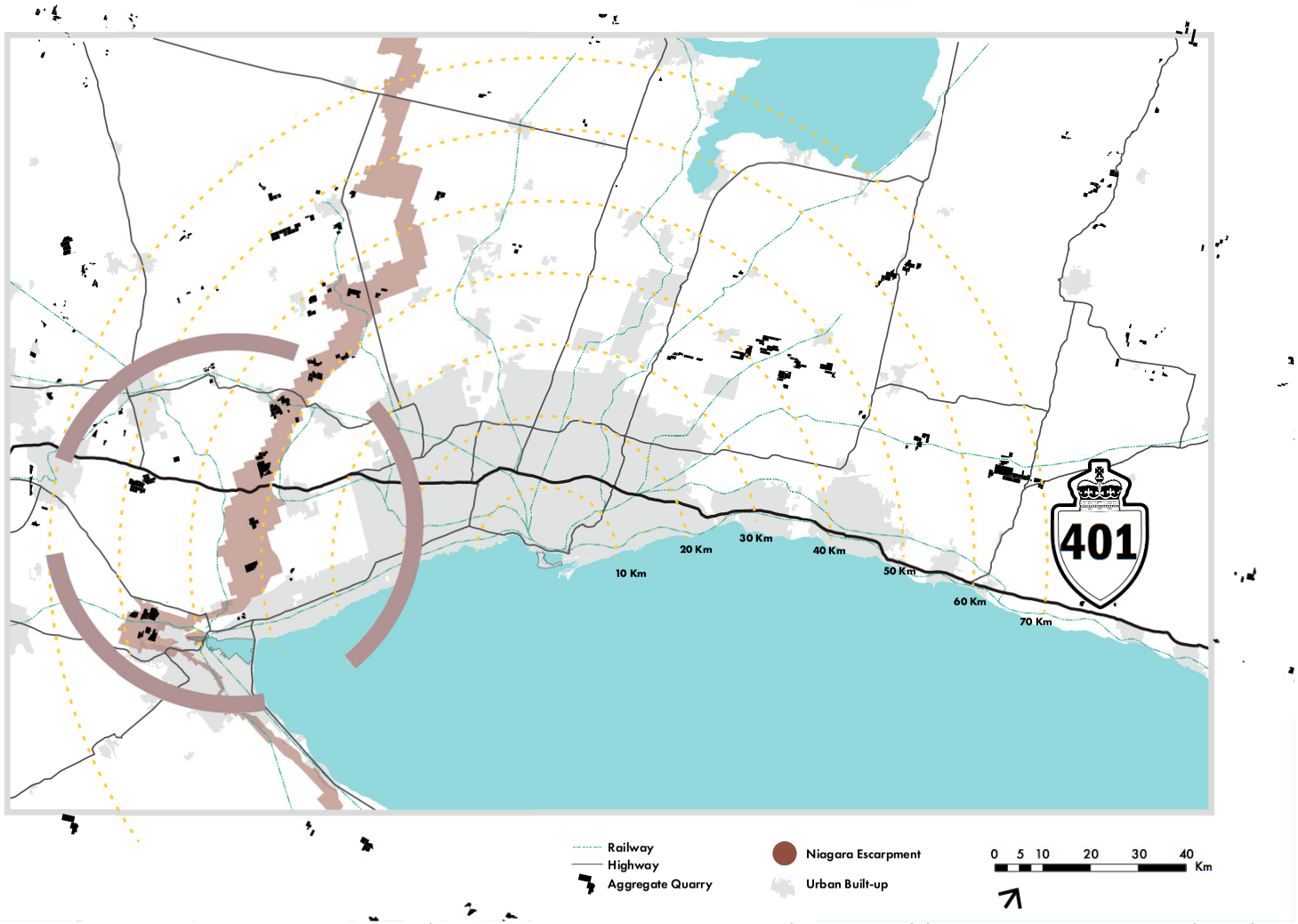
Growing Population

Toronto's relationship with aggregates can be analyzed through its unprecedented economic

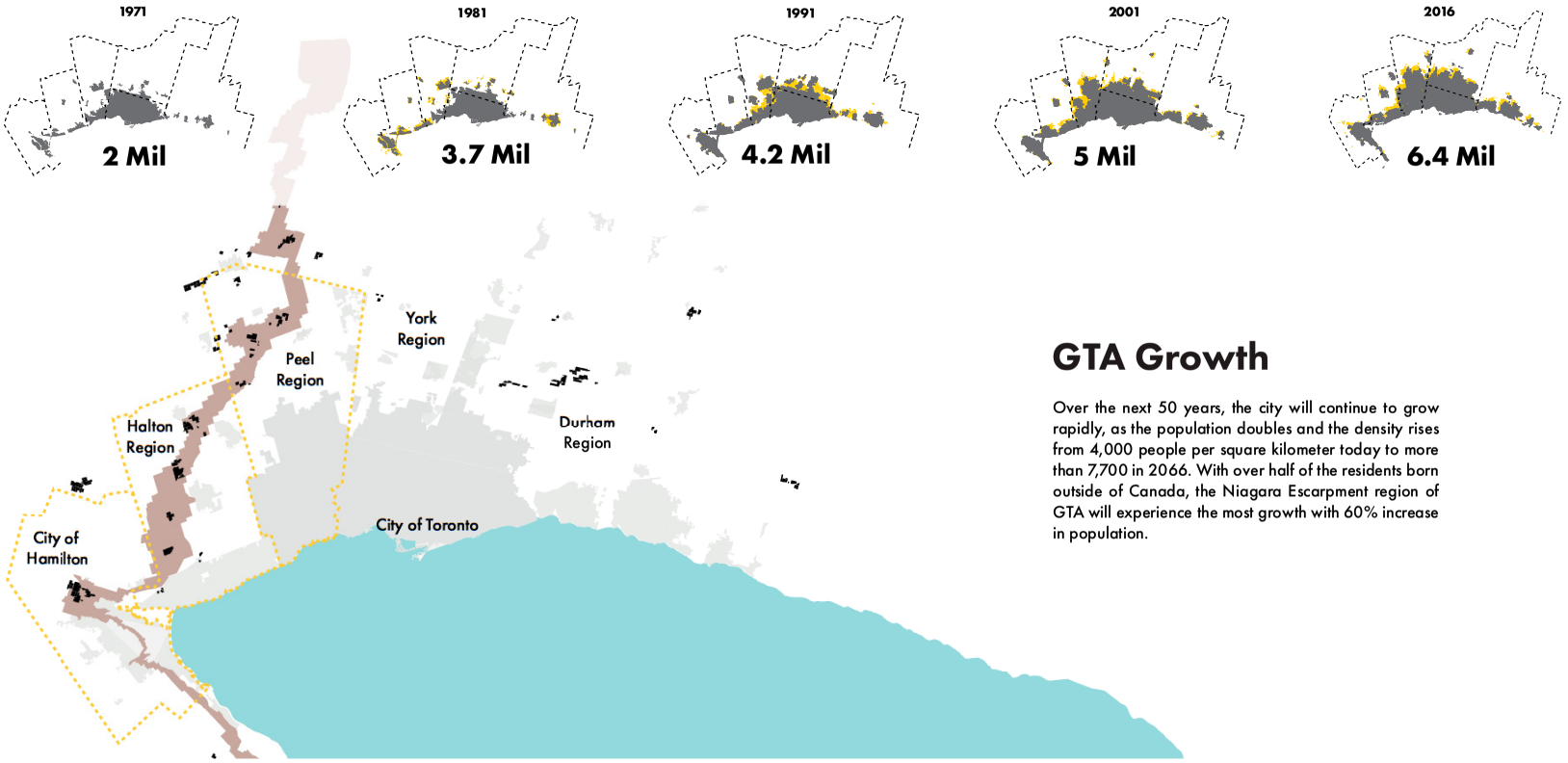
growth and pro-immigration reform. Emerging as the fastest growing Canadian city has attracted many immigrants from all over the world to settle in the adjoining city's, which is now known as the Greater Toronto Area (GTA). GTA is one of the fastest growing areas of North America. GTA today consists of 6.4 million and by 2041 it will be home to almost 10 million people (Ontario Ministry of Finance 2017). To settle a population of this magnitude planning for infrastructure, transportation and housing is imperative and aggregate will continue to be extracted in order to cope with this growth. At this rate the region will require over 2 billion tonnes of aggregate over that period (Ontario Stone and Gravel Association 2015, 7). Niagara Escarpment passes through the region of GTA that will see the most population settlement than any other part of GTA (Ontario Ministry of Finance 2017).

Quarrying in GTA

The Geological value of the Niagara Escarpment enables the intensive urbanization of the GTA with the aggregate needed to expand. The following maps take a closure look at the Niagara Escarpment weaving across the GTA landscape.



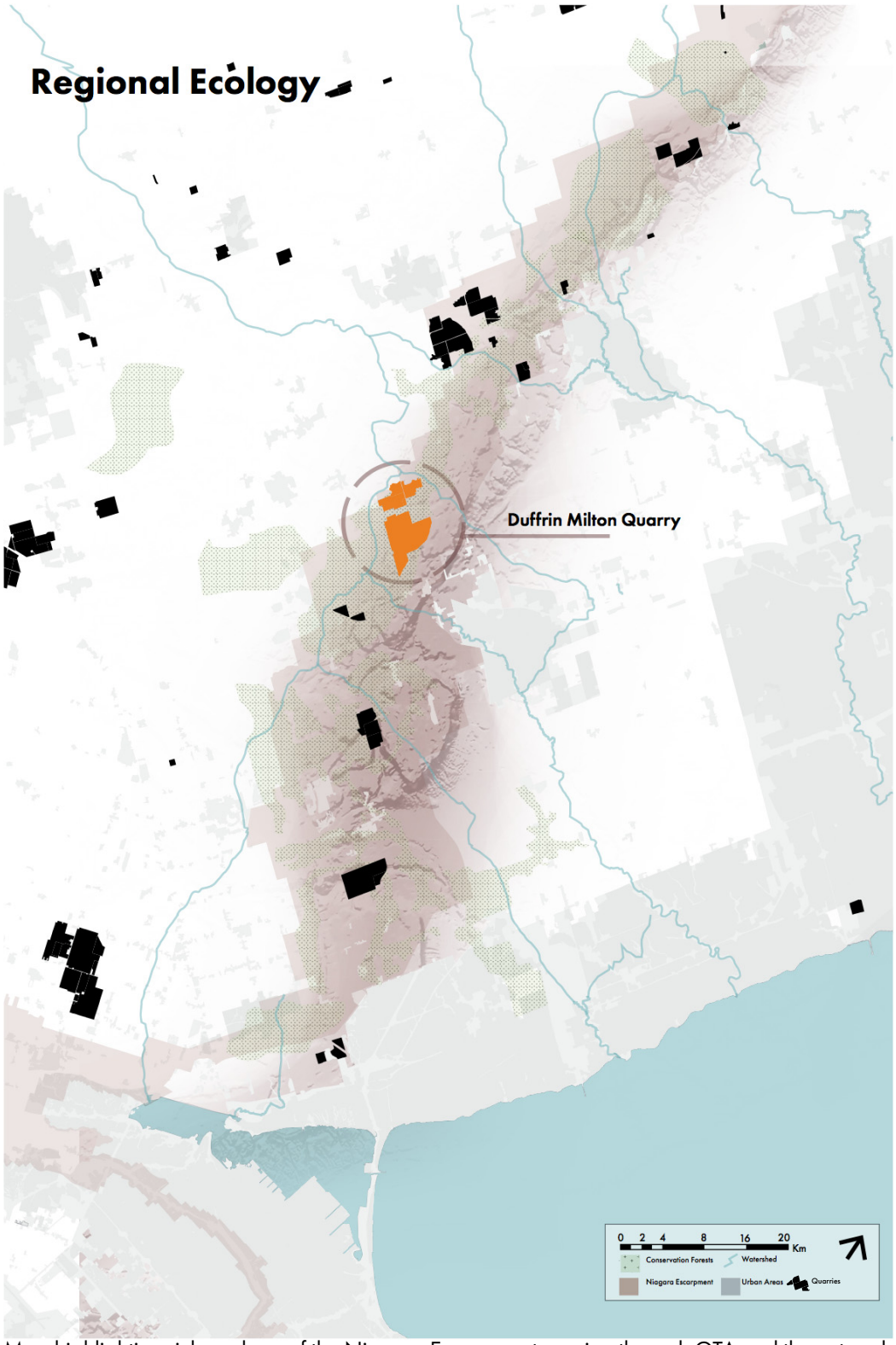
Map showing active aggregate quarries in Ontario along Niagara Escarpment. Quarries cluster around the Niagara Escarpment and are closer to urban areas and transportation infrastructure (base map from ArcGIS; Location of Quarries Data from Government of Ontario 2018)



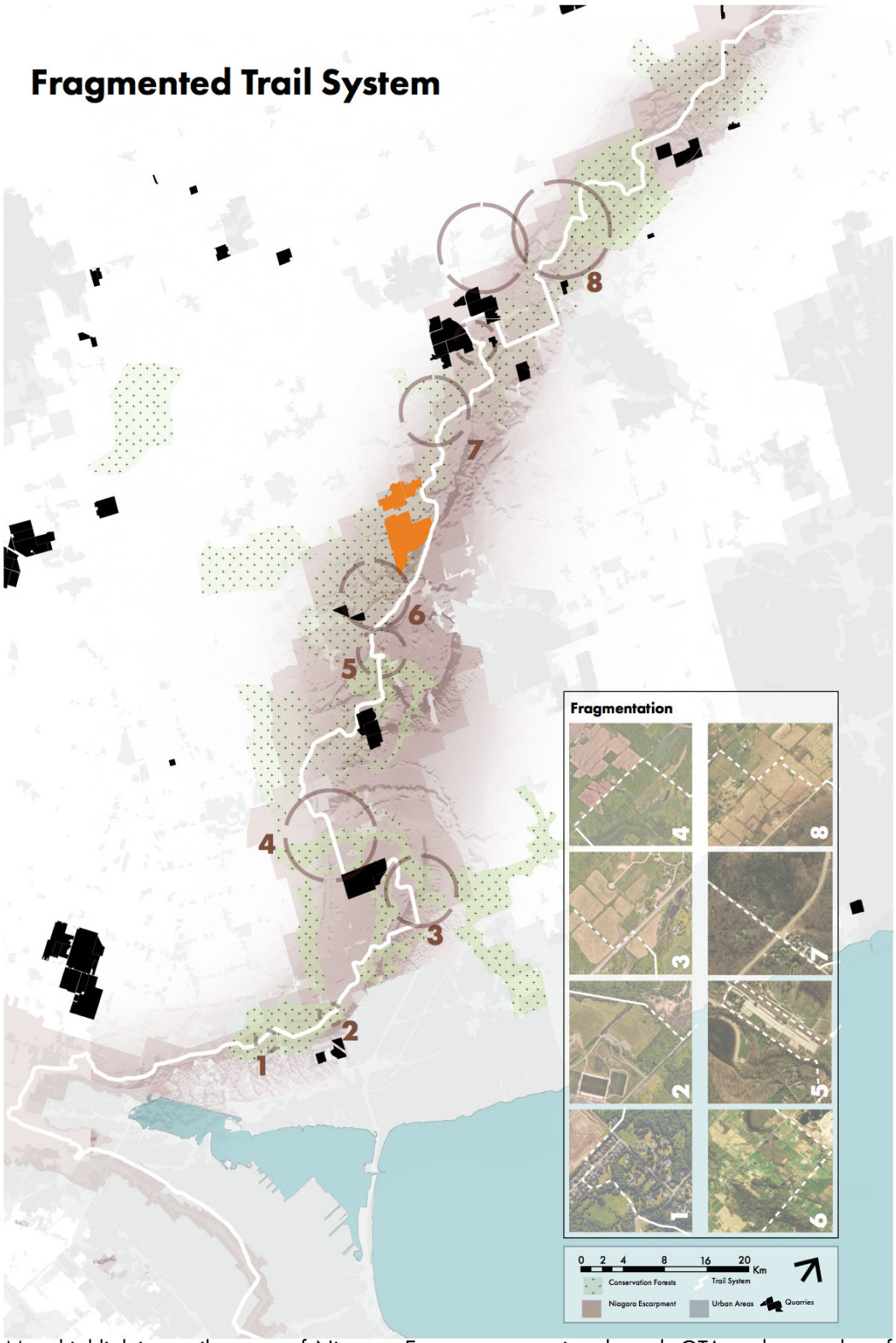
GTA Growth

Over the next 50 years, the city will continue to grow rapidly, as the population doubles and the density rises from 4,000 people per square kilometer today to more than 7,700 in 2066. With over half of the residents born outside of Canada, the Niagara Escarpment region of GTA will experience the most growth with 60% increase in population.

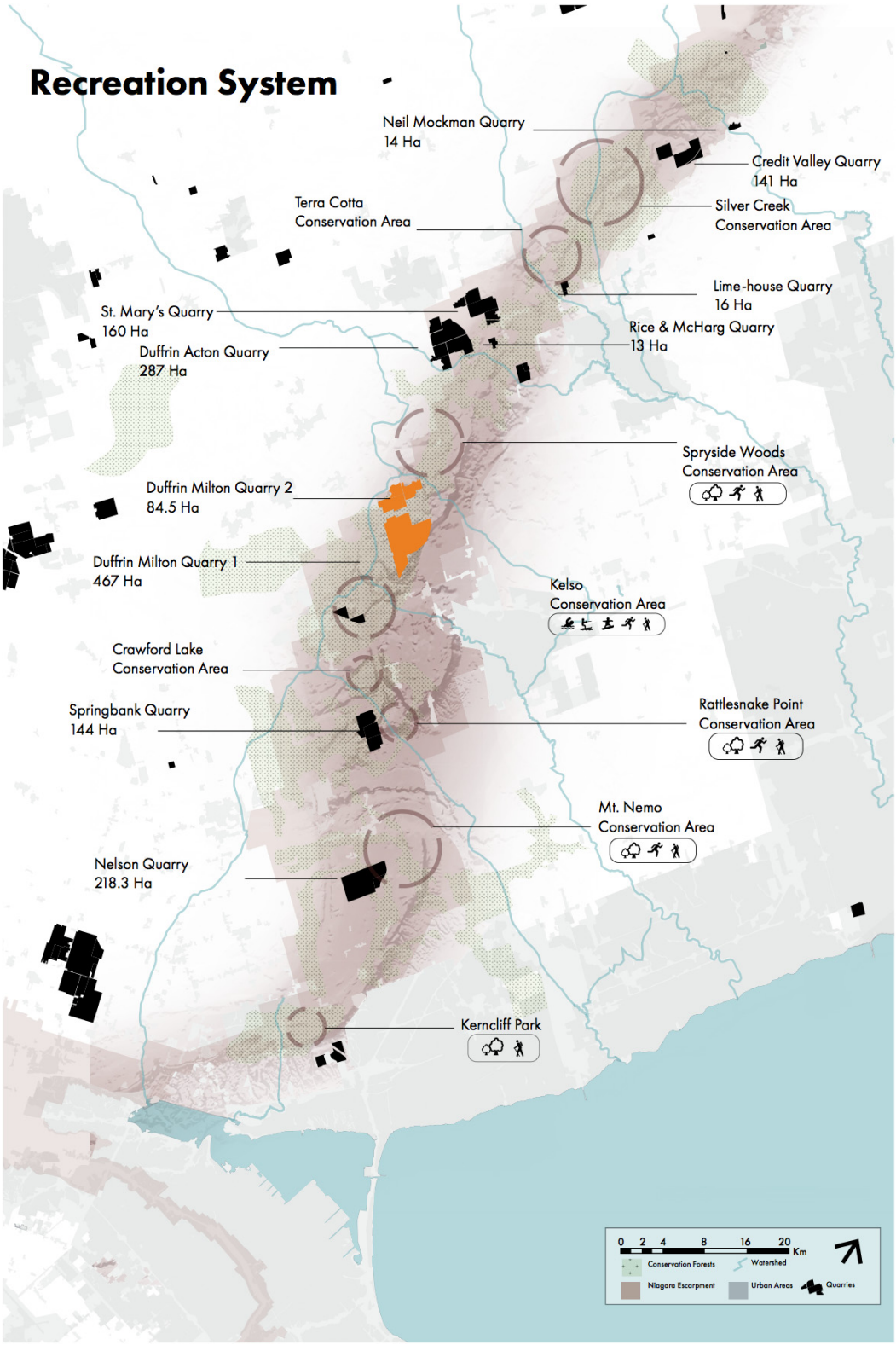
Diagrams showing growing GTA population over the decades. By 2061 the Niagara Escarpment region of GTA will see the highest levels of population growth (base map from ArchGIS 2018 and population data from neptisgeoweb.org 2019)



Map highlighting rich ecology of the Niagara Escarpment passing through GTA and the network of quarries that interrupt the natural areas (base map from ArcGIS 2018 and location of quarries data from Government of Ontario 2018)



Map highlighting trail system of Niagara Escarpment passing through GTA and examples of trail fragmentation (base map from ArcGIS 2018; Satellite images data from Google 2019; trail system data from Bruce Tail Conservancy 2019)



Map highlighting existing network of recreation in the Niagara Escarpment section of GTA (base map from ArcGIS 2018 and Google 2019)

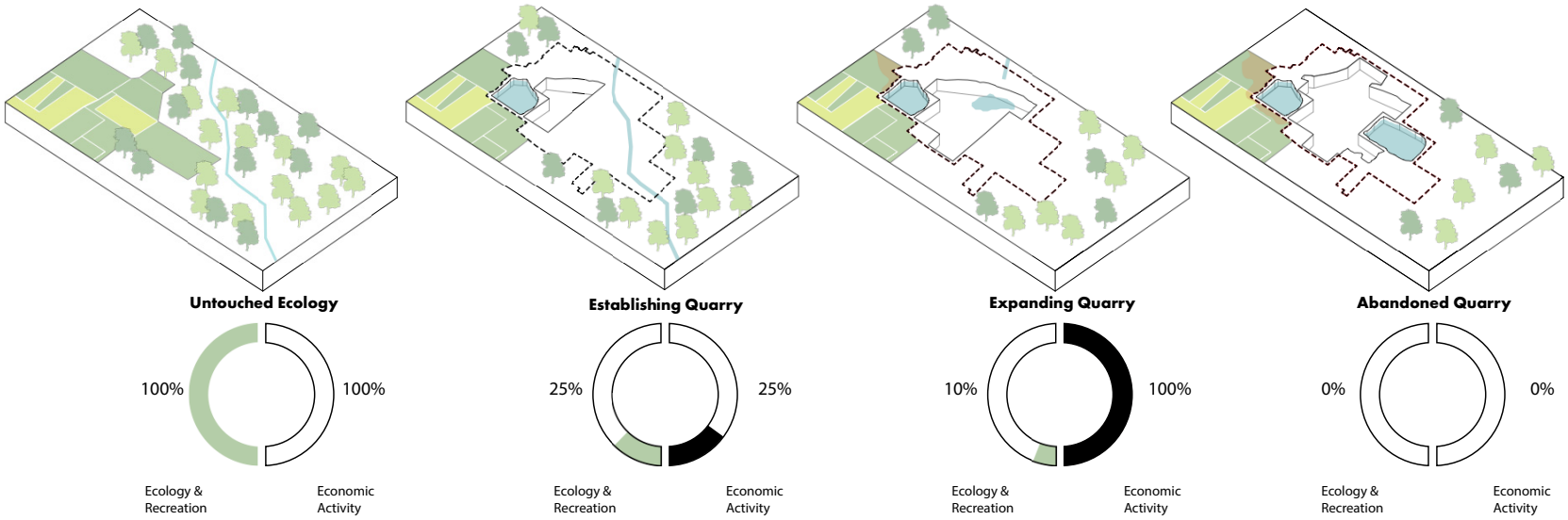
Criticism of Extraction

The extraction of aggregate resources in Ontario often becomes controversial for the damage it causes to natural landscapes and the impacts it causes in local communities as 40% of the Niagara Escarpment Landscape is covered with forrest and wetlands (David Suzuki Foundation 2008, 24). Pits and quarries remove natural vegetation, top soil and subsoil, leading to loss of animal wildlife, biodiversity and aquatic systems. Aggregate extraction can have negative effects on water quality and quantity, natural heritage features, and endangered species and can adversely impact nearby residents and those who enjoy recreation and tourism (Toronto Environmental Alliance 2009, 4). Adjacent communities and adjacent ecosystems are affected by noise, dust and vibration (Binstock and Carter-Whitney 2011).

Quarry Life-cycle

A typical pattern can be observed when aggregate operations begin, land begins to clear out, and eventually they renew their licenses and expand operations on productive land. At the end of this cycle the quarry's ecological and economic value is diminished, leaving a scar within the landscape.

As quarrying operations are dependent upon the aggregate reserves of a particular site, therefore there is very minimal infrastructure deployed on site. As the quarrying approaches the end of its life-cycle the infrastructure is dismantled and redeployed on a new site for extraction. The only built infrastructure that exists on site are enclosures for machinery that process and screen the rocks.



Interpretive diagram showing the systematic decline of Niagara Escarpment landscape and ecology as quarries establish operations. As aggregate resources are finite, when quarries are exhausted the operators dismantle infrastructure, leaving a manufactured landscape behind.

Chapter 3: Quarry Rehabilitation

Quarry rehabilitation is required by law in Ontario (LaGro 200, 5), (Ontario Aggregate Resources Act 1990), however progressive rehabilitation efforts are falling short and the current rate of aggregate site rehabilitation occurring in Ontario is not enough to moderate adverse environmental and social impacts (Port 2013). Although the province has continued to do a lot of work on capturing rehabilitation data, more work is still needed on data retention and long term monitoring of rehabilitated areas (Port 2013, 33)

Approaches to Quarry Rehabilitation

There are three drivers for rehabilitation: economy, biodiversity and a hybrid. Economic rehabilitation is not conducive to ecological performance, therefore a rehabilitation strategy with a balanced economic and ecological objective can be deployed with results similar to complete bio-diversity focused rehabilitation (Corry, Lafortezza, and Brown 2010).

Ecological Rehabilitation

Water logging parts of the quarry is encouraged to increase spatial heterogeneity and, consequently, biodiversity (Yanina, Oksana, Ivan, Vyacheslav, Alina, Evgenij, Dmitrij, Andrej, Kseniya, Ekaterina, Elizaveta, and Aleksej 2016) Impacted aggregate extraction sites, that are common in Southern Ontario, can easily be rehabilitated to wetlands (Duval, Waddington, and Branfireun 2010) Cultural acceptability of rehabilitation, through a survey conducted in southern Ontario, also suggests that it should not fragment forests, compromise water quality, or increase the appearance of “sprawl”(Corry, Lafortezza, and Brown 2010).

Economic Rehabilitation

As a function of UNESCO Biosphere Reserve, the Niagara escarpment needs to demonstrate fostering of economic and human development that is environmentally sustainable and facili-

tate environmental and sustainable development education, training research and monitoring.

Architectural Program Inherent in Hybrid Rehabilitation Strategy

The process of rehabilitation allows for architectural program to take shape. Considering high biological value, it is necessary to take measures to improve the infrastructure to benefit people's learning of the rehabilitation and conservation process. Programmed to facilitate lectures, eco-clubs, master classes, open-door days for excursion for events organized to attract local library, museums, teachers, and students (Yanina, Oksana, Ivan, Vyacheslav, Alina, Evgenij, Dmitrij, Andrej, Kseniya, Ekaterina, Elizaveta, and Aleksej 2016).

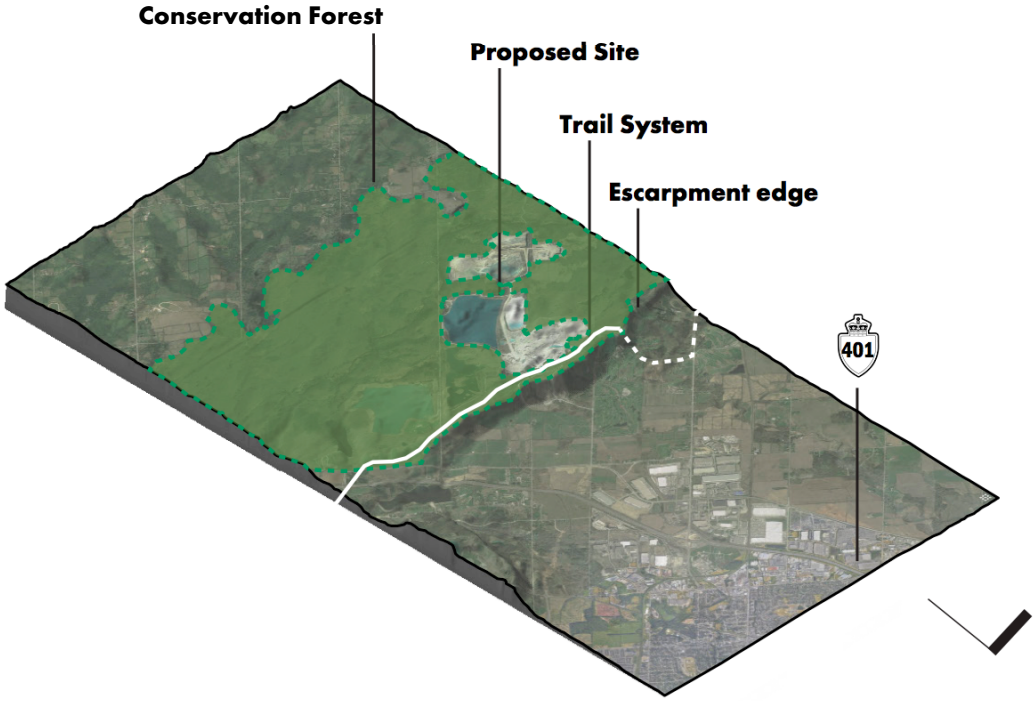
As experts, such as biologists and ecologists, representatives of public organizations begin work on rehabilitation, this will start to attract eco-tourists to the area, increasing its attractiveness, and thus have a positive impact on the socioeconomic development of the region. As the Bruce trail is reconnected with the quarries it can be expected that quite a large number of eco-tourists would visit these interventions and would therefore require a suitable place stay during their travel through the escarpment.

Chapter 4: Design

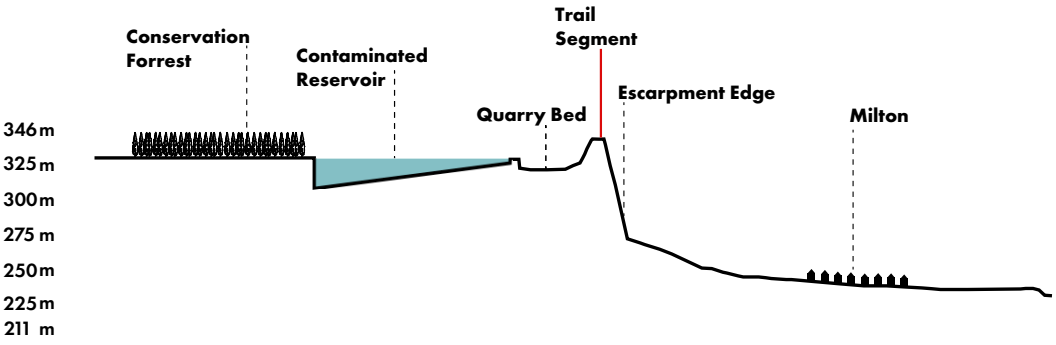
Proposed Intervention Site

The site selected to test this intervention is the discontinued section of the Duffrin Quarry located along the edge of the escarpment, roughly 5 KM North of the town of Milton in Halton region and bordering the 401 highway. The quarry has been active since the 1960's expanding over several decades on to conservation lands displacing habitats, disrupting ecology and interfering with the water table. As the quarry operations come to a closure, all non-built infrastructure is dismantled. The concrete footings of the screen-house are the only remains of its past life.

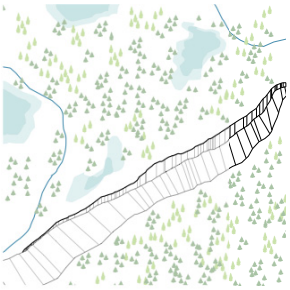
Map showing the proposed site in proximity to urban area and transportation network (base map from Google 2019)

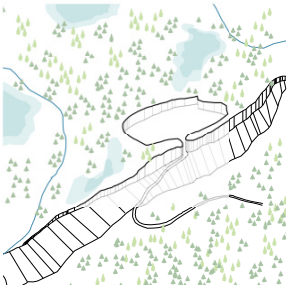


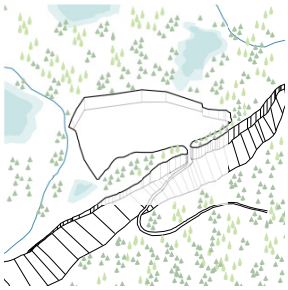
Map showing the site and Niagara Escarpment ridge (base map from Google Maps 2018)

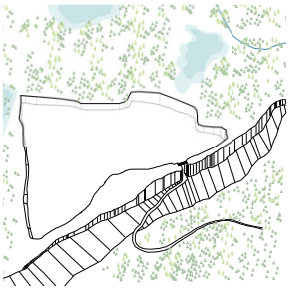


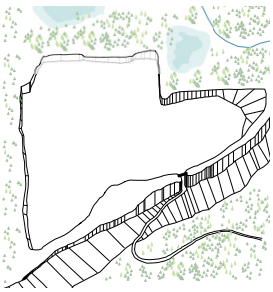
Section showing the quarries landscape and the drastic Escarpment elevation (data from Google Earth 2018)



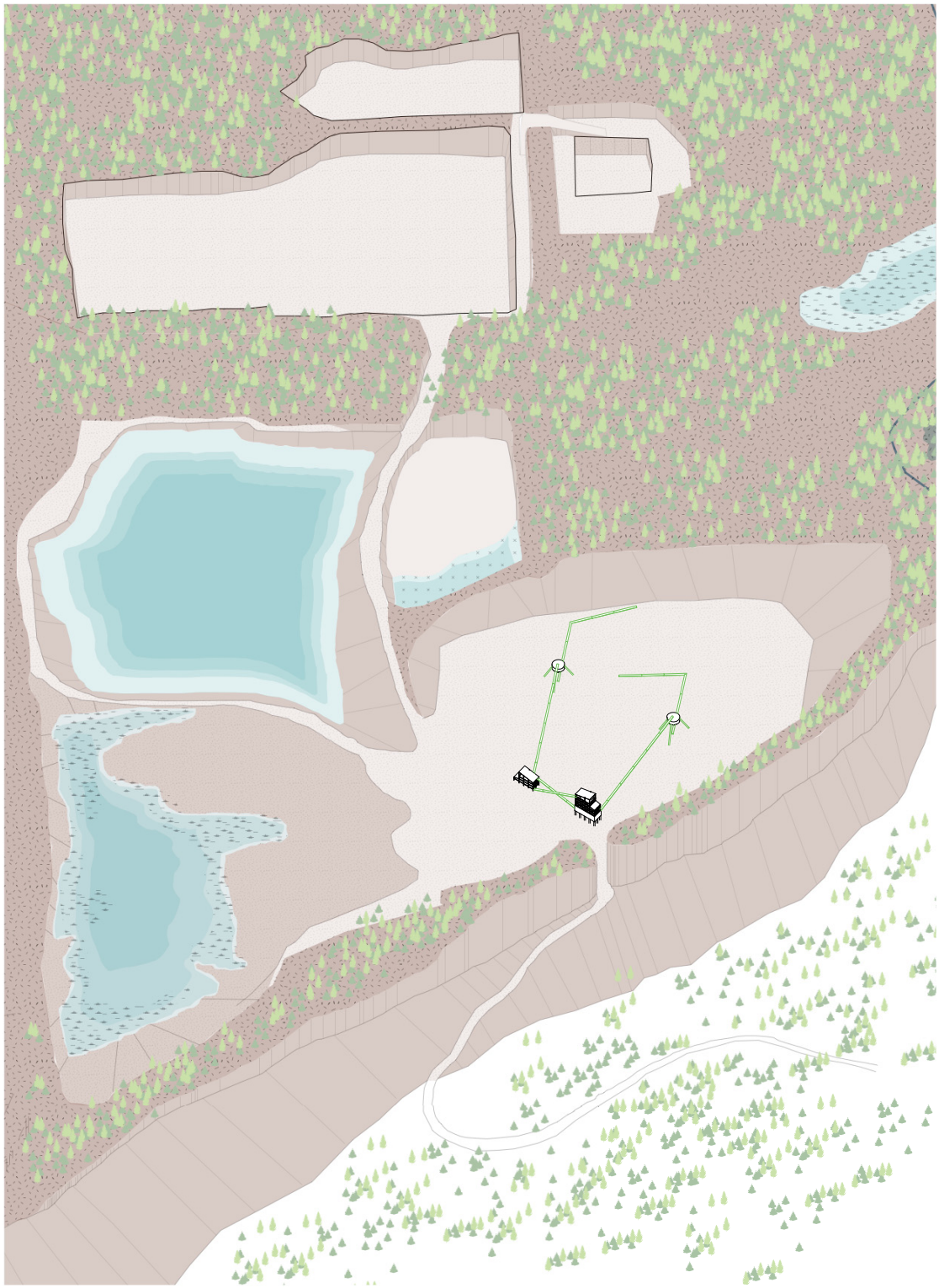








Left Column: Photos 1 - 3 showing the quarry landscape (CRH Canada 2017); Photo 4 screen house
Right Column: Interpretive diagrams showing various phases of quarry expansion.



Sketch of the quarry just before all infrastructure is dismantled and the operations seize.

Design Intent

The project emerges from recognizing these various systems, and the prototypical effects of quarrying. The design principles for the project are to design a building that engages with the contaminated water reserves on site, treat the water and use it for recreational purposes and at the end of the water's life-cycle, safely reintroduce it back to the watershed. The project aims to rehabilitate the landscape that was destroyed by aggressive industrial operation. The project intends to design a facility where active research and education can bring about an awareness of local ecology and natural systems, in this high growth region of GTA. Finally, the project aims to utilize the materials that are a product of the quarrying process.

Design Inspiration - Borden Park Pool

The Borden Park Natural Swimming Pool is the first chemical–free public outdoor pool to be built in Canada. The seasonal pavilion and landscaped pool precinct is designed for a capacity of 400 swimmers. At the NSP, the challenge of water quality control, essential to any public bathing facility, is compounded by the scale and the technical demands required to achieve an environmentally healthy and natural filtration process. The swimming program includes a children's pool, a deep pool, on–deck outdoor showers, a sandy beach, picnic areas, and spaces for other pool related recreational activities (gh3 Architects 2014).

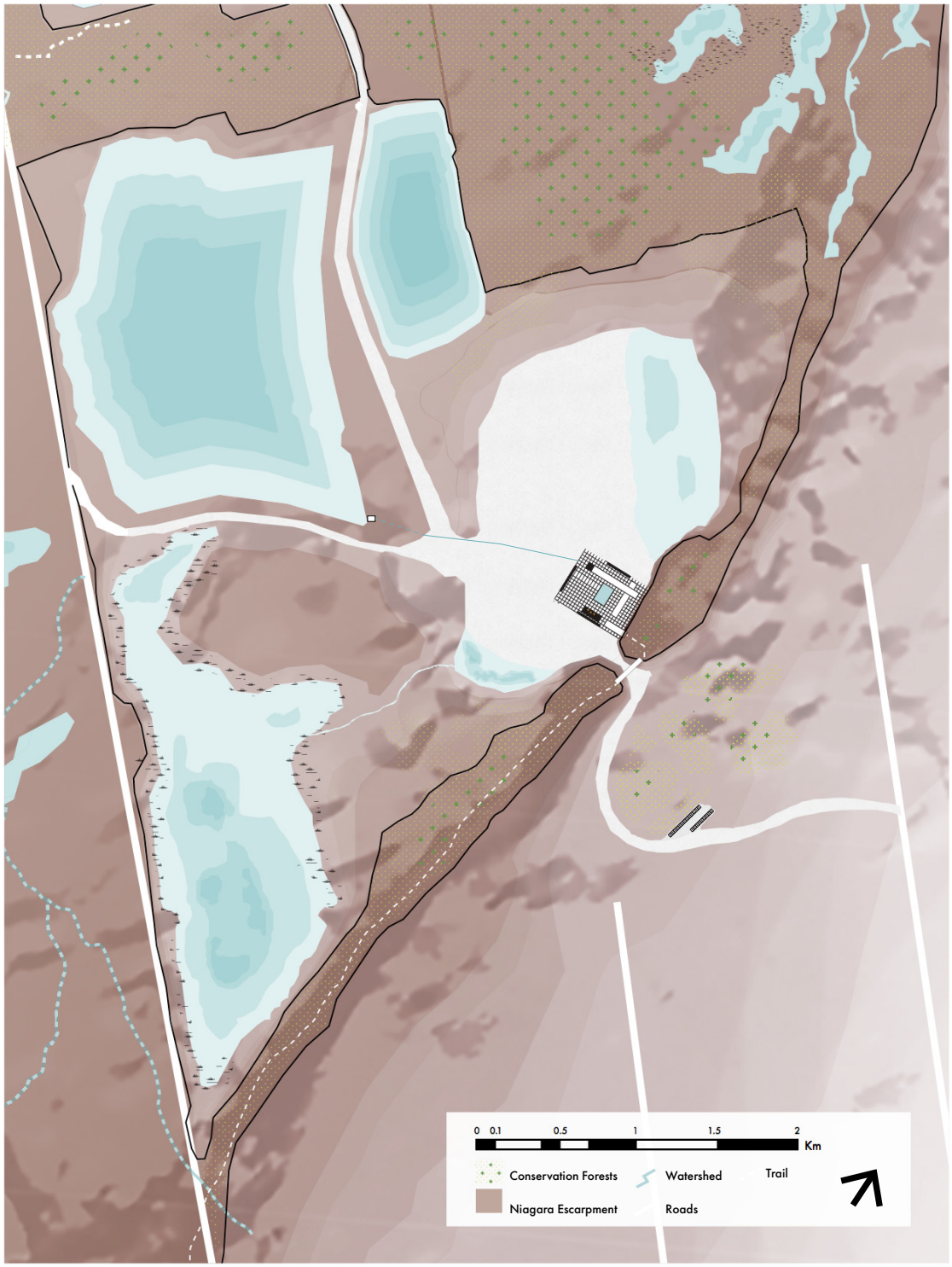
View from the Hydro-Botanic Regeneration ponds on the pool deck (gh3 Architects 2014)

Water filtration and treatment at this facility is achieved by the means of a natural process. The water is filtered through a raised gravel bed and is followed by hydro-botanic regeneration by the means of sand and stone subversive pond which includes plant materials and microorganisms. This is an unsterilized, chemical– and disinfectant–free filtering system (gh3 2013)

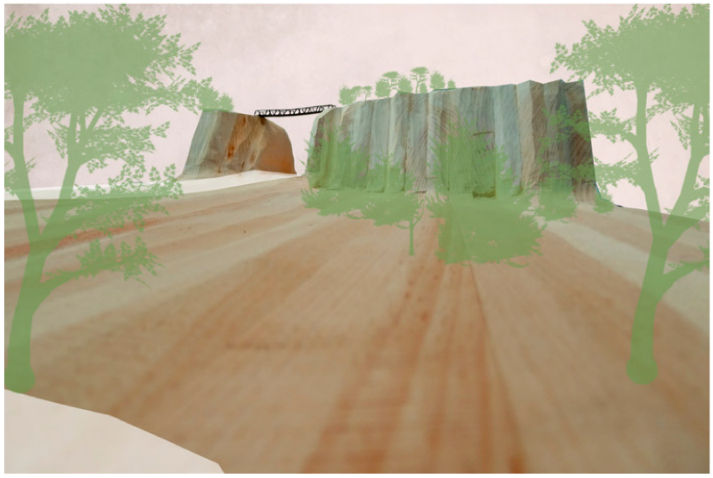
View of the busy swimming pool and deck (gh3 Architects 2014)

Access

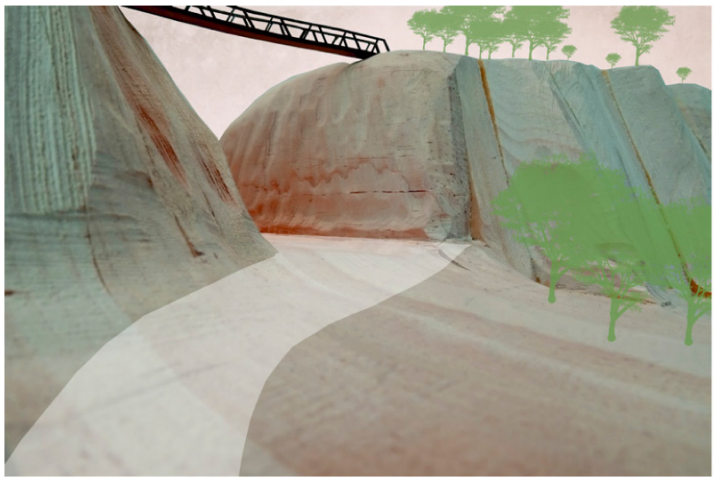
As the quarries are well connected through the transportation system, the vehicular traffic can access the quarries through the original access road that transported aggregate away from the quarry. Visitors can park their vehicles outside the quarry. The access road form this point becomes a pedestrian only path that winds through the quarry gap unveiling the project at the end of the procession. The hikers that are on the trail can access the quarry though the stairs that are cut into the edge of the quarry. As they descend the 35 meter quarry edge they are reminded of the aggressive scale of the quarrying and vastness of the room that is created as a result of the quarrying process.



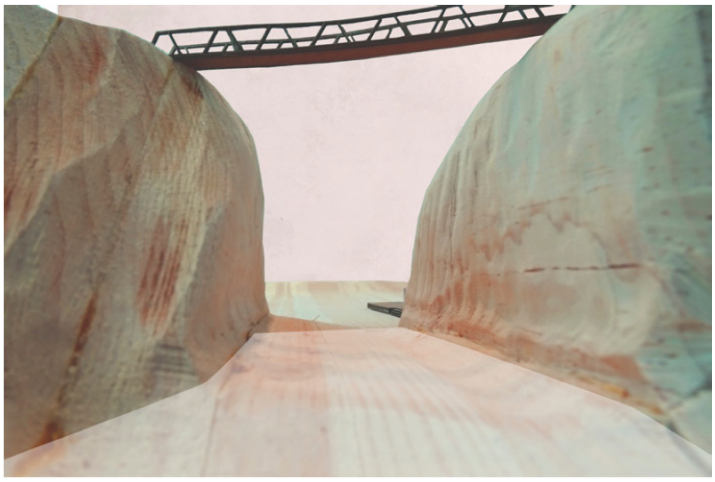
Site Plan, showing building in context and access road leading up to the building from the parking area.



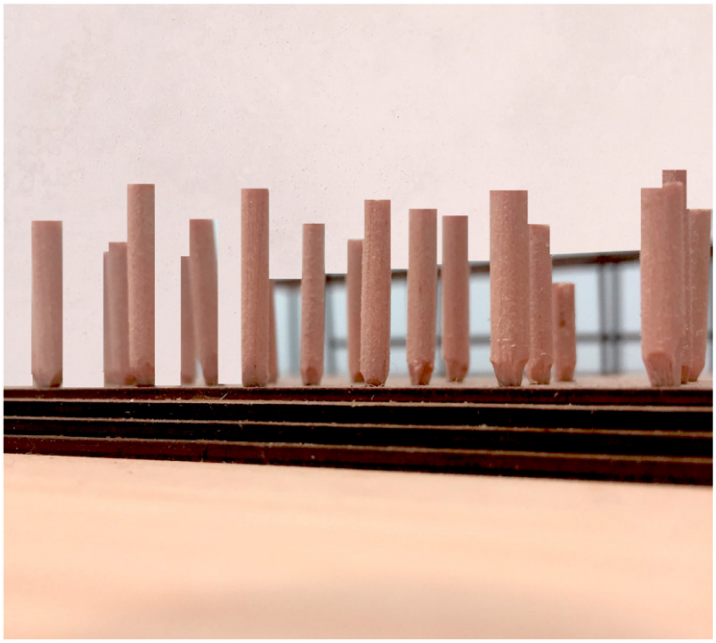
Sequence 1: Parking area



Sequence 2: Approach to the Quarry



Sequence 3: Through the escarpment gap



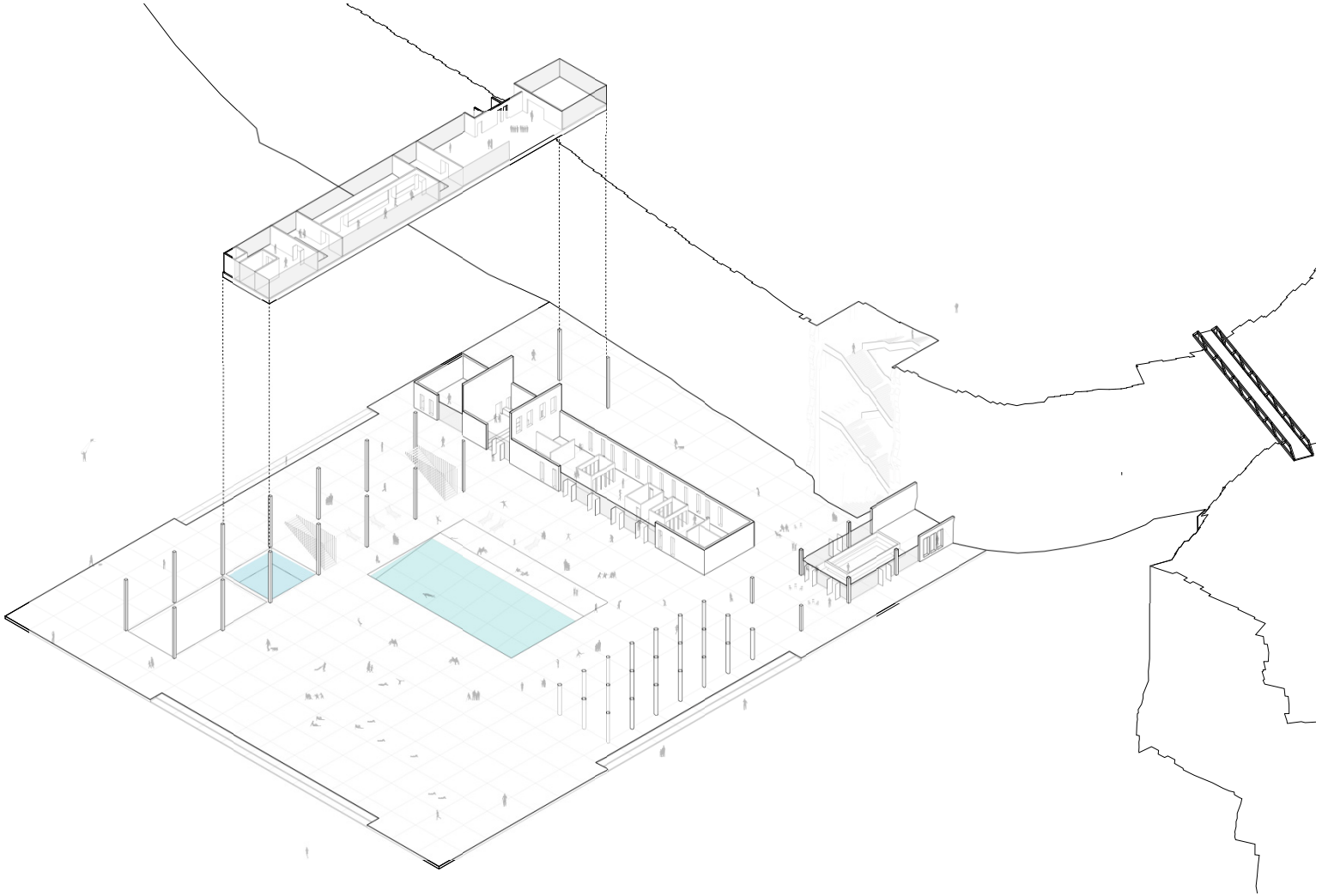
Sequence 4: Threshold into the project through the remains of the screen house.

Design Strategy and Program

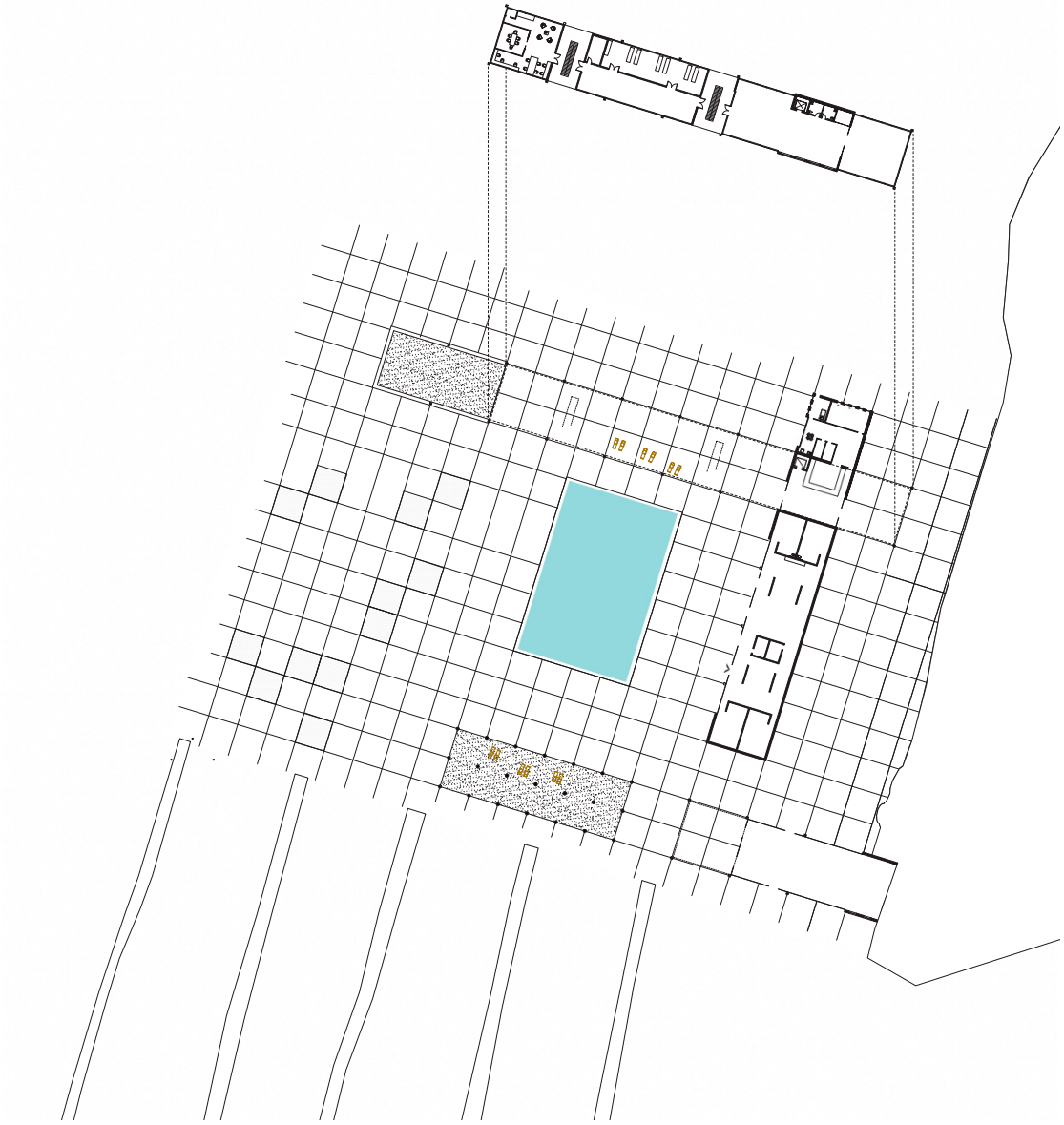
The remains of the quarry's former life begin to inform the grid of the project (20' x20'). As the quarry creates rooms in is this vast landscape, buildings begin to take shape near the edge of the manufactured cliffs. The ground level of the project is comprised of the public program of recreation and related activities, the pool deck, change rooms and showers, and cafe.

The stairs follow the grid and lead up to the research and education wing. This semi-public part of the building is designed to accommodate educational outreach, info-sessions about the quarry and the rehabilitation efforts through the constructed wetlands. The labs and office spaces are more restricted for public use but are designed with large glazing on the north side and skylights above so that the users can be reminded of the vastness of this landscape and the sky.

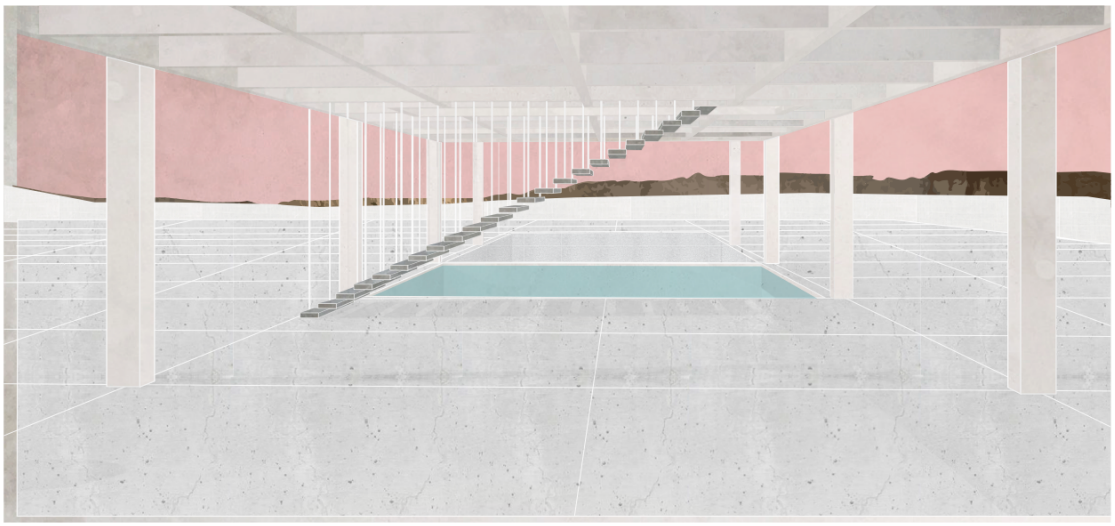
Raising of the second floor creates some shade for the swimmers and encourages unrestricted views to all parts of the quarry.



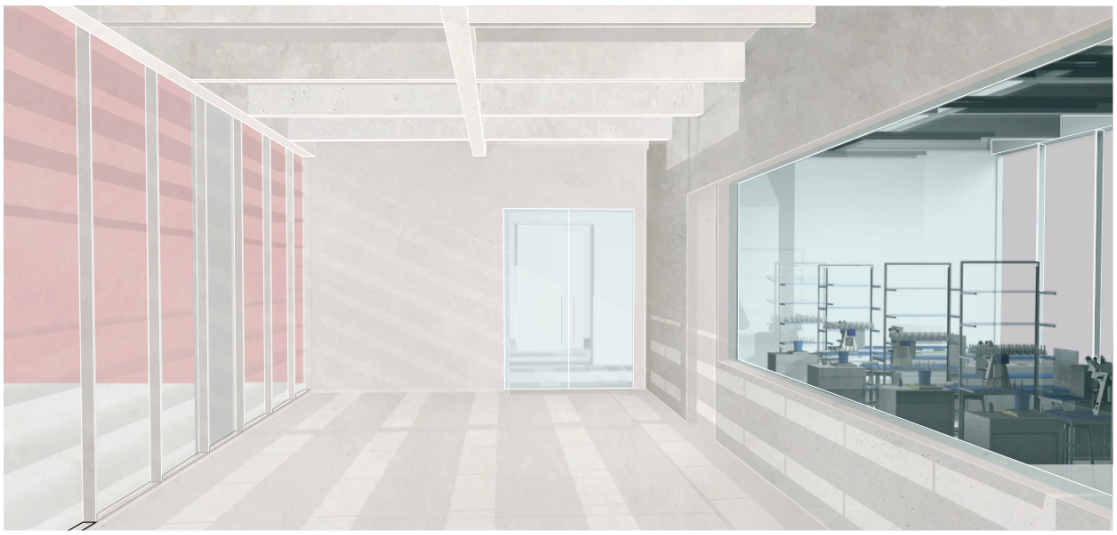
Programmatic drawing showing different parts of the project inhabited by different audiences.



Floor Plan of the pool deck level (bottom) and Research and Education wing (top)

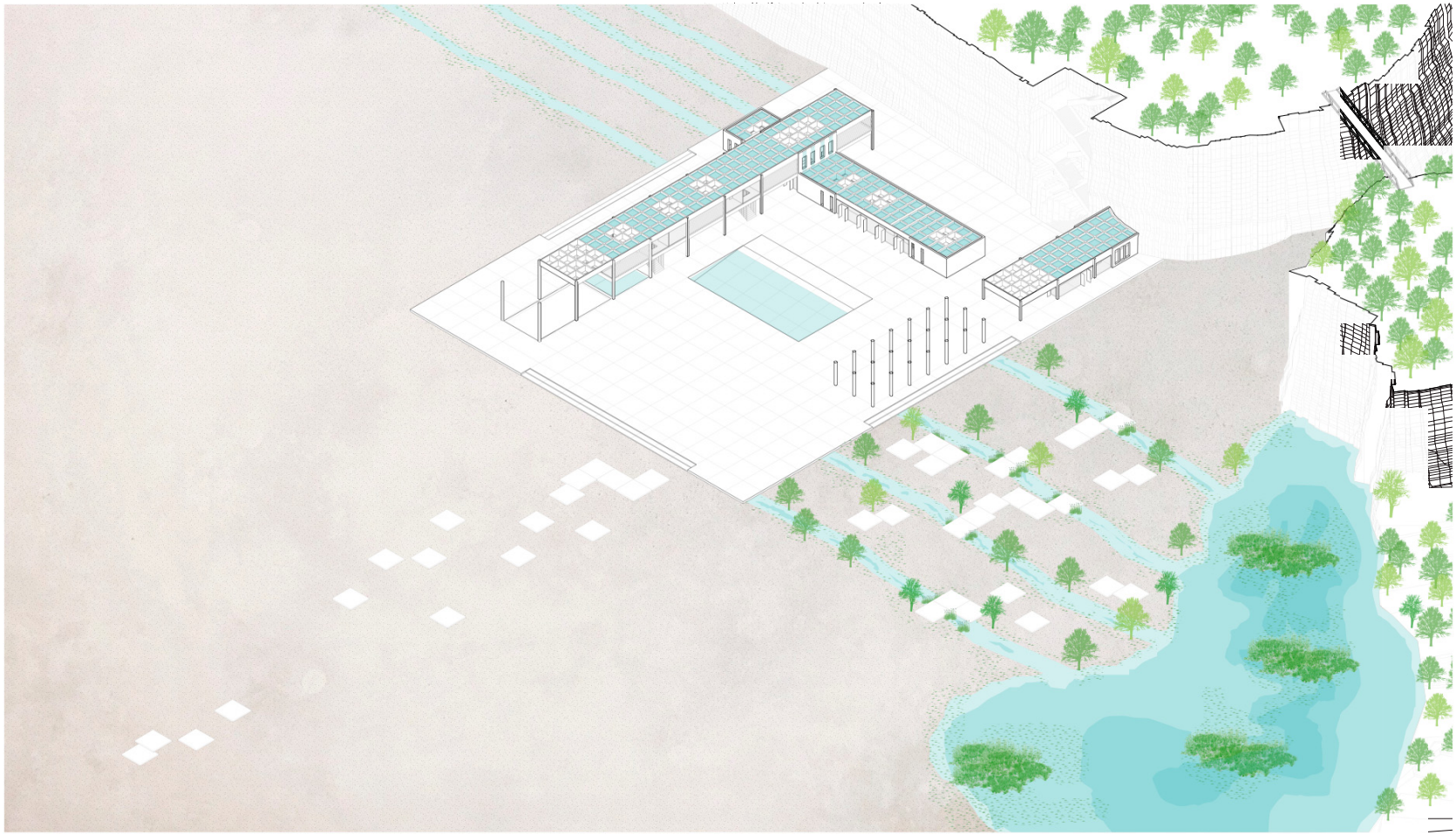


Looking towards the hydro-botanic regeneration ponds and to the vast quarried landscape beyond. The raised research and education wing allows unrestricted views to all parts of the quarry and provides a shaded area for the bathers.



Lab area with open north glazing and skylight enabling users to experience the vastness of the landscape.

Rendering of the pool deck and change rooms beyond. The research wing is on the left and the remains of the former quarry on the right.



Bird’s eye view from the south west showing the relationship of the building to the constructed wetlands and the quarried landscape.

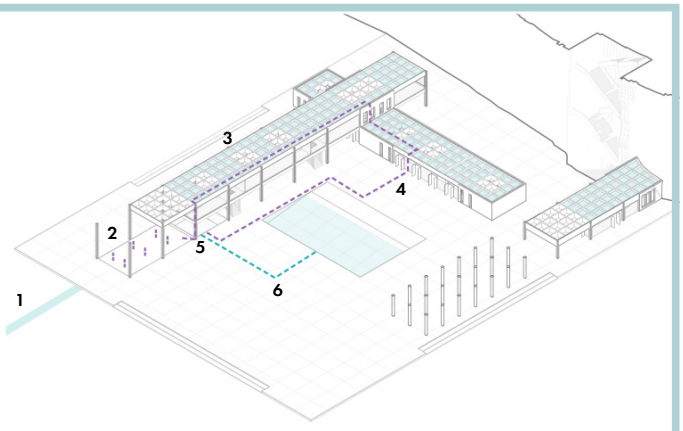
Water Handling

As water is the key component that gives the project its basis , there are different ways in which different types of water is handled to complement the program.

Water Extraction from the Contaminated Reservoir

Water is extracted from the quarry thorough a pump and is transported to the project via a channel cut into quarry surface, celebrating the movement of water. This contaminated water is first filtered through a gravel bed to remove any large particles. Next the water is pumped to the roofs of the buildings in order to aerate it. The water meanders through the coffered roof system, eventually making its way back to the ground catchment system to be led into the hydro botanic regeneration ponds. The hydro-botanic regeneration or Phytoremediation is the direct use of living green plants for in situ, or in place, removal, degradation, or containment of contaminants in soils, sludges, sediments, surface water and groundwater (unep.org 2018). After this process is complete the water is ready to be pumped into the program to activate the pool, change-rooms and bathrooms and to be used in the cafe.

1. Water intake from the reservoir.
2. Filtration through gravel bed.
3. Water aerated through roof.
4. Aerated water catchment.
5. Hydro-botanic regeneration pond.
6. Treated water supply to building.

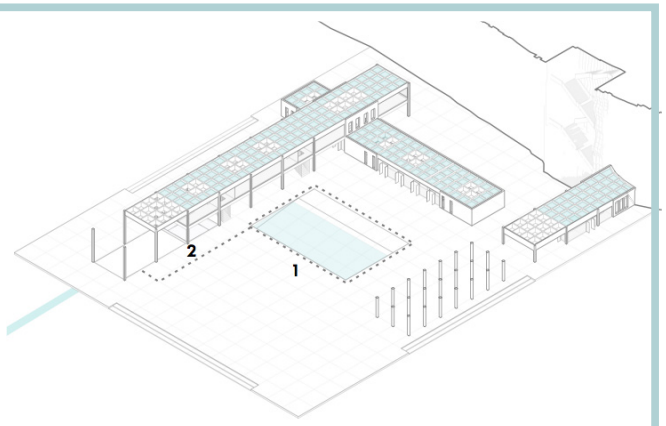


Water extraction and treatment cycle

Grey Water Collection and Treatment

Grey water from the project is collected and directed back into the gravel bed where the above cycle is repeated to reintroduce water back into the program.

1. Grey water collection.
2. Repeat water treatment cycle above

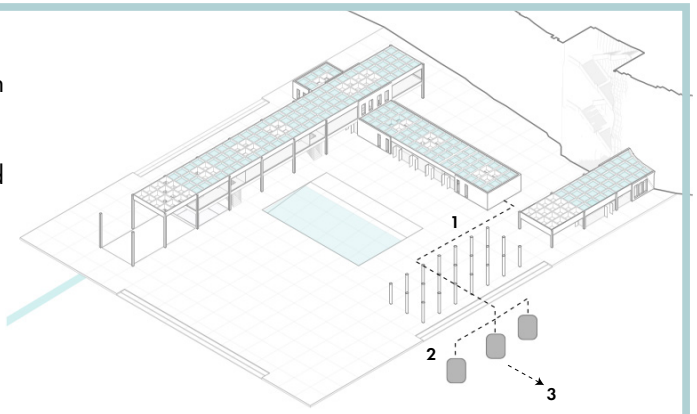


Grey water capture and treatment cycle

Black Water Discharge

Black water is collected and discharged into the bioswales that extend form the project on to the landscape. Water is guided into constructed wetlands from where the it slowly penetrates into the watershed, replenishing what the aggregate mining subtracted from the water table.

1. Black water segregation
2. Segregated water collected in septic tanks
3. Discharged to constructed wetlands



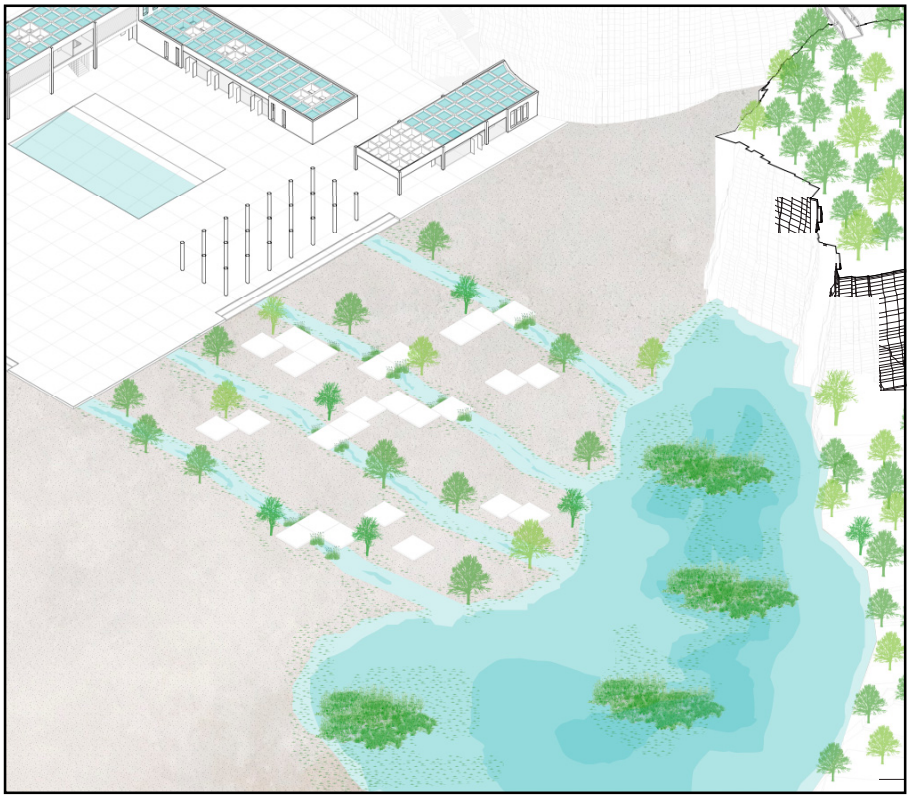
Black water segregation and discharge cycle

Section showing activities and movement of water.

Constructed Wetlands

Constructed wetlands have increasingly been recognized for the benefits that they provide for wastewater or contaminant treatment. Constructed wetlands offer several benefits for restoration of ecology and are fairly inexpensive to build (France 2003, 17).

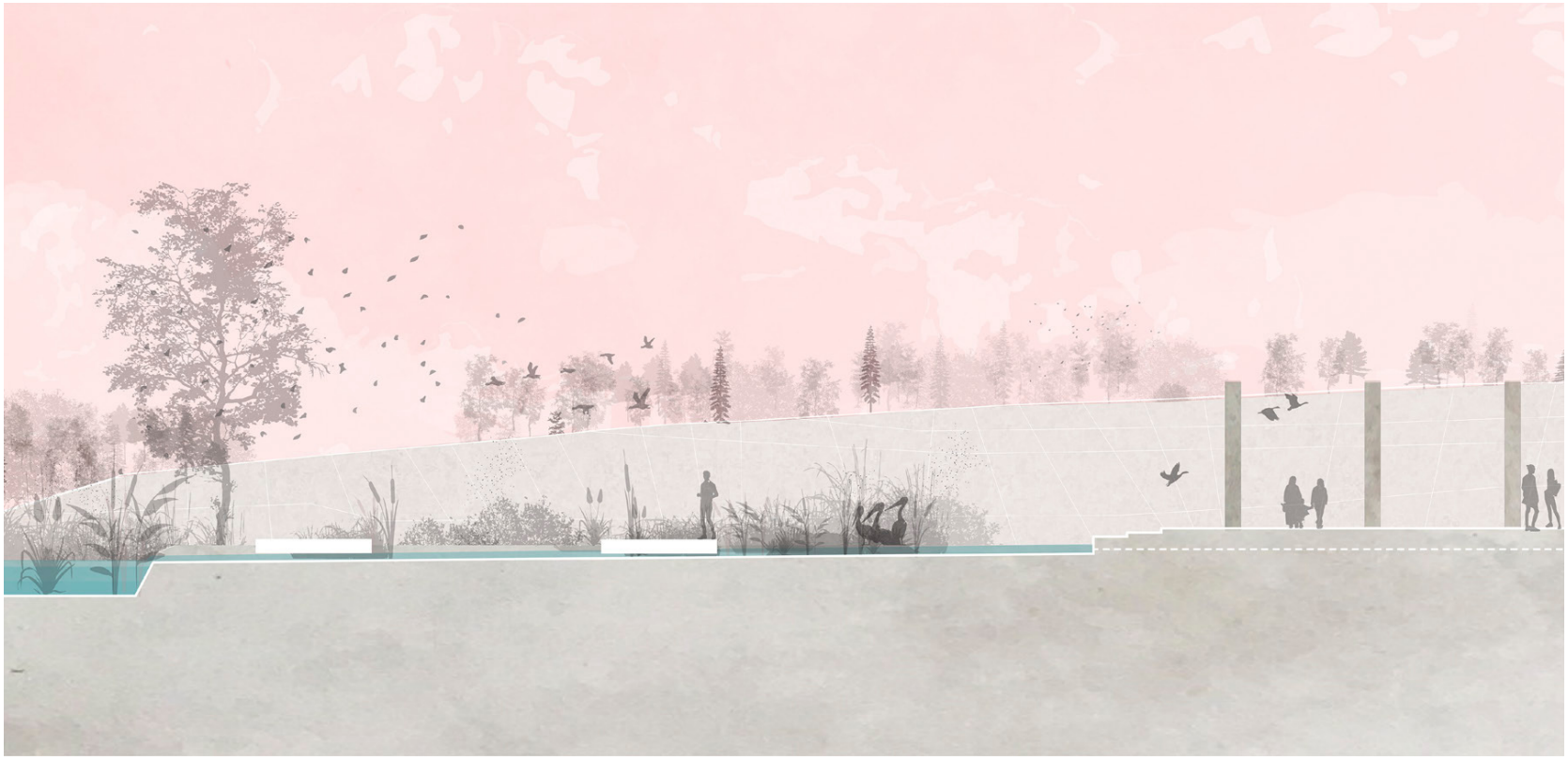
The varied water depths in wetlands allows for the development of emergent, submerged, and floating vegetation, which in turn attracts a wide variety of animals for spawning, nesting, breeding, feeding, predator refuge and nursery rearing purposes (France 2003, 20). Not only that, but studies have shown that over a third of all rare and endangered species are either direct residents of wetlands themselves or are closely dependent on wetlands for a variety of essential purposes (France 2003, 21). The constructed wetlands that are part of the project are designed to quickly become habitats for native and endangered species of the Niagara Escarpment.



Bird's eye view from the south west showing the constructed wetland in relationship to the building.

Long section showing building enclosure and its interaction with the pool deck and the rehabilitated landscape beyond. The detailed section on the following pages shows a closer view of the interior of the research laboratory and the pool deck below.

A closer view of rehabilitated landscape that are combining conservation with recreation, education and research, enabling the Quarry Pool to perform the functions of the UNESCO Biosphere.



A closer view of the inhabited laboratory space and the pool deck below combining the recreation program with the research and education wing. The black water septic tanks are ghosted in (bottom left).

Materiality

The project is intentionally designed in concrete as it uses all the materials that are a product of the aggregate process. Poured-in-place concrete columns support the coffered slabs that form the roof and floors. The coffered roof become roofs ponds and slow the flow of water on the roof, allowing it more time to aerate. At certain moments the roof is punctured to install a skylights. To minimize southern exposure on the second floor, concrete louvers are added to minimize solar gain.

Chapter 5: Conclusion

The Niagara Escarpment region is a treasure for the residents of Southern Ontario. The inevitable increase in population and subsequent demand for aggregate is threatening this rich landscape. As discussed earlier that the system of quarries is prototypical and since aggregate resources are plentiful within the GTA region of Niagara Escarpment, more quarries will establish. It is therefore proposed that using the design principles of rehabilitation and using prototypical conditions of these site, quarries can be naturally rehabilitated, they can rejuvenate the economy and provide opportunities for research and education to ensure that future generations of this region can continue to benefit from this ecological treasure.

Niagara Escarpment needs to meet the mandate for UNESCO Biosphere reserve by performing the functions of Conservation, Economic and Human development and Research and Education. Through these interventions along the Niagara Escarpment, another hybrid system can evolve to coexist with the existing regional systems to ensure the continuity of the Niagara Escarpment region and its ecological benefits.

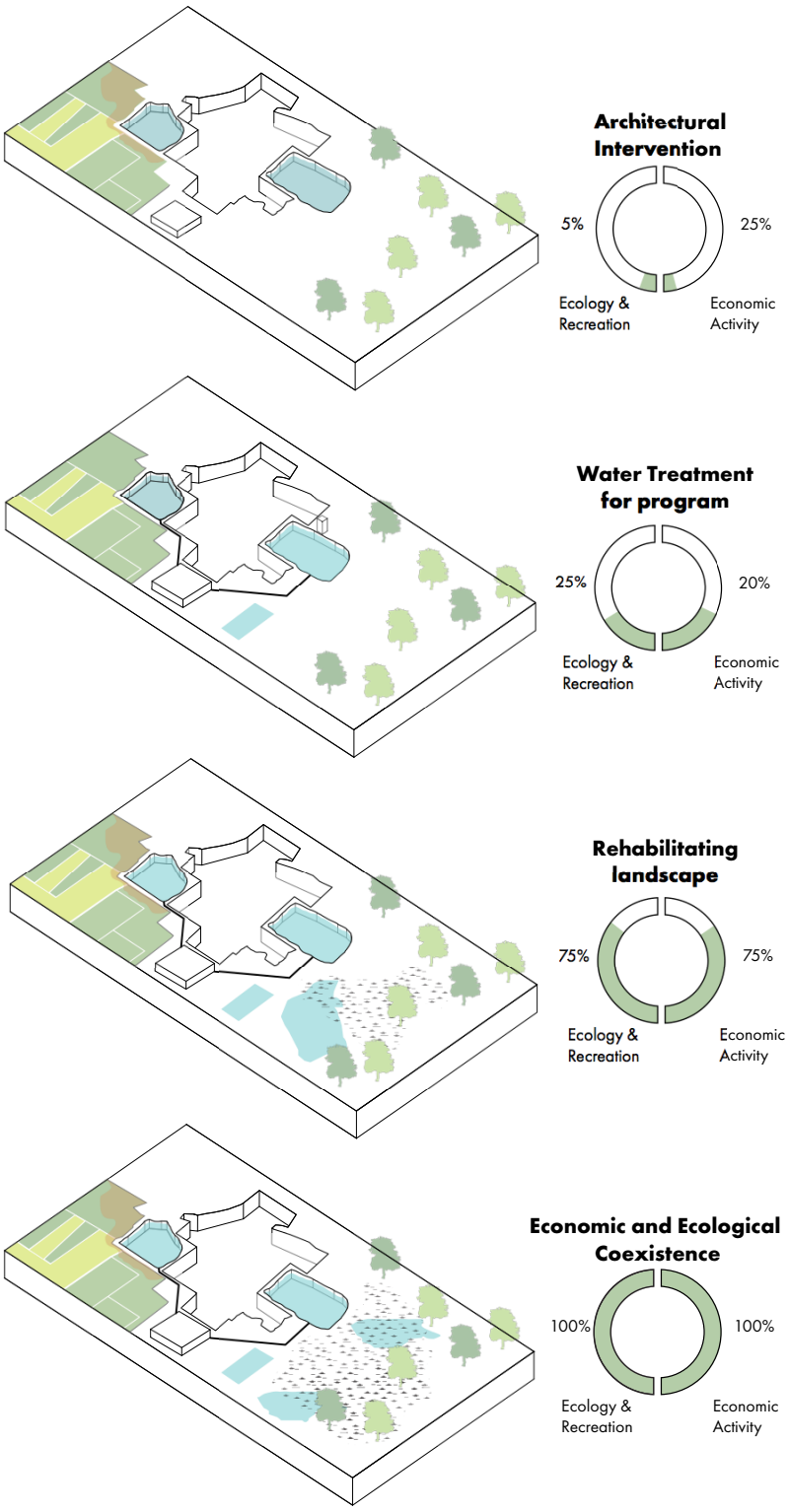


Diagram of system of conservation.

References

ArcGIS. 2018. "Ecology of Halton Region" [basemap]. Scale Not Given. Accessed on November 18.

ArcGIS. "Niagara Escarpment" [basemap]. Scale Not Given. Accessed on November 18.

ArcGIS. "Population Growth of GTA" [basemap]. Scale Not Given. Accessed on November 18.

ArcGIS. "Quarries in Southern Ontario" [basemap]. Scale Not Given. Accessed on November 18.

ArcGIS. "Recreation System" [basemap]. Scale Not Given. Accessed on November 18.

ArcGIS. "Trail Fragmentation" [basemap]. Scale Not Given. Accessed on November 18.

Binstock, Matt, Carter-Whitney, Maureen, Canadian Institute for Environmental Law Policy, and Canadian Electronic Library. 2011. *Aggregate Extraction in Ontario a Strategy for the Future*. DesLibris. Documents Collection. Toronto, Ontario: Canadian Institute for Environmental Law and Policy.

Bruce Trail Conservancy. 2019. Trail Sections. Accessed on September 1. https://brucetrail.org/trail-sections.

Canadian Geoscience Education Commission (CGEC). 2018. Geoscape - Toronto: The Niagara Escarpment. Accessed on December 24. https://www.cgenarchive.org/toronto-niagara-escarpment.html.

Conservation Halton. 2019. *Species at Risk in Halton*. https://www.conservationhalton.ca/halton-species-at-risk?fbclid=IwAR0Zso5ojRrQPieEF1jBPmlVVm5KG3RqcBxUgnvX-WESVsp2B902bcuj75dw.

Corry, R. C., R. Lafortezza, and R. D. Brown. "Ecological Functionality of Landscapes with Alternative Rehabilitations of Depleted Aggregate Sites." *International Journal of Mining, Reclamation and Environment* 24, no. 3 (2010): 216-32.

Corry, Robert C., Raffaele. Lafortezza, and Robert D. Brown. "Cultural Acceptability of Alternative Pit and Quarry Rehabilitations." *Ecological Restoration* 29, no. 1 (2011): 64-72.

CRH Canada, 2017. "Dufferin Aggregates Milton Quarry Overview". YouTube video, 4 min and 24 sec. Accessed on December 1, 2018. https://www.youtube.com/watch?reload=9&v=A-UlBQsp3YE.

David Suzuki Foundation. 2008. *Ontario's Wealth Canada's Future: Appreciating The Value of The Greenbelt's Eco-Services*. Accessed on January 2. https://davidsuzuki.org/wp-content/uploads/2018/02/ontario-wealth-canada-future-value-greenbelt-eco-services.pdf.

Dmitrakova Yanina et al. 2016. *Biodiversity in Space and Time*. https://www.quarrylifeaward.com/sites/default/files/media/ru-63_en-biodiversity_in_space_and_time.pdf

Duffrin Aggregates. 2012. "Duffrin Aggregates: Overview of Milton Quarry Groundwater Recharge System". 9 min 20 Sec. Vimeo Pro Video. Accessed on September 14. https://vimeopro.com/user9670035/video-samples/video/36703555.

Duval, Waddington, and Branfireun. "Towards Calcareous Wetland Creation in Flooded Abandoned Aggregate Quarries: A 3-year Field Mesocosm Study." *Ecological Engineering* 36, no. 4 (2010): 586-95.

France, R. L. 2003. *Wetland Design : Principles and Practices for Landscape Architects and Land-use Planners*. 1st ed. New York: W.W. Norton.

Gh3 Architects. 2014. *Borden Park Natural Swimming Pool #2*. https://www.gh3.ca/work/natural-swimming-pool-02.

Giant's Rib Escarpment Education Network (GREEN). 2014. *Formation of Niagara Escarpment*. http://www.giantsrib.ca/formation-of-the-escarpment/.

Google Earth. 2019. "Map of Duffrin Quarry and Elevation data." Accessed on November 8.

Google Maps. 2019. "Map of Duffrin Quarry and Town of Milton." Accessed on January 8. https://maps.google.ca

Google Maps. 2019. "Map of Halton Region." Accessed on January 8. https://maps.google.ca

Google Maps. 2019. "Map of Southern Ontario." Accessed on January 8. https://maps.google.ca.

Government of Ontario. 2019. *Find Pits and Quarries*. Accessed on November 25. https://www.ontario.ca/environment-and-energy/find-pits-and-quarries.

Government of Ontario.2018. *Ministry of Environment Aggregate Resources Act 1990*. Version c 23, Sched. 5, s 1-7. Accessed October 2. https://www.ontario.ca/laws/statute/90a08.

LaGro, James A. 2001. *Site Analysis : Linking Program and Concept in Land Planning and Design*. New York, N.Y. ; Toronto: John Wiley.

Ministry of Finance. 2017. *Ontario Population Projections Update, 2017–2041*. https://www.fin.gov.on.ca/en/economy/demographics/projections/.

Neptis Geo web. 2018. *Historical Urban Expansion (1971 - 2011)*. Accessed on November 13. https://www.neptisgeoweb.org/.

Niagara Escarpment Commission. 2012. *Periodic Review of the Biosphere Reserve*. https://www.escarpment.org/NiagaraEscarpment/UnescoWorldBiosphereReserve/PeriodicReview.

Niagara Escarpment Commission. 2019. *Biodiversity*. https://www.escarpment.org/NiagaraEscarpment/Environment/Ecology/Biodiversity.

Niagara Escarpment Commission. 2019. *Geological Timeline*. https://www.escarpment.org/NiagaraEscarpment/Environment/Geology/GeologicalTimeline.

Ontario Sand and Gravel Association. 2015. *The Future of Ontario's Close to Market Aggregate Supply: The 2015 Provincial Plan Review*. https://www.ossga.com/multimedia/0/789-2015_provincial_plan_review_aggregate_industry_discussion_paper_-_april_30_2015.pdf.

Government of Ontario, Ministry of Natural Resources, and Canadian Electronic Library. 2010. *State of the Aggregate Resource in Ontario Study Consolidated Report*. DesLibris. Documents Collection. Peterborough, Ontario: Ontario Ministry of Natural Resources.

Port, Caitlin Marie. 2013. *The Opportunities and Challenges of Aggregate Site Rehabilitation in Southern Ontario. An Evaluation of the Rehabilitation Process from 1992-2011*. https://uwspace.uwaterloo.ca/bitstream/handle/10012/7966/Port_Caitlin.pdf?sequence=1&isAllowed=y.

Port, Caitlin Marie. 2014. *Study of Aggregate Site Rehabilitation in Ontario: Bruce County, Dufferin County, Grey County & Simcoe County Part 2 addendum*. The Ontario Stone, Sand & Gravel Association. http://www.ossga.com/multimedia/31/702-ossga_rehab_study_part_ii__addendum_2014.pdf.

The Giant's Rib Escarpment Education Network (GREEN). 2014. E*cology of Niagara Escarpment*. http://www.giantsrib.ca/ecology/.

Toronto Environmental Alliance. 2009. *Dig conservation Not Holes: A Report on GTA's Thirst For Gravel and How to Quench it*. https://d3n8a8pro7vhmx.cloudfront.net/toenviro/pages/587/attachments/original/1418055316/TEAreport_Dig-Conservation-Not-Holes_2009.pdf?1418055316.

Unep.org. 2018. "Phytoremediation: An Environmentally Sound Technology for Pollution Prevention, Control and Remediation". *Newsletter and Technical Publications Freshwater Management Series No. 2*. http://www.unep.or.jp/Ietc/Publications/Freshwater/FMS2/1.asp?fbclid=IwAR12DDks_IBFU63JkLpK4dlI0jKfJlJ-KHA1X1aZNzfKjTYHz-b95Osg0hNE.

Unesco.org. 2017. *Main Characteristics of Biosphere Reserves*. http://www.unesco.org/new/en/natural-sciences/environment/ecological-sciences/biosphere-reserves/.