When Nature Goes to School:

A Green School Design for Milton, Ontario

by

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A thesis

presented to the University Of Waterloo

in fulfilment of the

thesis requirement for the degree of

Master of Architecture

Waterloo, Ontario, Canada, 2019

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

ABSTRACT

It is generally agreed upon that environmental education has an important place in 21st century schools, as the need to educate the current and future generations of young people on how to live in a sustainable way grows increasingly urgent. Within the framework of formal education in Ontario, efforts to prepare students to be environmentally responsible citizens has mainly concentrated on the integration of sustainability concepts into the curriculum. This thesis argues that equal attention should be given to integrating sustainability concepts into the physical environment of the school – the education facility itself – as it has the potential to be not merely the place where environmental education is taught but be the source of environmental education. This thesis takes the theoretical position proposed by environmental educator David Orr that architecture is a source of pedagogical instruction.[1] The power buildings have to teach people, can be harnessed to design a building that can be utilized to foster sustainability behaviour. Schools' role in society in preparing children for the future gives an educational building the unique advantage of teaching people to be sustainable-minded when they're at an impressionable age.

The project presented takes the form of a design proposal for a *green school* for K-8 students, located on a case study site in Milton, Ontario. A *green school* is an emerging architectural type, the term for which was developed by the Centre for Green Schools at the U.S. Green Building Council and is used to describe schools that advance sustainability by aspiring to reduce their environmental footprint, improve the wellbeing and performance of its students and staff, and ultimately producing graduates who are ecoliterate.[2] The design proposal concentrates on achieving these three goals through the architecture of the proposed education facility, through a design that demonstrates the environmental awareness it promotes.

Following the long-held tradition of the demonstration project, this thesis builds on strategies developed from a precedent study of existing environmental education centres in the same climatic region. These organizations consider their building an integral part in the fulfillment of their mission to educate the public on sustainability, using it as a demonstration tool. The climatic region of southern Ontario will inform key aspects of the design – the orientation, massing, form and materiality – as true sustainability responds to the specific conditions of the site. The design takes advantage of positioning a school on an ecologically-rich landscape to strengthen students' sense of connection with nature. The project scope encompasses the spatial design, materiality, structure, building systems and operations, the landscape and site design, and each of these aspects were considered with their potential for pedagogy. The design addresses these aspects of the built environment across different scales, presenting within the school a variety of learning space types whose environmental design has been fine-tuned to suit their function and climate.

1 David W. Orr, "Architecture as Pedagogy," *Conservation Biology* 7, no. 2 (1993): 226-228, www.jstor.org/stable/2386418.

2 Anisa Heming, "What is a green school?" Centre for Green Schools, U.S. Green Building Council, published July 30, 2017, https://www.centerforgreenschools.org/what-green-school.

ACKNOWLEDGEMENTS

This master's thesis is a culmination of my learning and experience at the University of Waterloo School of Architecture. Many people, both within and beyond the Waterloo Architecture community, have been a part of my success. In particular, I would like to thank:

My supervisor Terri Meyer Boake, for her endless patience, guidance and support throughout this long process. Thank you for your constant encouragement; I always left our meetings with renewed enthusiasm. Your advice was critical in steering me in the right direction. I truly appreciate all of the time and energy you gave to this project.

My committee member, Rick Andrighetti, for his support and enthusiasm for my work. Your constructive feedback and insightful comments greatly helped shape my design work in the developmental stage of this project.

My internal and external reader John McMinn and Paul Dowsett for kindly agreeing to be part of this thesis committee. Thank you for your time, and your questions and critiques at the defence.

All of the staff at the School of Architecture, for all of their friendly assistance.

My family, for their continuous love and support throughout my years of study. A special thanks to my sister Valentina, for all her help with proofreading my drafts and accompanying me at my defence.

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By Author.

CHAPTER 1:

INTRODUCTION

1.1 – The Diminishing Relationship between Children and Nature

> *"Our children have exchanged the experience of the outdoors and nature with the enclosed world of electronics. This is disturbing because a person for whom nature is a stranger will not notice, let alone care about, environmental degradation."*[1] *– David Suzuki*

The initial inspiration for this thesis work was Richard Louv's book *The Last Child in the Woods*, the publication of which brought increasing attention to the growing disconnect between children and the natural world. As Louv and countless other adults have observed, children growing up in the 21st century are spending less time outdoors than previous generations did, and as a result their relationship with nature is weakening. Louv developed the term "nature-deficit disorder"[2] to describe the impacts of decreased contact with nature which include, "diminished use of the senses, attention difficulties, and higher rates of physical and emotional illnesses."[3] While the term does not refer to an actual medical illness, by referring to it as a disorder, Louv frames it as a problem that is deeply related to the wellbeing of humans. And while people of all ages can suffer from "nature-deficit disorder," Louv concentrates on how children are affected because of the important role that nature has traditionally occupied in childhood.

Childhood as a cultural experience is different today than it was even just a few decades ago. Children are growing up in a world that is increasingly dissimilar from the one their parents knew growing up. How does the world of today's children differ? Children today are:

- **Growing up increasingly in urban areas**
  - Where more people are now living in urban areas than not. This is particularly true in North America which is considered the most urbanized region in the world with 82% of its population settled in urban areas.[4]
- **Growing up in a globalized world**
  - Where every conflict taking place in the world has become ours
  - Where our neighbourhood has extended to include all those people whose lives are linked with our own, rather than just the people living physically next to us.
  - Where many of our resources including food come from far away
  - Where they learn about rainforests and distant places, at the expense of intimately knowing the place they grew up
- **Growing up with the technology**
  - Where the current generation of children has never known life without technology
  - Where the proliferation of technology has resulted in children spending leisurely time engaged in sedentary activities involving electronics as opposed to

being physically active outdoors.

- **Growing up where play is increasingly structured**
  - Where play is meant to be an educational event, children are involved in a myriad of extracurricular activities, and free time is seen not as necessary downtime but a luxury
- **Growing up in a world where the environment is regarded as something that needs healing**
  - Where unprecedented levels of attention is given to environmental issues – in the news, media, and in class, consistently portraying nature in a negative light, making children consider it with fear rather than joy.[5]

Nature has long been an important part of childhood. A place to play, run around, explore, and be messy. But for many reasons, such as the ones listed above and including increased fear over safety[6] and lack of time,[7] children are spending less time outdoors than ever before. This is concerning for many reasons, not only because of the health and developmental benefits that children are missing out on, but also due to reasons related to the current environmental crisis. As the human species continues to negatively impact the planet through their actions, such as pollution, consumption of resources, habitat destruction, etc., there is a risk that they will destroy the planet to the point that it will not be able to sustain future populations. As children are the future stewards of the earth, it will be left up to them and future generations to find a solution to these problems. But why should they care about saving the Earth if they never knew it, and never learned to love it?[8]

The Need for Environmental Education



Figure 1.1 - Environmental education helps foster the potential all children have to be future keepers of the earth.

Environmental education has emerged as one of the key strategies in addressing sustainability,[9] as teaching children to be environmentally aware and concerned citizens is essential now more than ever if they are expected to be better environmental stewards than their predecessors. In order for them to be better stewards, it is desirable that children are not only made more aware as that is a precursor to action,[10] but that they develop a different way of relating to the earth. As such, environmental education often focuses on the development of ecological literacy which is defined as the understanding of the complex set of interrelationships existing between humans and the natural world.[11] This understanding is based on two components: a knowledge-based understanding of "how nature sustains life," and an emotional basis that leads to development of empathy towards nature out of which arises a desire to care for it. [12] [13] Direct experiences with nature are considered to be necessary to the development of ecological literacy, and it is especially important that these experiences and should occur during childhood as that is the period in life when the development of values relating to nature are believed to be formed.[14] But if children today are spending less time in contact with nature, they are less likely to form a connection to it. It has been observed by environmental educator David Orr that "achieving ecological literacy is becoming more difficult, not because there are fewer books about nature, but because there is less opportunity for the direct experience of it."[15] In order for children to develop

and strengthen their relationship with the natural world it is required that they spend more time interacting with it. Through repeated contact, children can learn to appreciate being in nature, to understand its value, and to begin to respond to the natural world with a sense of stewardship and care.[16]

For the first time, direct experiences with nature may need to be consciously designed into children's built environment, if we wish for them to learn to be more sustainably-minded.[17,18] As the place where children spend the most of their waking hours outside of home, schools emerge as the ideal place for this.

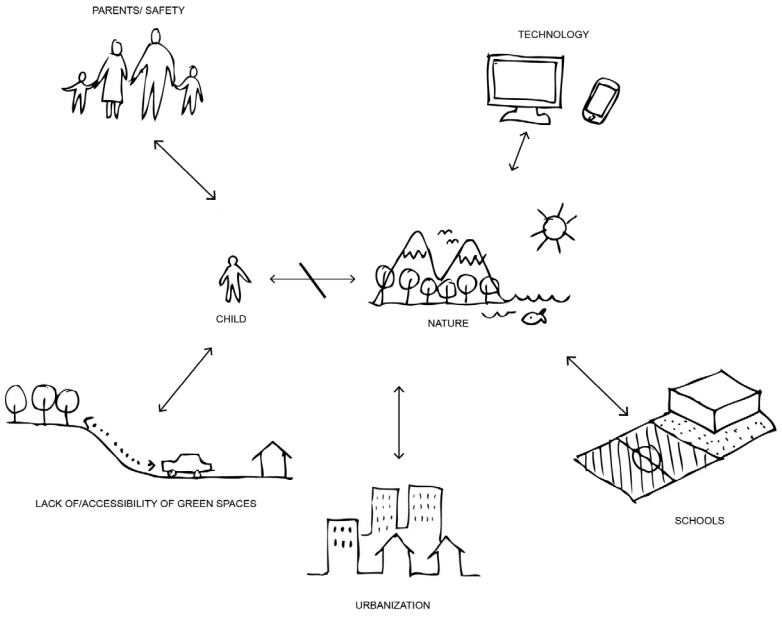


Figure 1.2 - Some factors contributing to the diminishing relationship between children and nature.

1.2 - Thesis Objective

This thesis explores how architecture can be used as an effective tool in helping foster environmental stewardship behaviour in children, focusing on the design of school facilities due to schools' prominent role in society as the place where education occurs. This thesis takes the position that buildings can be a source of environmental education, when designed in such a way as to support ecoliteracy. If the development of ecoliteracy is understood to be based on the improved understanding of one's interrelationship to nature, for effective environmental education to occur, the setting in which it takes place would need to alter students' relationship to the natural environment. One such way for this to take place, is by integrating sustainability concepts into the physical environment of the school through a building design that demonstrates the environmental awareness it seeks to promote.

Theoretically this thesis takes the point of view that the physical environment of a school is more than just the place where environmental education is taught, but is a source of environmental education in itself. This understanding is based on the belief that the built environment of the school – that is the physical place itself – plays an important role in students' education, whether intended to or not.[19] The idea that architecture is a source of pedagogical instruction comes from the writings of environmental educator David Orr,[20] and forms the theoretical foundation and approach that this thesis takes towards environmental education. Orr believes that values are taught through the design of one's built environment, as embedded in the design of every building are certain values which are transmitted to the occupants thereby lending it the ability to shape people's behaviour.[21] In a school building, this power is even more potent, due to its very nature as the place where people go to be educated. Many designers share this belief about the power of the school building to influence the values that education transmits to children. Architect Anne Taylor refers to the school as a "three-dimensional textbook,"[22] assigning to it an ability to instruct as well as to be read. The term "the third teacher," whose origins lie in Loris Malaguzzi's Reggio Emilia education program, similarly suggests that learning occurs not just as an interaction between a teacher and student, but also through the interaction between the student and the learning environment,[23] thus similarly suggesting that the design of the school can either enhance or detract from the values and message that 21st century schools wish to impart on their students. When this theoretical approach is applied to the goal of educating for sustainability, it is thus suggested by Orr and others that school facilities themselves must be designed to be sustainable in order to physically demonstrate the environmental awareness it seeks to promote.

Thus, the physical school environment can play a vital role in supporting environmental education, through an architectural design that integrates sustainability concepts into educational facility itself. In this way, the power buildings have to teach people, can be harnessed as a tool in helping foster sustainability behaviour. Thus, this thesis asks the question: How can the architecture of a school teach ecoliteracy and promote environmental stewardship behaviour through the design of the facility, site and building system? The answer to this question will be presented in the form of a design proposal for a K-8 *green school*, located on a case study site in Milton, Ontario. If ecological literacy arises out of the development of an emotional connection to nature, and through instruction that builds up one's knowledge of the earth's natural processes and how people interact with them, then the design response will seek to create a learning environment that supports these qualities.

1.3 – Breakdown of Thesis Structure

This thesis is structured into four main chapters, the first three of which explore strategies for the thesis problem, which are then synthesized in the final chapter in the form of a design proposal for an elementary school (K-8) that is the focus of this design oriented thesis.

The first part of this thesis, ***Chapter 2***, begins by providing an overview of the theoretical background within which the thesis operates, laying out the situations to which the design responds to in section *2.1*. The first section explores the degradation of the environment as both a design and educational problem, connecting the way we design to the way we have been taught to view ourselves in relation to nature. It goes on to suggest that education for sustainability can be one way that the challenges of the environmental crisis can be addressed. The first section then briefly looks at how environmental education is currently taught within the formal education framework of the province of Ontario, which is where the project site is located, setting up the background educational context in which the thesis operates. Section *2.2* of ***Chapter 2*** establishes the theoretical approach and design framework upon which the proposed design will be built. The section introduces the concept of a *green school,* an emerging architectural type for schools that seek to advance sustainability, the term and design framework for which was developed by the *Centre for Green Schools*. The *green school* typology provides a measurement framework referred to as the three pillars of green school design which will be used as design criteria for the design proposal. This section investigates in greater detail potential design strategies for achieving the three pillars of green school design which will be applied to the final design proposal. The final part of this chapter addresses the theoretical approach of how architecture can be a source of environmental education by examining the texts of environmentalist David Orr and school designer Anne Taylor. Orr's concept of how architecture is a source of pedagogical instruction is explored in two ways: the first part looks at the negative lessons that a typical school building, that is one designed without a conscious regard for its relationship with the environment, can teach its occupants; and the second part looks at the potential lessons related to environmental education that a green school could teach its occupants when it physically embodies and demonstrate these values related to sustainability. This is followed by a brief exploration of Taylor's concept of the school operating as a "three-dimensional textbook" for sustainability which forms a strategy for how a green school can teach.

In ***Chapter 3***, a series of precedents are looked at and analyzed, as a way of developing design strategies to inform the thesis design proposal. This chapter is broken down into five categories, looking at precedents that encompass a range of scales, but all seek to in some sense utilize the built environment to improve their occupants' sense of ecoliteracy and/or promote environmental stewardship behaviour, as well as improve the health and wellbeing of the both people and the natural environment. The first section explores an existing green school in Ontario – Dr. David Suzuki Public School – breaking down by category the sustainable features incorporated into its design that led it to become the first LEED™ platinum

certified school in Canada. As this is the only such school within the climatic-region of Ontario, the second section is a precedent study of existing environmental education centres. Environmental education centres are considered to be ideal precedents for this project as they have similar goals to that of green schools, which is to educate the public on sustainability and increase people's awareness of environmental issues, as well as generally providing people with the opportunity to have experiences in nature. Due to these centre's role in supporting environmental education, it is generally expected that the building will be designed to demonstrate sustainability and many tend to seek LEED-certification. For this reason there are a greater amount of environmental centres with inspiring sustainable designs to study than there are schools. The selected projects are investigated in terms of the strategies the buildings utilize for reducing their environmental impact, for increasing the buildings' relationship to the site, and for increasing visitor's environmental awareness. The third section moves to a more specialized category of study – the biological wastewater treatment process referred to as the Living Machine® – that will be one of the highlight features of this project's design proposal due to how the system is an example of ecological design and makes a natural process visible. The fourth section moves down a scale to look at the classroom unit and how it can be designed in such a way as to support the objectives of a green school. The fifth section briefly investigates the importance of food education and how it fits in within the environmental education curriculum of a green school. The thesis design proposal will build up on the strategies derived from the precedent studies.

Chapter 4 introduces the project site of Milton, Ontario, which forms the background context for the design proposal. The first section ***Site Context*** provides an overview of the existing site conditions to which the design responds to, specifically the town's rapid rate of growth and urban development which is quickly transforming and putting pressure on its rural landscape. It describes the criteria according to which the specific plot of land on where the project will be proposed was chosen. The decision was made in part of the town's abundance of significant natural features, which the project takes advantage of by positioning the proposed school on an ecologically-rich landscape that allows it to demonstrate potential strategies for how students' sense of connection with nature can be strengthened. A series of photographs serves as a site walkthrough, illustrating the existing site condition. The second section ***Climate Analysis*** describes the climatic conditions of the region and briefly the microclimates of the site. Based on this information, a list of design strategies and priorities for the climate of southern Ontario is created. This climate analysis helped the proposed school form a design response that is more sustainable because it responds to the specific conditions of the site, allowing the building to provide high levels of thermal comfort but at the same time be more energy efficient by working with the natural forces of the site. The climatic analysis was used to inform key aspects of the design such as the orientation of the building on the site, the form and massing of the school, as well as the material choices for the building envelope.

The final chapter, ***Chapter 5***, synthesizes the green school framework with the design strategies derived from the precedent study, adapting both to the specific conditions of the project site to envision a green school design for Milton, On-

tario. The project presents the design proposal of *Creekside Valley EcoSchool*, addressing in its scope the building in terms of both its spatial and material design, the building systems and operations, and the site and landscape design. Section *5.1* provides an overview of the design establishing the parti of the building and programmatic layout of the school, constructing an overall sense of the building through key drawings such as the site plan, ground floor plan and elevations. Section *5.2* deals with the material design of the proposed school describing the approach taken towards the structure and building envelope of the building, and how this approach supports the goals of a green school. Section *5.3* thoroughly examines the environmental system design of the school, explaining the passive and active system strategies that were taken to ensure thermal comfort within the interior of the building, as well as the sustainable site strategies integrated to manage the flow of resources across the site. This is followed by section *5.4*, a design narrative that looks more closely at the major programmatic spaces within the interior and exterior of the school, presenting them through a series of rendered perspectives and zoomed-in floor plans which highlight the key design features of each space at room scale.



Figure 1.3 - Atmosphere collage of the inner courtyards concept of the proposed design, exploring the potential programs that could be contained within such as a reading area integrated within a larger pollinator garden that contains colourful native vegetation species.

Figure 1.4 - (opposite page) Image of author holding up a maple leaf picked up while exploring the ecological features of the site of the proposed project.



1.4 – Basis of Design

Educational Mission and Curriculum Goals

The Creekside Valley EcoSchool is envisioned as a private elementary school serving 400 students in kindergarten through Grade 8. The school's mission is to foster environmental stewardship behaviour in its students, to produce graduates who are ecoliterate, and to prepare students with the awareness and knowledge they need to take action as leaders in addressing the sustainability challenges of the future. The hope is that students will be inspired to make a positive change beginning today in their own community and as they grow up expanding out in the world.

With this mission in mind, the school offers a specialized environmental science-based curriculum that focuses on instruction in the natural sciences, ecology and environmental education. The sciences are studied with emphasis on the relationship between human activity and the natural environment, concentrating on issues of sustainability and conservation. Similarly to the way arts-based schools structure their teaching timetables,[24] about half the day will be focused on instruction related to the specialized curriculum, with the other half of the day being spent on teaching core academic subjects (math, reading, writing, history, geography, arts, etc.) through an integrated curriculum approach that connects these subjects to the current unit of study within the sciences.

Promoting ecological literacy and stewardship of the environment from an early age, is one of the main goals of the curriculum. An integrated curriculum supports this goal on the basis of the idea that "all education is environmental education."[25] Through the understanding of what ecological literacy is and what it is concerned with – relationships – it has been concluded by environmental educators that it cannot be taught as effectively as a single subject due to its complexity as it is a part of every subject. Integrated learning forms interrelationships between subjects. For this reason it is beneficial to the learning process due to its closer resemblance in operation to the way the brain or the real-world works, where disciplines are rarely isolated as they are as subjects.[26]

Fostering a "sense of place" is another key curricular goal. The term "sense of place" can be defined as an "experientially based intimacy with the natural processes, community, and history of one's place."[27] This is supported by the curriculum which takes on a special theme of focus on the local nature of the site. The specialized science curriculum instructs students in the study of the local ecology directly on school's site (made possible by the school's siting on an ecologically-rich landscape next to the Sixteen Mile Creek). Students also focus on the relationship between themselves and the human and natural community which they are part of. This helps students develop a deeper connection to and knowledge of their neighbourhood, helping them to relate what they're learning to themselves, and instill a sense of belonging to their community.[28] [29] [30]

Going along with this is the development of a "sense of wonder" for the natural world. Nurturing children's sense of wonder towards the earth is considered to be an important step in developing ecoliteracy. This is because if children develop an emotional connection towards nature, they will be more likely to seek out knowledge about it.[31] If they do not feel affection for nature first, the knowledge about it is less likely to stick.[32] Children can develop a sense of wonder through direct experiences in nature, particularly ones where a trusted adult is present (such as a teacher) to guide them, share with and discover with them the wonders of this world.[33] The curriculum of the school supports this by incorporating instruction that allows for learning through direct experiences in nature. This form of learning is referred to as "experiential education,"[34] and it emphasizes learning through hands-on activities, allowing the student to learn by doing or experiencing something. In this education model, learning extends beyond the walls of the classroom taking place in a multitude of areas throughout the building, on the school grounds or out in the natural environment. The direct experiences support and complement the more formal instruction. This approach nurtures children's natural curiosity, and desire to explore and experiment.

The educational approach is one that focuses on the development of the whole child. A whole child approach to education is holistic, giving equal priority to the development of the one's mind, body, and spirit.[35] This is in alignment with the second pillar of the green school framework, placing the health and wellbeing of the school's students (and staff) into a place of high importance. This is supported through a curriculum that offers opportunities for instruction that support different styles of learning, and in a variety of indoor and outdoor settings.

Design Goals

The curricular goals are supported by the architectural response of the school grounds and facility. The environmental stewardship theme of the educational curriculum was the driver of the proposed design, and the school uses site elements for demonstration of sustainability themes. Each element of the site is viewed with its potential for pedagogy. The design of the school building and landscape help promote the development of ecological literacy and environmental stewardship behaviour through:

1) Physically Demonstrating the Principles of Sustainability through a Green Building Design

A sustainable building is one that is designed, constructed and operated in such a way that reduces its environmental impact. By designing the school facility for sustainability, the proposed building will physically demonstrate and model a more positive relationship between the human and natural environment. This helps develop ecoliteracy and stewardship behaviour because as is concluded in the literature reviewed in *Chapter 2,* as part of the development of a theoretical approach to the design, a building must demonstrate the values and behaviour that the educational system wishes to teach in order for them to be effectively passed on.[36] The project's proposed green school design targets LEED® Platinum, the highest level of certification under the LEED (Leadership in Energy and

Environmental Design) rating system. The categories that are measured under the LEED framework acted as a starting point for the project's design, as they address sustainable design throughout all areas of the building. Other sustainability objectives that the proposed green school aims to work towards are a net-zero energy building design, net zero water use for the facility, as well as seeking to reduce the building's carbon footprint.

One of the key strategies that the proposed school design takes is an ecological design approach to sustainability that first targets reducing the environmental impact of the building by utilizing the free services of nature – the sun, wind, and rainwater – and utilizing them as sources of renewable energy and resources.[37] These are harnessed through basic elements of the building design such as the orientation of the building on the site coupled with a skin-load dominated building form and the fenestration design, which are all designed as a response to the specific climate of the site. Passive design strategies are another one of the main sustainability strategies that are employed in the design proposal to utilize the energy of the sun and wind in order to reduce the building's energy demand and improve thermal comfort without requiring any additional input from mechanical equipment; some of the main passive design strategies that are demonstrated in the proposed design are a sunspace heating system, thermal mass surfaces, direct solar gain, natural ventilation through cross-ventilation and controlled admission of daylighting. The proposed building will also feature several green technology systems that produce renewable energy to power the building or operate as an energy efficient mechanical system; these include photovoltaic panels, geothermal heat exchange system, earth-tube ventilation system, and an energy recovery ventilation system, among other active strategies.

The landscape strategy further supports the overall sustainability goals of the building by not just acting as a decorative element of the project, but by playing a role in the management of resources and supporting the operations of the building. Some of the strategies that will be presented that support this function of the landscape include water-wise landscaping through the use of native species of vegetation, the on-site management of stormwater run-off, and the integration of an onsite wastewater treatment process that allows the building to re-use its wastewater.

2) Providing Opportunities for Direct and Indirect Experiences in Nature

The programmatic elements of the building and site respond to the experiential learning component of the curriculum. The programming strategy provides access to a variety of indoor and outdoor environments that support the curriculum by providing opportunities for direct and indirect experiences in nature. To support the specialized curriculum and its goals, the building offers program spaces that are unique to the school, and that respond to the environmental science theme. One way this is supported in the proposed design is through the provision of science laboratories as part of the building program; these labs serve as dedicated spaces that provide access to the necessary space and equipment to allow for specialist activities to occur. Outdoor spaces gain importance in the program of the green school because as much of the learning happens outdoors as it does indoors. In reflection of this, the design of the landscape was programmed with as

much attention as the indoor environment. Three courtyards are enclosed within the campus and each is designed with their own identity and theme. The centre courtyard is designed to serve as a productive landscape and supports the food education component of the curriculum. The vision for the food education component of the curriculum is that students grow vegetables and fruit in the onsite garden or greenhouse (during cold months), help care for chickens in the school's small coop, learn how to cook by preparing their harvest in the learning kitchen classroom as part of their integrated curriculum classes, and that they are provided with healthy school lunches in the cafeteria that are made with food that is grown on site or locally sourced. This is an important part of the curriculum as it supports the development of ecoliteracy by enhancing children's understanding of where their food comes from, as well as providing opportunities for experiential education by involving students in growing and preparing the food they eat for lunch. It models some of the ecological relationships found in the natural environment, just on a smaller scale. The courtyards create a contrast between the "wild" nature of the Sixteen Mile Creek site (the adjacent woodland, creek and meadows) and the "cultivated" nature within the courtyard. Small structures scattered throughout the site, such as a pavilion and access stairs and ramp, improve the accessibility to the nature on the site, easing their incorporation into the daily school lessons.

3) Increasing Connectivity

Learning is about making connections. Learning does not just occur as the transfer and assimilation of knowledge. The building supports the development of ecoliteracy by seeking to connect students to the site in order to guide them to developing a "sense of place," and further their connection to their community (both human and natural). The design creates a "sense of place" through architectural elements that communicate the unique characteristics of the project site in Milton, reflecting both the rural history and present use of the land as well as the natural features of the landscape. The design of the new school takes on a building form that is inspired by the traditional agrarian architecture of the region with pitched roofs overtop of larger open-plan volumes, an exposed timber frame, and a material palette that consists of local regional materials such as wood, stone, and a copper metal roof. The natural character of the site is similarly reflected within the proposed design through the selection of materials that reference the colours, textures and forms of the various natural ecosystems (woodland, prairie meadow, and creek) contained within the site, which helps harmonize the building with the landscape and enhance its sense of place.

Another way that the project strengthens the proposed school's connection to the community is by opening up areas of the school facility to the community for after-hours use. This helps maximize the usage of the various programmatic spaces within the school, which due to the distinct hours of operations of schools means the spaces would otherwise sit empty for a large part of the day/week/season. The operational schedule followed by the proposed school allows several of the spaces to be utilized by the community in the evenings and on weekends for classes, community events, social gatherings and recreational activities. During the summer it is planned that parts of the school would be utilized to host children's day camps. The resources that the school offers with its access to a variety of outdoor spaces in close proximity to shelter and amenities allows for a wide range of activities to

TRADITIONAL PROGRAM TEMPLATE

Instructional Areas	Non-Instructional Areas
Classrooms	Administration Office
Kindergarten Classrooms	Staff Room
Science Rooms	Teacher Work Rooms
Gymnasium	Meeting Rooms
Library	Washrooms
Computer Lab	Circulation
Resource Room	Academic Storage
Special Education Area	Gymnasium Storage
Instructional Flex Space	Change Rooms
	Mechanical & Electrical Areas
	Non-instructional Flex Space
	Cafeteria
	Playground & Sports Field

+

GREEN SCHOOL PROGRAM

Indoor Spaces	Outdoor Spaces
Mudrooms	Garden
Environmental Technology Room	Green Roof
Living Machine	Outdoor Classrooms
Kitchen (Instructional)	Natural Play Area
Pavilions	Rain Gardens & Swales
Specialized Science Classrooms	Rainwater Collection System
Greenhouse	Boardwalks
	Livestock
	Amphitheatre

Figure 1.5 - Traditional Program Template + Green School Program. Added to the programmatic spaces that constitute a typical elementary school (chart to the left), are special spaces that reflect what the green school is about and that express its unique theme (chart on the right). They support the specialized instruction of the environmental education curriculum. Note that outdoor spaces gain importance in the program of a green school.

take place supporting all sorts of themed camps for children, giving it an advantage over some of the more traditional places that host summer day camps that can be sometimes be limiting to the activities that can take place (i.e., arts and crafts indoors). Opening up the school to community use is beneficial both ways, as the school's vegetable garden requires people to take care of it during the summer. A food education-themed camp which focuses on activities related to cooking and gardening would be ideally positioned to take place within the school facility. The need for the garden to be cared for would also suggest the formation of a community garden program that is catered towards adults and seniors, where town residents would take care of a piece of it in exchange for a share of the harvest. Thus, community use of the facility becomes an important design consideration to the project, as it helps strengthen the school's presence and sense of belonging to the community, thereby enhancing its connection to the neighbourhood.[38] Architecturally, community use is supported in the proposed design by: providing multipurpose spaces that are flexible in their use and are able to accommodate large assemblies of people; by locating the shared programs near the front entrance where they form the face of the school; and by providing separation between the more private and shared programs for security purposes so that they can be accessed separately, and so that they can operate as their own thermal zone without requiring that the whole school be mechanically conditioned.

4) Increased Connection to Nature

The relationship between the students and natural world is strengthened by increasing their connectivity to nature from within the indoor environment. The proposed school design does this through several strategies that strengthen occupants' indoor outdoor connection. Firstly, elements of nature and spatial qualities that are found in the natural world are brought into the interior built environment through the incorporation of biophilic design principles.[39,40] Secondly, the boundary between the indoor and outdoor spaces is mitigated so that students are able to move freely between indoor and outdoor spaces. Architecturally, this is supported through the incorporation of transitional spaces between the classrooms and outdoor environment such as covered porch areas, screened-in decks, pergolas and canopies that ease the transitions from the indoor spaces to the outdoor ones. The provi-

sions of outdoor classroom spaces and free-standing shelters allow for learning to occur across the entire site. The courtyards at the centre of the school facility are in themselves a transitional outdoor space as they are protected from the elements and the more "wild" portion of the site. The third way in which the occupants' relationship to the natural world is strengthened is by connecting the operations of the building to the natural processes on the site. For example, within the proposed school rainwater is collected and stored in cisterns, solar panels harvest the energy of the sun to power the building, and the ecological processes of wetlands are utilized to clean wastewater for re-use, among other strategies.

5) Supporting Flexibility

Flexibility is understood in this project in several ways and supports sustainability though in a less obvious way. Academically, it recognizes that all students learn differently and each has individual strengths and different needs that the learning environment should consider and support. An understanding of this is backed by Howard Gardener's widely known Multiple Intelligences Theory which recognizes human intelligence as varied and multifaceted.[41] That a one-size-fits-all approach to learning is not effective for all students, as it does not allow for them to adjust their mode of instruction so that it enhances their personal strengths and accommodates their academic, emotional, social and physical needs. Inherent in this theory is that the architecture of the learning environment responds to this understanding by being designed to allow for flexibility and variety.[42] The proposed school design supports this by providing a:

- Variety of spaces within the classroom module – this is made possible through a classroom spatial design that is a variation of the L-shape floor plan layout, which increases the flexibility of uses within the space, thereby supporting an assortment of learning modes.[43]
- Variety of learning environments throughout the school that differ in terms of size, physical characteristics, program adjacencies, furniture, and their level of connection to the outdoors; examples include breakout spaces, laboratories, outdoor classrooms.
- Flexibility of uses within a single space, designing spaces to be multipurpose. This concept is most evident within the public programmatic elements of the school which are designed to be flexible in use and who can use them; i.e., the cafeteria, gymnasium, front lobby, parking lot are designed to be multipurpose and are shared by the school and local community.
- Flexibility in terms of adapting to the future needs of the building. Pedagogy is always changing, and the school building is more sustainable if it is designed so that it can easily adjust to accommodate future uses.[44] The design proposal responds to this through the incorporation of a few strategies. The selection of a wood structural system is one strategy that makes it easier to adapt the space to future needs as it minimized the need for load bearing walls. Designing the classroom as a repeatable module is another strategy. The module allows for ease of expansion in the scenario that the school reaches over capacity as the town of Milton continues its upward trend of growth, as the L-shape classrooms block can be easily added on to the existing wing, or could form a new classroom wing with its own courtyard that is connected to the existing corridor.

6) Become a "3-D textbook" for Sustainability

One of the goals of the thesis is to design the building in such a way that the green building components of the school can be integrated into the curriculum, supporting and demonstrating concepts that are traditionally studied from textbooks. When this occurs, the building evolves into what is referred to as a "three-dimensional textbook" and becomes an active source of learning.[45] Students not only learn about the sustainability features of the school, but also the building's connection to the ecology of the site and its relationship to the environment. The more specific ways in which the building can support this will be described in the conclusion of the thesis, but the main strategies involve: increasing the visibility of the elements within the building by making mechanical processes and operational systems visible and exposing the structural system, and by involving students in the operation of the building thereby providing opportunities for experiential learning.

SUMMARY OF BASIS OF DESIGN:

A synthesis of the main architectural goals and motivations:

- Design a school that encourages students' connection to and interaction with nature
- Design a sustainable building with a reduced environmental impact resulting from its construction and operation. The design is to target LEED Platinum building performance. Design integrates building strategies that respond to the climate of the project site.
- Integrate the principles of biophilic design throughout the building
- Create a healthy and comfortable indoor learning environment
- A building that is able to function as a "3D textbook" for sustainability
- Reference the site's existing natural communities in the design of the building. Site is to inform the material choice. Architectural gestures are to communicate the natural characteristics of the site, eliciting a feeling that one is immersed in nature even when indoors.
- Enhance the school's "sense of place" by referencing the site's past and present natural and human history in the architectural design
- Increase the school's connection to the neighborhood community
- Design is not to be static. Reveal and make visible the passage of time: over days (weather), months (seasons), or years (building ages)
- Provide flexible pedagogical spaces

SUMMARY OF CURRICULUM GOALS:

- An educating the "whole child" approach – designing for the development of body, mind, and spirit
- Promote the development of ecological literacy and stewardship of the environment from an early age
- Fostering a "sense of place" through a curricular focus on the local environment and local ecology
- Nurturing a sense of wonder through hands-on experiential learning out in the natural world.

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CHAPTER 2:

THEORETICAL BACKGROUND AND APPROACH

2.1 – Background Situation

2.1.1 – The Environmental Crisis

> *"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."*[1]

The environmental crisis has emerged as an unprecedented period in human history. The last two centuries have seen significant changes to the earth and natural environment as a result of the rapid and immense human population growth and economic development that occurred during this period. As a consequence of this burst of human activity, numerous environmental problems have emerged such as pollution, habitat destruction, biodiversity loss, resource depletion, and the interrelated problems of global warming and climate change, to name a few. Addressing these issues is becoming an increasingly urgent concern, as the environmental problems are only accelerating.

The Environmental Crisis as a Design Problem

The environmental crisis is not so much a problem with the environment itself, but the negative environmental consequences of the way we have designed the systems that support us. Ecological designers Simon van der Ryn and Stuart Cowan along with a growing number of professionals in the design industries have made the connection between the environmental crisis and design. They believe that "in many ways, the environmental crisis is a design crisis. It is a consequence of how things are made, buildings are constructed, and landscapes are used."[2] Van der Ryn and Cowan put forward the idea that ultimately it is a design problem.

They argue that if design is understood to be "the intentional shaping of matter, energy, and process to meet a perceived need or desire,"[3] then the problem of how we have designed the systems that support us lies at the heart of the environmental crisis. We have constructed our daily experience in such a way that while it fulfills its purpose in meeting human interests and comfort, it does so with disregard to our relationship with all other life Earth. "Our present form of agriculture, architecture, engineering, and industry are derived from design epistemologies incompatible with nature's own."[4] Throughout much of the past century, we have designed in such a way as where our design decisions are generally made independent of their ecological repercussion, and in the process overlook humans' dependency on nature.

The Environmental Crisis as an Education Problem

In this sense, the environmental crisis is not only a design problem, but also an education problem. The failures of our designs go hand in hand with how we have

been educated to view ourselves in relationship to the environment. We often see ourselves as independent from nature; not a part of it. This separation of "us" from the natural world, was historically necessary for our survival. Our early ancestors lived in constant and close interaction with nature, during which they evolved to respond to the challenges presented by the environment. It was necessary for humans to modify the environment, as a way of controlling the nature to their benefit. A large part of history, particularly North American, has been a celebration of man's struggle against and domestication of nature. Nature was and still is seen as something for us to beat and exploit in order to survive.[5] Conservationist Aldo Leopold described our current relationship with the natural world accurately in one of his most famous statements. "We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect."[6] This view of ourselves in relationship to the Earth has led us to forget that humans are as much a part of nature as any other species. Our health is dependent "on the health of other species and… ecosystems."[7] It is natural ecosystems that support all life on this planet, through the services and benefits they provide which are referred to as "ecosystem services," and they are crucial to our survival.[8]

A child that has grown up only in an urban environment is more likely to believe that it is "human technology, economics, and industries that create our habitat and fulfill our materials needs."[9] With this comes a broken sense of interconnectedness to nature, and accompanying it a lack of responsibility. When we see ourselves as belonging to nature, this is the beginning to a more healthy relationship. The development of the knowledge of the earth as a complex system and the understanding of the interrelationships between humans and this natural system is known as ecological literacy.[10] Ecological literacy is the goal of environmental education as its acquirement has been shown to lead to the development of environmental stewardship behaviour.[11]

Ecological literacy also involves the understanding of the damage that humans as anthropogenic agents have caused to the environment, and that due to our interconnectedness and dependence on it for survival, the solution to the environmental crisis must be one that works with nature.[12]

Looking Towards a Sustainable Future

Sustainable development calls for development that addresses the future while balancing present economic and social development with that of environmental protection.[13] The solution to the environmental crisis and its accompanying issues will be more complex and will require the shared awareness, responsibility and action of everyone on all levels – global, local, and individual. Children are central to sustainable development not only in regards to the future, but in their potential to effect change in the present. Recognizing that their participation is critical, UNICEF has made "a call to action to put children at the centre of sustainable development."[14] It is children who will have to deal with the repercussions of the environmental crisis, and it is for them that current efforts for sustainable change are being made. Education is considered to be the key tool of sustainable development, as in order for the current and future generations to be able to bring about

sustainable change they must be educated on how to live in a sustainable way and be instilled with the awareness and knowledge they need to make informed choices in their everyday lives.[15] Essentially, they must become ecoliterate citizens.

Schools inherently play a critical role in shaping our young people, thus they have the potential to be vital in leading the way towards a sustainable future. School's place in society in preparing children for the future gives them the opportunity to teach young people to be sustainable-minded when they're at an impressionable age, influencing and shaping their values when they are at a key developmental stage in life. It is for this reason that environmental education has an important place in 21st century schools.

2.1.2 - Environmental Education in Ontario

As the location of the site on which the thesis design is proposed is in the Town of Milton, the public education system of the province of Ontario forms the background educational context. Thus, it is important to briefly look at how the government defines environmental education and the ways in which it is currently incorporated within the formal education framework. Environmental education is officially defined by the Ontario Ministry of Education as:

> *"... education about the environment, for the environment, and in the environment that promotes an understanding of, rich and active experience in, and an appreciation for the dynamic interactions of:*
>
> - *The Earth's physical and biological systems*
> - *The dependency of our social and economic systems on these natural systems*
> - *The scientific and human dimensions of environmental issues*
> - *The positive and negative consequences, both intended and unintended, of the interactions between human-created and natural systems."* [16]

This definition was developed as part of the 2007 document *Shaping Our Schools, Shaping Our Future* which developed a set of recommendations for improving the state of environmental education within the schools of Ontario.

Though the definition is general, it acknowledges the importance of students learning not just about the symptoms of environmental issues, but also developing an understanding of the complex system of relationships that environmental education is concerned with, a key part of becoming ecoliterate.[17] It also mentions the potential role that outdoor education can have in this, though it does not elaborate how. However, its shortcomings are that it does not state the specific ways in which environmental education can be implemented, leaving it open to interpretation and resulting in unevenness of implementation between classes, schools, and school board.[18]

Within the framework of formal education in Ontario, efforts to prepare students to be environmentally responsible citizens has mainly concentrated on the integration of sustainability concepts into the curriculum. Environmental education is taught by incorporating concepts into other subjects within the existing curriculum, primarily within the areas of the "science and technology curriculum and the social studies, history, and geography curriculum."[19] The Ontario government has developed a guidebook for educators which outlines strategies and areas for implementing it in every subject across all grades; this resource is titled *Environmental Education: Scope and Sequence of Expectations*. It is, however, not taught as its own subject, nor is its implementation officially tested for through the EQAO standardized testing such as with subjects like mathematics and language arts.[20] Thus, its level of implementation varies by school board, school, and class.[21]

Many schools also introduce concepts of environmental education to their students through extra-curricular activities and school events such as clubs, school ground waste cleanups, outdoor yard greening efforts, and school-wide awareness campaigns.[22] A voluntary certification program known as *EcoSchools Canada* has been developed to inspire the incorporation of environmental education initiatives into schools' curriculum and culture through these types of activities, awarding participating schools a certification level– bronze, silver, gold, or platinum – based on the extent to which such activities have been implemented.[23]

What is largely overlooked in the existing educational framework however, is the potential role that the school building itself can have in enhancing environmental education. This thesis argues that equal attention should be given to integrating sustainability concepts into the physical environment of the school as it has the potential to be not merely the place where environmental education is taught but be the source of environmental education. Existing literature reviewed in the subsequent section not only supports this view, but in fact proposes that this is necessary in order for effective environmental education to occur, as it is not enough to only passively learn about sustainability, if the setting where it occurs does not alter the students' relationship to the natural environment.[24]

2.2 – Sustainable Schools

2.2.1 – What is a Green School?

Introducing the Concept of a Sustainable School

The concept of sustainable schools has gained prominence in the last decade. They may be referred to by different names such as eco-schools, green schools, but what these schools all have in common is their commitment to both promote and model environmental stewardship by incorporating sustainability into all aspects of the school – "the educational program, physical place and organizational culture."[25] These schools thus teach sustainability by not only integrating environmental education concepts into the curriculum and extracurricular programs, but by also ingraining them into the design, construction and operation of the school facility.

In 2010, the U.S. Green Building Council (USGBC) started *The Centre for Green Schools* to promote the development of healthier and more sustainable schools. As time is a key point in sustainability, the ambitious mission of The Center for Green Schools is to "put every child in a green school within this generation."[26] The centre helps advance this vision by providing designers, educators and policy makers with the resources to guide and support this transformation of the educational landscape; these include research publications, curriculum development, events and resources for continuing education and building construction.[27]

The Center for Green Schools uses the term "green school" as a definition for schools that advance sustainability by successfully meeting these three goals:

> *"1. Reduced environmental impact*
>
> *2. Increased health and well-being*
>
> *3. Increased environmental and sustainability literacy for all graduates"* [28]

The organization refers to these three points as "pillars" and uses them as a "basic measurement framework"[29] to measure the success of a green school's progress. This framework acknowledges that green schools will differ according to their location as they respond to local challenges and needs, and thus it creates a set of common goals to guide their development.[30]

Green Schools in Canada

This framework has been adapted globally. In 2013, the Canadian Green Building Council (CaGBC) joined the *Global Coalition for Green Schools*, as one of 26 countries.[31] The Canada Coalition has since formed, and is made up of experts and professionals from the nation's green building industry who are committed to helping transform the country's schools into ones that are healthy and sustainable learning

environments that support environmental education.[32] Though the current list of green schools in Canada is not expansive, they are slowly growing in number as the concept and benefits of green schools become increasingly recognized.

Within Ontario there are a small number of K-9 schools that have pursued a high level of sustainable building design and operations and have achieved certification under the LEED (Leadership in Energy and Environmental Design) certification system. The list of LEED-certified K-9 schools in Ontario can be referred to in *Appendix A*. Majority of these schools are new construction projects, which represent a small portion of the total existing school infrastructure in the province. Some action has been take to improve the environmental performance of existing infrastructure through renovations and upgrades to the building systems as a way of demonstrating environmental stewardship and improving the energy efficiency of the buildings. Under the Commercial Building Incentive Program (CBIP) run by Natural Resources sector of the Government of Canada from 2002 to 2006, more than 100 school in Ontario were able to attain energy savings of an average of 39%, with 11 schools achieving over 50%.[33] Another government program was the Ontario Green Pilot Initiative which provided funding to install innovative and energy efficient technologies in existing school facilities across the province. The technologies helped reduce energy use, produced renewable energy as well as reducing water use, making an impact on the efficiency of the school's building operations as well as creating the opportunity to showcase green technologies.[34]

Though the success of a green school rests on the transformation of all aspects - "the educational program, physical place and organizational culture"[35] which come together to make up an institution and is referred to as the *Whole School Sustainability framework*, as an architectural design thesis, this project will be focusing on three pillars of a green school design principally as they pertain to the physical place component of schools. For *The Center for Green Schools* the "physical place" of a school encompasses its "building environment, surrounding natural environment, and the resources that flow through the school,"[36] and this project similarly addressed those components of the school facility in its proposed design.

The following sections will explore these three pillars of green school design in relation to the place component of sustainable schools, including the motivation behind them as well as introducing strategies towards reaching these goals that will be applied in the ***design proposal.*** The conclusion of this chapter will be followed with a precedent study of the Dr. David Suzuki Public School, examining how the school successfully met all three "pillars" and how its design allowed it to become the first public school in Canada to obtain LEED® Platinum certification, an achievement that has earned the school the title of "The Greenest School in Canada."[37] This study helped me gain an understanding of how the LEED for Schools rating system works, and served as a starting point for how a LEED Platinum level of sustainable design can be applied to a school.

2.2.2 – Reduced Environmental Impact

The first pillar of the green school framework is based on the recognition that buildings are a large contributor to climate change and other environmental degradation issues. In 2003, architect Edward Mazria evaluated architecture's accountability in this by looking at the building design and construction industry as a whole, grouping together both residential, commercial and the related building aspects of the industrial sector (such as the production and transportation of building materials). He concluded that buildings in the US contribute to almost half of the country's total energy expenditure (48%) and total carbon dioxide emissions (46%), a much greater percentage than was generally attributed to be from buildings.[38] The statistics on the environmental impact of the Canadian building sector are proportionally similar to that of the US. The CaGBC has calculated that heating and cooling demands of buildings in Canada produce "35 per cent of all greenhouse gases,"[39] with an additional "10 to 15 percent" generated by the industrial sector in regards to construction materials.[40] Other statistics on resource use related to the building industry indicate that buildings in Canada have wider negative environmental implications; the CaGBC reports that they are the source of "35 percent of landfill waste" and that 70% percent of water use demand on a municipal level results from them.[41] Thus, the first goal of a green school is to support sustainability by designing, constructing and operating school facilities in such a way as to reduce their environmental impact and energy costs. The result is a school building that demonstrates to its students the sustainable principles of green building design.

Ecological Design and Net-Zero Energy Buildings

One way to minimize the environmental impact of buildings is to design them with reduced energy demands and to meet the remaining energy need through the use of renewable sources of energy instead of fossil fuels. [42] These are the basic principles of net-zero energy building design, which will be targeted in this project's proposed green school design. New construction school projects have the benefit of being able to greatly impact the energy consumption patterns by considering the building's impact on the environment from the onset of when it is built and for the rest of its considerably long lifetime.[43] This requires that not only high-efficiency mechanical equipment is used to reduce the building's energy use, but that the sustainable design of the building takes an ecological design approach to the architecture. Ecological design is defined "as any form of design that minimizes environmentally destructive impacts by integrating itself with living process."[44] An ecological design approach, connects the building to the flows of energy on the site – the sun, wind, and water – using them as sources of renewable energy and resources.

The extent to which the building can harness the energy from the natural processes of the site is highly dependent on its architectural design. The basic elements of building design such as the form, massing, orientation on site, the materials selected for the building envelope, the size and placement of window openings as well as the site and landscaping design can have a significant impact on the energy efficiency of the building as they determine its future energy consumption from

the onset and for the rest of the building's lifetime.[45, 46] Furthermore, they influence the extent to which the building is able to harness the sun's and wind's energy for heating, cooling and daylighting thereby determining the effectiveness of passive design strategies that are integrated into the building.[47] In a net-zero energy building the basic building design and integrated passive strategies are typically the first steps in reducing the building's energy demand. The next step is choosing mechanical equipment for HVAC and lighting that operates with a high degree of energy efficiency, to supplement the passive design strategies in maintaining thermal comfort.[48] Together, these strategies help the building reduce its total energy demand, and then the balance is supplied through the renewable energy generated on-site if possible, and if not, then off-site or by being offset.[49]

Reducing the environmental impact of the building can go even further by seeking to reduce carbon emissions generated by buildings over their entire lifecycle. This requires the consideration of carbon emissions produced not only through the operation of the building, but the embodied carbon within the building materials due to CO_2 emissions resulting from their "extraction, manufacture, transportation, assembly, maintenance, replacement, deconstruction, disposal and end of life."[50] Considering the building's embodied carbon from the beginning of the design process is important because once the building is constructed the carbon emissions of the materials can no longer be lowered with time, as those related to operations can be via renovations or through renewable energy production.[51]

The LEED™ Rating System

The LEED™ (Leadership in Energy and Environmental Design) is a voluntary rating system developed by the USBGC that has been a powerful force in advancing the adoption of green building design and construction across the world, and has become the most mainstream third-party verification system.[52] The rating system "promotes a whole-building approach to sustainability,"[53] measuring a building's performance across a broad range of categories related to the project's effect on reducing its environmental impact, improving the health of its human occupants as well as the way in which it bolsters sustainable lifestyle choices. The key areas which are measured are in the LEED™ v4 framework are:

- Location & Transportation: which relates to the choice of site and the ways in which dependence on cars for transportation is reduced
- Sustainable site development
- Water Efficiency: relates to the reduction of water use both indoors and on the site
- Energy & Atmosphere: relates to energy efficiency of the building operations and sources of energy used
- Materials & Resources: considers materials throughout their lifecycle
- Indoor Environmental Quality

The LEED certification system supports an ecological design process as it is

aligned with one of its key principles that call for buildings to weigh their impact through "ecological accounting."[54] A building is evaluated based on a point system, earning points for achieving credits and prerequisites which when added up allow the building to achieve one of four levels of certification: certified, silver, gold, or platinum (arranged from lowest to highest).

LEED for Schools

In a move to address the specific construction and operational needs of different building types, LEED developed individual rating systems for various building market sectors. The LEED for Schools rating system was developed for K-12 educational facilities. While the basic framework remains the same as the general LEED™ for New Construction rating system, some of the credits and prerequisites have been changed to better reflect the areas that most impact the health of children, help support the learning process, and advance the educational goals of the school in relation to environmental education. As well, they address the unique nature of school buildings as spaces that encompasses a large range of programmatic spaces within a rather small footprint.[55]

Prerequisite Areas:

A big focus of the LEED for Schools rating system is on enhancing the environmental quality of the indoor learning environment, due to research that has concluded on how influential improved indoor environmental quality can be on students and teacher health and academic performance. These research findings which will be outlined in the following section. The rating system reflects this by making several of the indoor environmental quality (IEQ) credits prerequisite. The health of students is further given importance by requiring an environmental site assessment to be undertaken in order to detect whether the site is contaminated.[56]

Sustainable Sites:

The Sustainable Sites category includes the addition of a "Site Master Plan" credit to encourage the facility to plan for future use and expansion, as well as requiring the achievement of at least 4/7 Sustainable Sites credit.[57] This can be understood as a reflection of the role of the school site as a recreational landscape for students. Another credit that has been added under the Sustainable Sites category is the "Joint Use of Facilities" which encourages green schools to allow the community/general public to utilize parts of the school and site after school hours for non-school related purposes.[58] This helps maximize the usage of the various programmatic spaces within the school, which due to the distinct hours of operations of schools means otherwise the spaces sit empty for a large part of the day/week/season. The other option under this credit is for schools to utilize other public facilities nearby rather than constructing new spaces within the building. This is applicable to programme spaces such as gymnasiums, cafeteria, large gathering halls, additional classroom space or other athletic facilities and fields.[59]

"Innovation: School as a Teaching Tool:"[60]

The LEED for Schools framework offers a point under the innovation category

for incorporating the sustainable aspects of the building into the curriculum. This reflects the school's educational potential as a demonstration of sustainable building design and operation. Under the credit, schools can develop a specific curriculum around the building, focusing not just on the features but "explore(ing) the relationship between human ecology, natural ecology and the building ecology of the building."[61]

2.2.3 – Health and Well-being

The second pillar of green schools directs schools to provide a learning environment that improves the wellbeing, health and performance of their students and staff.

The design of the physical environment can have a huge influence on the health and wellbeing of occupants. Considering that people today spend up to 90% of their time indoors[62], the design of the interiors matter. Many of the design strategies employed to reduce the environmental impact and operational energy required in a school building, at the same time serve to improve the environmental quality and habitability of the learning space.[63] Good environmental quality within the interior spaces of a school building has been linked through numerous studies to having a direct positive impact on its occupants' performance, health, attendance rate and overall satisfaction with the facility.[64] Environmental quality is primarily concerned with the following four issues: indoor air quality (IAQ), thermal comfort, daylighting and acoustics.

Indoor Air Quality (IAQ):
Indoor air quality refers to the ventilation levels within the interior, that is the amount of fresh air being introduced into the space and is often measured in terms of the rate of air exchange and CO_2 levels. Air quality is also affected by the presence of pollutants or contaminants in the air, such as mold or off-gassing from toxic materials.[65] In schools, IAQ is a big concern due to the long period of the day that is typically spent indoors, as indoor air generally contains a higher level of airborne pollutants than outdoor air – a concentration that is typically "two to five times" and sometimes even 100 times greater.[66] The quality of indoor air for these reasons is important, as poor IAQ conditions have a negative effect on the health of school users, which manifests in decreased learning achievement and attendance as a result, in both teachers, staff and students.[67, 68] Improved air quality has been found to correlate with improved health. Positive impacts on health include reduced symptoms of "asthma, flu, sick building syndrome, respiratory problems and headaches."[69]

The fastest way to improve indoor air quality is by increasing the amount of fresh air intake. Potential environmental building design strategies include increasing outdoor air intake delivery through operable windows, or the installation of a Heat Recovery Ventilator (HRV) which brings in fresh air while expelling stale air outside. HRVs also helps control indoor humidity levels, which is important as excess moisture in the indoor air can lead to mold growth. Moisture problems

can be further prevented through proper building drainage which can be achieved through sloped rooves, deep overhangs, ground surfaces sloping away from the building, and a well-ventilated building envelope assembly.[70] Use of toxic building materials should be avoided to ensure the health and safety of school occupants. The Living Future Institute's "Red List"[71] compiles a list of the most harmful construction materials whose use in the interior should be avoided to prevent the off-gassing of toxins into the air. The use of green cleaning supplies can further lower levels of contaminants in the air, reduce irritations, and ultimately protect the health of school users.[72]

Thermal Comfort

Thermal comfort is formally defined as "that condition of mind in humans which expresses satisfaction with the thermal environment."[73] The temperature that is considered comfortable varies depending on the person, their level of activity and the amount of clothing one is wearing, as well as being influenced by environmental factors such as humidity, internal heat gains from surrounding occupants and equipment, and air speed.[74] However, there is a temperature range that has been found to generally be considered comfortable by the majority of people. Based on the recommendations of ASHRAE Standard 55, the CSA Guideline for Office Ergonomics suggests that the ideal indoor temperature range is between 20-23.5˚C during the winter, and 23-26˚C in the summer (when the humidity is at 50%), for occupants in an office environment where their level of activity is lower (e.g., sitting or reading) and they are wearing indoor clothing corresponding to the season.[75] Similarly, studies focusing specifically on ideal room temperatures for learning spaces, recommend a temperature range between 20-23˚C and humidity levels in the mid-range between 40 to 70%, as the most facilitative to learning and academic achievement.[76]

As thermal comfort can be perceptional, giving students and teachers control over the temperature of their environment is important, with studies confirming that this leads to better performance for both teachers & students, improved quality of learning and increased productivity.[77] In fact, most teachers expect to have full environmental control over their classroom and it can affect their morale and work satisfaction if otherwise.[78]

Daylighting:

Classroom daylighting likewise plays an important role in student wellbeing and performance. The term daylighting refers to the admittance of natural light from the sun into a space. Humans are instinctively drawn to spaces filled with daylight, as it has a positive effect on both mental and physical health. Exposure to sunlight is essential to the production of hormones responsible for regulating biological processes such as the human body's circadian rhythm, and mood.[79]

The importance of daylighting in schools to students' wellbeing and performance is not surprising. Increased daylighting has been linked to improved academic performance, with one well-known study having found a direct correlation between the two. In the study, students learning in the classrooms with greatest amounts of daylight progressed faster on tests by 20% in math and by 26% in reading. Increased window surface area or the use of skylights in a classroom had a similar positive effect on student improvement.[80] However, there is such a thing as too

much daylight, which results in visual comfort issues if not controlled. Issues of glare can impact productivity levels – a study has found that people who work in offices without glare worked 15% more efficiently than those workers with glare.[81] Thus, ideal daylighting conditions are achieved when sunlight is appropriately admitted and controlled. While artificial lighting can be used to achieve suitable illumination levels in indoor spaces, natural daylighting is generally considered (and scientifically supported) to create the most positive lighting conditions.[82]

Acoustics:

"Noise is cacophony, the acoustical equivalent of clutter."[83]

Proper acoustics are important within the space of a school – students can't learn if they can't hear. Studies support the connection between low noise levels and higher academic achievement, and vice versa. Poor acoustics in classrooms are found to negatively impact students' performance, effects which are worsened in younger children whose word comprehension skills are poorer. Student's ability to concentrate decreases making them more prone to misbehaviour. Excessive classroom noise can also be a source of stress for students, as well result in greater dissatisfaction in both students and teachers with the classroom space.[84]

Oftentimes within a school, the main source of excessive background noise is the school's HVAC system.[85] This can be reduced/eliminated with the design of a quiet mechanical system, or by reducing the system's size. The school's site location is another early design choice that can have a huge impact on eliminating noise pollution. Schools should be ideally located at a distance from any nearby railways, highways or airports. Within the school facility, early programming should make sure to separate areas with higher levels of noise such as the gymnasium or cafeteria from the classroom spaces. External sound infiltration can be reduced with thicker building envelope assemblies, and increased insulation. Indoor sound transmission and reverberation can be reduced through the use of interior finishes that absorb sound such as acoustical tiles and the introduction of soft materials into the space.[86]

While every building should ideally provide a healthy indoor environment, the need for a school to do so is imperative as sub-standard conditions pose a greater risks to children than adults. This is because children are still developing, meaning their bodies are more sensitive to exposure to environmental hazards and toxins.[87] The importance of environmental quality within the school environment is reflected in LEED for Schools rating system by making "Minimum IAQ performance" a prerequisite point. The importance of acoustics to learning is also emphasized through the creation of a separate credit for it that is made prerequisite. The "Daylight" credit is expanded to offer up to three points if optimal levels of natural lighting achieved.

Aesthetical Aspects of the Learning Environment

Qualities related more to the aesthetical aspect of the design are also important to the environmental quality of indoor learning spaces. The connection between students feeling better in spaces that are more attractive seems obvious, but what more, the visual qualities of the classroom have been found to have an influence on

students' academic performance. A study called "Clever Classrooms," published as part of the HEAD (Holistic Evidence and Design) Project assessed the qualities of the physical environment of the classroom and their effect on student performance. It found that together the physical characteristics, when designed effectively, resulted in students achieving 16% greater academic progress, over students in classrooms whose space is designed less effectively.[88] While half of the impact was due to the environmental qualities such as daylighting, air quality, and thermal comfort of the space, the study found that a quarter of the learning impact was due to visual characteristics of the space such as beauty, colour, and complexity, suggesting that the aesthetical design of a space is equally important to students overall wellbeing.[89]

Biophilic Design

Biophilic design is a methodology developed by Stephen R. Kellert, which endeavours to translate the biological need people have to interact with or be in contact with the natural world into the design of the built environment.[90] It is based on the theory of "biophilia" developed by biologist Edward O. Wilson in 1984 to describe the inherent need humans feel to affiliate with the living systems and organisms found in the natural world.[91] This desire is considered to be a part of human nature – it develops in us from the time we are young and is reflected by the way we respond to life on a daily basis.[92] This biophilic behaviour can be understood as a set of "learning rules" from which our different feelings in response to nature arise, "from attraction to aversion, from awe to indifference, from peacefulness to fear-driven anxiety."[93] This behaviour is found to be biological and is built into our brains, as a result of the evolutionary environment in which humans developed.[94] While the natural environment is no longer the environment most of us live in today, our brain has still kept those learning rules that it originally developed as responses that helped our ancestors in their survival, and manifests itself through the attraction people feel towards natural environments.[95]

Biophilic design is considered by some to be the missing piece from the LEED rating system,[96] as its main goal is to improve humans' health and wellbeing by recognizing that we benefit from maintaining a relationship with the natural world, as it has a positive impact on both our mental, physical and spiritual development.[97] The benefits of nature on human wellbeing extends so far as to having been found to have a therapeutic benefit and help with healing.[98] Biophilic design attempts to bring elements of nature into the built environment as a way of strengthening people's connection to nature, and increasing the frequency of experiences with nature. The biophilic design framework consists of a set of design strategies that are broken down into "three basic elements and twenty-five associated attributes."[99] The three elements relate to ways and various levels at which nature can be experienced, and the attributes are characteristics that define and are of the natural world, and are categorized between them.[100] The three ways in which nature can be experienced are through either direct or indirect contact with nature, or through "the experience of space and place"[101] in a way that reminds people of spatial qualities found in nature.

2.2.4 – Environmental and Sustainability Literacy

"A green school's influence on students and the student community is likely its greatest environmental impact."[102]

This third pillar of the green school framework is perhaps the most important of the goals as it relates to the core mission and values of a green school. That is to create a generation of environmentally literate students who will hopefully go on to become environmentally responsible citizens.[103] A green school teaches ecological literacy and promotes environmental stewardship behaviour by physically modelling these concepts within the design, construction and operation of the learning environment. In a green school, students do not just hear and read about sustainability within the curriculum, but can see it and experience it in their immediate physical environment as a green school demonstrates to its students the sustainable principles of green building design. The school is able to enhance the environment education curriculum through the use of the school facility itself as a "teaching tool" in support of the curriculum. [104, 105] Inherent in this is the understanding that the built environment plays a role in students' education.

"Architecture as Pedagogy"

Influential in the development of my understanding of how the architecture of a school is connected to its curriculum, and how in turn it can play an important role in teaching its students environmental stewardship behaviour is the work of environmentalist David Orr. He is a professor of environmental studies at Oberlin College, who has written extensively on environmental education. He conceived the theory of "architecture as pedagogy"[106] in reference to the important role the built environment of the school plays in students' education. Orr proposes the idea that architecture is a source of pedagogical instruction, and thus the school building is not merely the place where learning happens, but a source of education itself whether it is intended to be or not.[107] He believes that school facilities are "a kind of crystallized pedagogy and that buildings have their own hidden curriculum that teaches as effectively as any course taught in them."[108] We have generally assumed that students do not learn from the building itself. But Orr hypothesizes that they do learn – sometimes things that we do not want them to. It is this understanding that connects the "physical place" of the school to the environmental education curriculum. Before listing some of the teaching potential available in a green school, in order to gain an understanding of how a building can negatively impact students, we will examine what values and behaviour a typical North American school instills in the students that pass through its doors. Thus, Orr goes on to ask "what lessons are taught by the way we currently design, build, and operate academic buildings?"[109]



Figure 2.1 - Example of a typical upper grade classroom in a K-8 elementary school.



Figure 2.2 - Example of a typical primary grade classroom in a K-8 elementary school.



Figure 2.3 - Example of a typical kindergarten classroom in a K-8 elementary school.



Figure 2.4 - Example of a standard science laboratory classroom in a K-8 elementary school.



Figure 2.5 - Example of a library found in a K-8 elementary school.



Figure 2.6 - Examples of typical corridors in a K-8 elementary school. Both examples contain personal storage spaces (i.e., lockers, coat rack).



Figure 2.7 - Example of a typical full-sized gymnasium in a K-8 elementary school.



Figure 2.8 - Example of a typical smaller gymnasium/auditorium in a K-8 elementary school.

Negative Lessons Taught by the Typical School Building:

1) Exclusion of community

Students learn about the concept of power; that only those who have the authority are allowed to decide on the architecture of the building. Buildings thus become an exercise of outside power, not that of students and teachers. Those in power have the privilege to design buildings however they think is suitable without involving the future users. This view arises out of the supposition that the process of learning as well as how people relate to each other is not affected by the design of the building.[110]

2) Passiveness

Building design is seen as a technical practice and thus is viewed as something that can and should be done only by those who are trained in it - architects and engineers. This view prioritizes the importance of the technological aspect of the building before other elements of consideration such as "ethical, ecological or aesthetic" ones.[111] This belief teaches building occupants to be passive building users.[112] Essentially students learn to not care about the place they spend half their waking hours in. This is in sharp contrast to the past when everyone was a designer of their own environment, when building construction was considered as more of an intuitive process. Rather, today we leave the task of the design and construction of buildings to experts, allowing them to "shape the material basis of our lives."[113] The repercussion of this is that most people have lost awareness of the negative effects of building design on the environment.[114]

3) Carelessness and Indifference

Many schools model attitudes of carelessness and indifference towards the environmental impact that results from the construction and operation of our buildings. Through aspects of the learning environment such as the inefficiency of many schools buildings (resulting from outdated mechanical systems), or the high embodied energy of some of the most common school construction materials (steel and concrete), schools teach students that "environmental and energy costs of buildings do not matter much."[115] This models to students an insensitive disregard for how our buildings affect others (people, plants, and animals), and furthermore that we do not have to take responsibility for how these actions negatively affect others, so long as we ourselves are comfortable inside.[116]

4) Ignorance and Detachment from Surroundings

In most schools, the facility's mechanical systems and processes are running in the background, hidden away from the students' view. If everything in this system is working as it should, the occupants won't hear it, and may not even realize that it's there. Ironically, it is when something is broken for example like the HVAC on a hot humid day, that we realize its presence and how important that piece was in maintaining our comfort. However this standard practice, by not "requiring care and interaction" teaches students "passivity and disengagement from our surroundings and irresponsibility."[117] This is the opposite of being a steward. Stewardship by definition is the act of taking care of someone or something, implying

a certain responsibility over it.[118] But this goes beyond just caring and if never exposed to it can result in ignorance, teaching the inhabitants that it's acceptable to be unaware of the fundamental elements that make building inhabitable and make life as we know it possible.[119]

5) Disconnectedness from the natural environment and from local place

As David Orr says, "all education is environmental education."[120] The building teaches its occupants about their relationship to nature through how it is constructed and operated. When nature is excluded from the learning environment it teaches students that they are not a part of nature. Science laboratories are singled out by Orr in a separate essay for the reason that it is the subject between which connections to environmental education are most easily made, and yet they are designed to have no connection to nature, but rather as an engineered and controlled environment.[121] A disconnectedness from the specific site of the school is another related aspect. Many school facilities do not promote a sense of place as they tend to look the same regardless of their location. Likewise their bioclimatic function does not necessarily relate to their location. Such design suggests that building could be located anywhere, as the place makes little difference to the design.[122]

6) Unimportance of Creativity and Imagination

That creativity and imagination are not important skills and do not belong in learning process. This is communicated through the limited creativity involved in the design of the school, perpetuated according to Orr by spaces, such as the factory-model classroom (refer to Section 3.4 for further information) or the typical lecture hall, that continue to look and function the same as they did a century ago. This thought has been echoed by many designers and educators such as Prakash Nair and Roy Fielding,[123] and Anne Taylor,[124] among many others.

However these do not have to be the lessons and values school buildings teach. When the power buildings have to teach people is realized, Orr believes that their design can be harnessed to foster sustainability behaviour in its occupants. School building thus can be designed to demonstrate the values and model the behaviour that we would like this generation of children learn.[125, 126] Orr proposes an alternative set of principles that align with the goals and mission of green schools.

What Lessons *Could* Green School Design Teach Us?

1) Participation and Action

Civic responsibility and being active participants in their community are a component of environmental stewardship behavior that can be encouraged through the involvement of the community in the design and construction process of a new school. This allows the community to decide what values it wishes to demonstrate, and what local and ecological issues it would like to bring attention to.[127] If the community so chooses, the resulting school building has the potential to become an architectural symbol of sustainability[128] and the capacity for influencing the behaviour of the wider community by bring awareness to issues of sustainability.[129]

Participation can also be understood in another sense, in that students can be involved in taking care of the building as well as helping operate it. This is a popular practice in schools in Japan, referred to as *o-soji* where it is students, not janitors who are responsible for cleaning and caring for the classroom and some of the shared area of the school. This occurs on a near daily basis for a period of approximately 20 minutes, and all students take part in it, even the youngest grades who are helped by the older students.[130] While it seems almost unimaginable that students in North America would be responsible for cleaning their classroom, by inviting participation in caring for the school, students develop a sense of ownership and responsibility over their learning environment, as well as learning important life skills.[131] The result is that they behave more respectfully toward their school. This idea can be translated on a wider scale, where students' participation in taking care of the natural environment alters their behaviour to be more respectful of it.

2) Ethics and Environmental Responsibility

When a school design is informed not just by economic considerations such as upfront budget constraints and square footage, but also examines the ecological costs, it demonstrates to students that the impact of one's actions must be considered in relation to the environment. Students learn that a way of measuring what is good becomes the question of how it impacts others – the whole community including the ecological community. This teaches a sense of respect not only toward other humans but also towards other living creatures.[132]

This practice of assessing the ecological cost of a building in addition to its economic cost is referred to as *ecological accounting*[133], and involves considerations of all aspects of the design. Questions can be asked such as where the material comes from, was it sustainably harvested, is it or can it be recycled, and what happens to the waste we produce, for example.

3) Ecological Literacy

Orr states that, "within the design, construction and operation of buildings is a curriculum in applied ecology."[134] Through the principles of ecological design, natural cycles and processes can be integrated into the function of the school building. These systems and processes can be made visible or be designed in such a way that the occupants are conscious of their presence, and so are able to become more knowledgeable on how the natural world works, as well as how the building harnesses them to run. The building operations system can teach students about ecology and sustainability by including components that require active participation from the students; the Living Machine used for cleaning wastewater is one such example. The result Orr writes is "buildings and landscapes that extend our ecological imagination … and ecological competence."[135] This helps students develop ecological literacy as it models to them on a smaller scale the relationships that occur in the natural world, as well to begin to understand themselves in relation to them.

4) A sense of place

A building designed to be adapted to the specific conditions of its site, as well as the way in which it communicates the special qualities of a place, helps connect

its occupants to the particular location. This is important to the cultivation of eco-literacy which is based on the development of knowledge and affection towards a local piece of land.[136] A building design that integrates itself with its context in "a way that respects the health of the place,"[137] communicates a different kind of relationship with the land, one of interconnectedness. Furthermore, an architecture that gives the building a local identity can help form a feeling of belonging to a place which is related to interconnectedness; belonging leads to a sense of ownership which results in care for the place.[138]

Green schools ideally do just this.

The Green School as a Teaching Tool

Having just examined *what* a green school can teach its students, this section will briefly explore *how*.

The work of design educator Dr. Anne Taylor, focuses on how the educational potential of school buildings can be harnessed to create more holistic and sustainable learning environments. Similarly to Orr, she believes that school buildings have a "silent curriculum," that can either enhance or detract from the goals of education.[139] Going beyond just passively communicating values related to sustainability and stewardship by physically modeling them, the school building itself can be integrated into the environmental education curriculum as an active source of learning. In this sense the building and landscape become what Taylor refers to as a "three-dimensional textbook" for sustainability. Architects, designers and educators consciously design the building with all its elements, features and systems so that within them are "educational implications or concepts embedded."[140] These elements are referred to as "manifestations" by Taylor, and act as physical "cues or prompts for learning."[141]

When the school is designed as a 3D-textbook it functions as the context and students "read" it by interacting with it and exploring the concepts integrated in the space.[142] The success of this is dependent on the use of visual cues. One of Taylor's recommendation is designing the school to be more like a children's museum, with signage explaining features, graphics that illustrate how things work, and interactive elements that can be manipulated, to name a few.[143] Transparency becomes important so that components of the building are visible to the eye and not hidden from view. The idea of transparency is one of the principles of ecological design which calls for making natural processes and the flows of energy across the building visible, as a way of helping people understand the complex set of dynamics that are behind the inner workings of the building.[144] Furthermore, in green schools this should, according to David Orr, extend to the transparency of building operations by allowing students to monitor the building's energy performance by making the data accessible. This data should be displayed to the public, as this helps prevent hypocrisy as it holds the building accountable to its promised commitment to sustainability.[145]

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CHAPTER 3:

PRECEDENTS

Chapter 3 Overview

In this chapter a series of precedents are studied and analyzed as a way of developing design strategies to inform and build up on in the final design proposal. The projects investigated are grouped into five categories, looking across a range of scales at how elements of the built environment, in terms of both the building and site design can help advance sustainability, as well as improve people's ecoliteracy and promote environmental stewardship behaviour.

3.1 – LEED-Certified Schools in Canada
The first section explores how these are achieved within the formal education environment, looking at an existing green school in Ontario - the Dr. David Suzuki Public School. The precedent study breaks down by category the sustainable features incorporated into its design that led it to become the first LEED® platinum certified school in Canada, and how they support the pillars of green school design. This study served as a starting point for how a LEED Platinum level of sustainable design can be achieved within the context of an elementary school that is sited in the same climatic region as the thesis project.

3.2 – Environmental Education Centres
The second section looks at several environmental education centres, investigating the selected projects in terms of the strategies the buildings utilize for reducing their environmental impact, for increasing the buildings' relationship to the site, and for increasing visitor's environmental awareness. Environmental education centres are considered to be ideal precedents for this project as they have similar goals to that of green schools, which is to educate the public on sustainability and increase people's awareness of environmental issues, as well as generally providing people with the opportunity to have experiences in nature. Derived from this section are strategies that inform key aspects of the final design including sustainable and passive design, materiality, the building form, and the promotion of a sense of place.

3.3 – On-site Wastewater Treatment
The third section moves to a more specialized category of study – the biological wastewater treatment process referred to as the Living Machine® – that will be one of the highlight features of the final design proposal due to how the system is an example of ecological design and makes a natural process visible. More specifically, the section will investigate the basic operational principles and components of the Living Machine system, and strategies that can be taken to help adapt it to the cold climate of Ontario.

3.4 – The Classroom Module
The fourth section returns to the formal education setting, going down in scale to look at how the design of the classroom unit in itself can support the objectives of a green school. The section addresses qualities such as the spatial configuration of the classroom, and flexibility within the learning environment.

3.5 – Food Education
The fifth section briefly investigates the importance of food education and how it fits within the environmental education curriculum of a green school.

3.1 - LEED-Certified Schools in Ontario

Dr. David Suzuki Public School

Teaching sustainability by demonstrating it firsthand in the building

Architect: McLean + Associates Architects

Gross Floor Area: 5433 m^2

Building Population: 550 students and 38 staff

Program: "Classrooms (Grades 1 to 8), kindergarten classrooms, music, arts, science and special education classrooms, library, gymnasium, office spaces"[1]

Location: Windsor, Ontario

Site Context: Urban

Completion: 2010

Certification Status: LEED® Platinum



Figure 3.1 - Exterior view of the Dr. David Suzuki Public School building. The solar panels which form a canopy over the entrance, are a symbol of the school's commitment to sustainability education. Photo by Greater Essex County District School Board.

The following section will be an investigation in how this elementary school became the first school in Canada to achieve LEED Platinum certification. As the first school to which world-famous environmentalist David Suzuki has lent his name, it seeks to accomplish the same mission as its namesake – promoting environmental stewardship and teaching people how to live more sustainably. It does this through the design of its facility – a high performance energy-efficient school building that is designed with the intention of acting as a teaching tool to its student body. The school was designed around the theme of "earth keepers," and serves as a demonstration project of what a school conceived based on an environmental ethos can look like and function.[2] It is exceptional for the numerous sustainable technologies that have been successfully incorporated into its design and operations.

The intention of the highly sustainable building design was that not only would it have a reduced environmental impact and lower energy cost, but that the building itself would be able to teach students. Where possible, educational opportunities were integrated into the design. The many green features and technologies are made visible to students, giving transparency to how the building operates. Some of these reveals include:

- A glass wall to mechanical room where pipes of systems are painted in bright primary colours for visibility
- A "truth window", that is a glazed panel to reveal the radiant floor pipes underneath the concrete floor topping

- Rooftop garden where the sun tracking skylights can be directly observed
- Clear rainwater leader so that water travelling from the rooftop to the cistern can be watched
- Earth tubes, PVC pipes in this case, are revealed in an area by the fitness room
- The concept of wind turbines is explained through an interactive bicycle, which humans spin the pedals on to generate electricity that is stored in a battery
- Electronic screen distributed throughout parts of the school that display energy data.

One primary method of communicating to students how the building function is through the development of an interactive website which explains the key features of the building through videos and diagrams, as well as provides real-time data through a continuous monitoring of the systems. This website allowed the school to earned LEED points in the Innovation category, and is available to both students and the public with sections separated by age group.

For younger students who are not yet able to quite understand how the technological systems work, a series of art features is placed around the school. These artworks were designed to represent the distinct biomes of Canada. The Canadian Shield is represented by a statue at the entrance set on a piece of stone from there. The Carolinian Forest is represented through a planter box with rocks and artificial forest vegetation adjacent to the Library/Resource Center. The Arctic is represented by a life-size beluga whale sculpture above the two-storey atrium. Large photographs of nature in the prairies, oceans and mountains of Canada are hung around the school. A large-scale globe that rotates and lights up is hung in the stairwells.[3]

However, this school is too expensive to replicate across the whole schoolboard. It is a demonstration project of what can be achieved, with the expectation that other schools will be able to look at the project and utilize some of the elements that would best suit their needs.[4] The project received some financial support from the government in the form of energy incentives totaling approximately 2 million to pay for the installation of some of the innovative technological systems.[5]

The following is a break-down of the sustainability features of the school:

Daylighting:

The project achieved high levels of daylighting throughout the building, meeting the LEED minimum criteria, giving access to daylighting in 76% and access to views in 98% of occupied areas.[6] The following daylighting strategies were employed to achieve optimal illumination levels and reduce the use of electrical lighting:

- The building is oriented along an east-west axis to maximize southern exposure, and reduce number of openings on the east and west faces.
- Large windows facing South in almost all classrooms, with the exception of a few which face North



Figure 3.2 - Interior view of typical classroom window wall at Dr. David Suzuki School. Photo by Greater Essex County District School Board.

- South and north facing clerestory windows reflect daylight into the corridors and two-storey glazed atrium.
- Solatube tubular skylights to get daylight deep into the floorplan of the gymnasium, stairwells and other areas located near the building core.
- Two rooftop skylights with a sun tracking system are installed above the kindergarten classrooms. This skylight relies on a GPS to follow the sun's position with a mirror and lens tracking it in order to intensify the level of natural daylight that is conveyed indoors.
- To reduce glare and provide even levels of light, light shelves are installed in the classrooms. Translucent glass panels known as Solera panels replace some of the upper window panes, acting in a similar way to light shelves to evenly distribute & diffuse light into the space.
- Occupancy and day-light level sensors work in combination to reduce the need for artificial lighting; dimming or switching off artificial lights according to daylight levels to maintain appropriate levels of illumination when the classroom is occupied.
- Exterior shading of windows is provided by the building canopy at the front entry of the school and roof overhangs on the south face
- Interior shading of windows is provided through operable sunshades made of a translucent material in order to maintain views outside.

Ventilation:

The project uses a combination of mechanical and natural ventilation to maintain high indoor air quality. The mechanical ventilation system utilizes a combination of energy-efficient technologies to deliver conditioned fresh air throughout the school, but at a reduced energy cost.

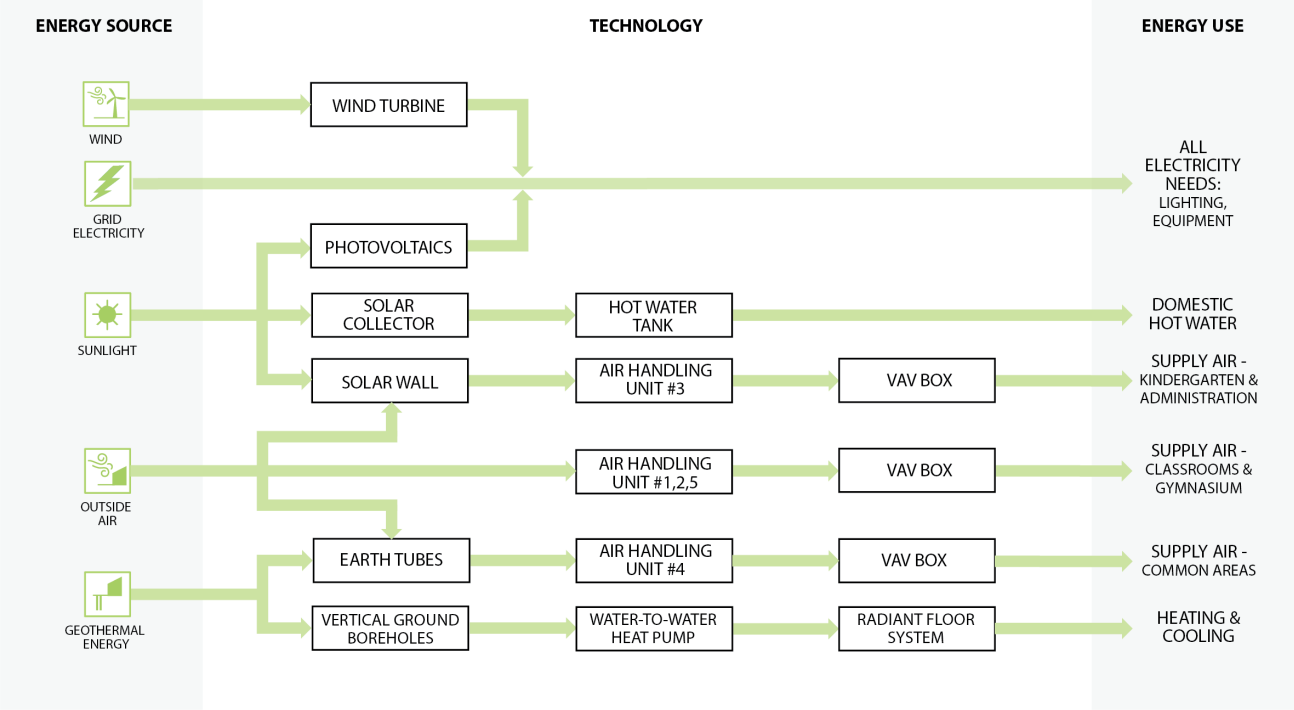


Figure 3.3 - Energy flow diagram of the various energy system technologies demonstrated at Dr. David Suzuki Public School.

- The mechanical system consisting of five air handling units (AHU's) serving four different zones in the building. Outdoor air is conditioned by a hydronic heating/cooling coil connected to the geothermal heat pump. An enthalpy wheel, a type of energy recovery heat exchanger, is incorporated into each air handling unit, allowing for air-to-air heat exchange to occur between the incoming and outgoing air streams.

- Air is distributed by a displacement ventilation system (which means the inlet is located at floor level and the exhaust is near the ceiling at the opposite end). The air supply is incorporated into the classroom millwork (a bench below the window sill) delivering tempered air near the floor at low velocity to help limit fresh/stale air mixing and drafts.

- A variable air volume (VAV) box is used to supply conditioned air as it allows for air delivery to be controlled based on the room's energy requirements and whether it is occupied. This is controlled through occupancy and CO_2 sensors.

- While the ventilation air distributed to the classrooms is heated and cooled entirely through the AHU, the school took the opportunity to showcase some other innovative green technologies – mainly earth tubes, the solar wall, and the living wall, which they incorporated with the HVAC system serving some of the other zones.

- Earth tubes are a passive system used in the school to pre-temper the outside air before it enters the AHU and is supplied to the common areas. Fresh air is drawn through an inlet above the ground and carried through underground pipes where an air-to-earth heat exchange with the ground occurs, much like in the geothermal energy system.

- The SolarWall® is a transpired solar air collector panel designed to look like a typical metal-clad wall that has been incorporated into a small area on south façade of the school. Outside air is drawn into the wall cavity behind the perforated metal panel

where the energy of the sun heats it before it is pumped to the AHU serving the kindergarten classrooms and administration area.

- The living wall uses plants to filter the circulating air, breaking down air pollutants and improving its quality through the natural processes. A fan is incorporated into the living wall system to cool the air before it is supplied to the resource centre.
- There are operable windows available in each classroom and the gymnasium for natural ventilation when conditions are appropriate.
- An indicator light system notifies classroom occupants when outdoor conditions are ideal for natural ventilation. It turns green to inform users to open windows; red to close.

Heating & Cooling:

One of the project's notable accomplishments was to reduce its energy costs by 64% of code standard, allowing it to earn 10/10 points for the *Optimize Energy Performance* credit on its LEED ® scorecard (version 1.0).[7] This was achieved due to the high level of energy performance to which the school's mechanical system and building envelope were designed.

- A geothermal system provides a large portion of the heating and cooling energy used in the building. The components used are a vertical loop with 28 vertical boreholes that extend 113m below ground as the heat exchanger, which connects to two heat pumps, circulating the earth-conditioned water to in-floor hydronic system and air handling units.[8]
- The radiant in-floor system provides heating throughout the whole building, but cooling through the radiant floor system is limited to classrooms only. User control provided via thermostats.
- Cooling in the other areas of the school is supplied through separate systems; an air-to-water source heat pump in the gymnasium and a VRV air-conditioning system in other areas.[9]
- Natural ventilation from operable windows provides passive cooling when conditions are appropriate.
- The building envelope is designed to be airtight with moderately high amounts of insulation. The roof assembly has an R-value of R-30 and the exterior walls perform around R-24.[10]
- Energy efficient windows with a "U-value of 0.35 and solar heat gain coefficient of 0.3"[11] were installed. The insulated glass units (IGU's) are double glazed, with the space between the two panes filled with argon gas, and a low-e glass coating on the exterior.

Water:

The design includes a set of strategies for water conservation that allowed the school to reduce their potable water demand.

- Rainwater is collected from the roof surface and stored in underground cisterns with a 20,000 litre[12] capacity. The collected water is filtered and stored for non-potable uses (toilets, urinals, irrigation).

- Potable water is drawn from the municipal water supply.
- Water for domestic hot water supply is heated by the sun's energy through two flat panel solar collectors installed on the rooftop, and stored in a tank. A supplementary electric water heater is provided for periods when there is insufficient gain.
- Installation of efficient plumbing fixtures and devices - dual-flush toilets, motion sensors on faucets, low-flow urinals and shower heads - helped reduce the building's water use.
- Wastewater is not treated on site, but connected to the municipal sewage system.
- Native species of vegetation and hardy grasses were selected for the landscaping so as to nearly eliminate irrigation requirements.
- Stormwater runoff from impervious surfaces is managed through bioswales located near the parking lot and drop-off.

Renewable Energy Production:

- A 36kW photovoltaic (PV) panel array is installed, architecturally integrated as a canopy at the front of the school. The panels are ideally oriented and sloped towards south to maximize solar access. The solar panels generate energy equivalent to approximately 10% of the school's electricity demand.[13]
- Through Ontario's Feed-in-Tariff program, the school sells the energy it produces back to the grid. It earns about $34,000 per year, meaning the cost of installation for the PV system will be payed back within roughly 10 years. Afterwards, the system will be a source of revenue for the school board.[14]
- Two different wind turbine models are installed on the site. Though they do produce some energy, it is fairly insignificant and mostly they serve for demonstration and teaching purposes.

Materials:

- The structural system consists of structural steel framing, concrete floors and foundation. The building envelope is masonry.
- Recycled materials make up 15% of the total used. Recycled components include steel, a portion of the concrete aggregate, and gypsum board.[15]
- 96% of construction waste was diverted from the landfill.[16]
- The carbon footprint of the materials was reduced by supplying 43% of them from local sources.[17]
- FSC-certified wood was used in construction, as well as in millwork production.
- Flooring is made from renewable natural materials, such as linoleum and cork. In other areas like the corridors and lobby the concrete is polished and left exposed.
- To reduce the potential for heat-island effect the roof was finished with a white-coloured gravel, a green roof was installed in other areas, and light-coloured reflective concrete was used for the parking lot.

While the Dr. David Suzuki Public School successfully meets the three goals of green schools – reducing its negative impact on the environment through a building that performs to a high standard of energy-efficiency, improving the wellbeing of its students and staff through the creation of a healthy learning space, and promoting the development of ecological literacy and sustainability behaviour in its graduates through the use of the school facility a teaching tool – its relationship to its site and local community is not as strong as it could be. What I mean by this is that the design does not strongly communicate the unique qualities or characteristics of its immediate site. Yes, the landscaping does use native species of plants and features a couple of large rocks that were sourced locally, but beyond that the exterior and particularly the interior of the building does not do much to communicate a "sense of place." A case in point, is the arctic marine mammal sculptures hanging above the main entrance; arctic animals have little in connection with the southern-most city in Canada. While it is understood that the school sought to represent the many diverse habitats found in Canada, it could be argued that it does so at the loss of representing what is unique about the local community. The school feels like it could be placed in anywhere in the country.

As green schools are not yet common-place in Ontario [i] , and with Dr. David Suzuki Public School being only one of two LEED-platinum certified schools in all of Canada,[ii] I chose to look elsewhere to a different building type for precedents of buildings/projects that support the teaching of environmental literacy. For this reason, I turned to the environmental education centres which have long had an important role in both formal and non-formal environmental education.[18] Due to the inherent purpose of these buildings to teach people environmental awareness, they are usually designed as green buildings that can meet the highest standards of sustainable design. In this way, they lead as examples of sustainability in the community.

i Refer to Appendix A for a complete list of all the LEED-certified K-9 schools in Ontario, as well as chart with statistics on how Ontario compares to the rest of the provinces in terms of the number of certified schools.

ii The other LEED-platinum certified school is *Amber Trails Community School*, a K-8 school built in 2015 and located in Winnipeg, Manitoba. I chose not to study this school because of the differences in climate between Winnipeg and southern-Ontario, with Winnipeg's climate being a cold continental climate as typically found in the Prairies region.

3.2 – Environmental Education Centres

"Nature centers are sanctuaries that guide people to a "sense of place."[1]

What is an Environmental Education Centre?

I use the term *environmental education centre* as a general phrase to refer to organizations whose purpose is to develop people's awareness of environmental issues through various programs and activities that aim connect and educate people to the specific piece of land which they manage.[2] These places can go by a variety of names such as nature/interpretative/ outdoor education centres among others, which can be used to emphasize the centre's method or approach to environmental education, but generally regardless of the specific term used, these centres are built to support environmental education outside of the formal education framework.

Relationship to Site

An environmental education centre's relationship to its site is an important aspect in its design. Michael Gross and Ron Zimmerman, who have written numerous guides on designing effective interpretative centres, in their definition of what a nature centre is acknowledge the important role these places can have in environmental education because of their relationship with the land they are built on. They write: "Nature centers are more than mortar and brick or trails through a natural area. They are human institutions that guide our search for a sense of place. A nature center is land based, serves a local community and fosters sustainable relationships between people and the earth."[3] This understanding is based on the knowledge of the importance of developing a mental (knowing) and emotional (feeling) connection towards a piece of land – in other words a "sense of place" – as steps in becoming ecoliterate.[4] Thus the unique qualities of the site on which the centre is located on, such as the natural and cultural history, become an important influence in shaping the architectural design and programming of the environmental education centre.

Environmental Education Centres as Precedents

It is for these reasons that I looked towards existing environmental education centres as one of the primary inspirations for the thesis designs. One thing all three centers that have been chosen as precedents have in common is a close relationship between their site and the design. In each project the site's history and context help determine the goals and unique qualities of the building's design and education program. While understanding that every environmental education center is unique because of the special characteristics of its site and circumstances of the project; the following three centres were chosen a precedents because of how the building helps develop people's understanding of and connection to the environment through the architecture. Their study helped set the overall architectural direction of the thesis design. Their siting in the same climatic region as the thesis site helped identify key strategies for sustainable design that works in this climate.

Bill Fisch Forest Stewardship and Education Centre

Looking to the Forest Ecosystem as an Architectural Precedent

Architect: DIALOG

Gross Floor Area: 370 m^2

Program: Community Classroom, Multipurpose Assembly Space, Municipal Administration, Washroom Amenities

Location: Whitchurch-Stouffville, Ontario

Site Context: Rural

Completion: 2015

Certification Status: LEED® Platinum; "Living Building Challenge" certified for all 7 petals as of May 2018 [1]



Figure 3.4 – Main entry approaching from parking, south face of the BFFSEC building.

The Bill Fisch Forest Stewardship and Education Centre (BFFSEC) serves as a precedent for this project's choice of main building material – wood construction. The *proposed school design* references BFFSEC's innovative use of mass timber products not only in a tectonic sense, but also the way in which it approaches working with the materials to create a building that blends in with its site, in both its physical appearance and operation.

The densely forested site that encircles the BFFSEC building serves as the main inspiration in the design of the facility. The centre was built on one of the forest tracts of the York Regional Forest, with the purpose of teaching visitors about forest ecosystems. It provides a space for community educational programs and meetings, as well as serving municipal operations. What is special about the York Regional Forest is that it is a successful forest restoration project now nearly a century old, and has achieved FSC-certification for its sustainable management practice. With such a site, it was important for the facility to demonstrate sustainable use of this resource, as well as be representative of the natural environment, thus the decision to showcase wood products heavily on both the interior and exterior was an obvious one.[2]

To that end, the main wood products used in the construction of the BFFSEC are as follows: (1) The structural elements consist of cross-laminated timber panels (CLT) for the walls, and a glulam column and beam system to support the CLT roof deck. (2) The exterior cladding consists of recycled Douglas fir boards
(3) Interior finishes are either the exposed CLT walls, or maple-veneered plywood panels. All wood used in the project is FSC-certified, and almost all materials used are sourced locally (within a 1000km radius of the site).[3]



FOREST CANOPY

The roof with its large overhangs and pronounced appearance acts like the thick foliage of the forest canopy; both covers give "protection from the elements"* to that beneath.

UNDERSTORY

Clerestory windows running around the entire perimeter of the building bring in daylight from above, reminiscent of sunlight filtered through the upper story down to the forest floor.

UNDERSTORY

The combination of the verticality of the exterior wall elements, and the alternating rhythm between transparent and solid panels, "evoke an image that is just like trunks of the trees outside."*

SHRUB LAYER

Small trees and shrubbery are planted above the wastewater infiltration bed, and directly adjacent to the windows. These low-level plants are a continuation of the forest just beyond and symbolic of the ecological succession that takes place over time.

FOREST FLOOR

The rough texture and irregularity of the stone paving creates a similarly uneven ground plane to that of the forest floor.

* International Living Future Institute



FOREST CANOPY

The continuity of the exposed CLT roof deck throughout the whole building gives the ceiling plane a monolithic but natural appearance that has similarities to the uniform mass of green of the forest canopy.

UNDERSTORY

The effect of the light coming through the maple louvre screen is like that of dappled sunlight through branches.

UNDERSTORY

The glulam columns, being a solid and upright mass of timber, are the more obvious elements to resemble the trees outside, but nevertheless contribute to the over- all forest-like feeling of the space

FOREST FLOOR

The deadfall found in this layer of the forest is represented by the front desk which is constructed out of logs from trees that were destroyed by Emerald Ash Borers, retaining their tracks.

FOREST FLOOR

Leaf imprints in the concrete floor gives the sense that a gust of wind has carried the leaves inside.

"The building was always conceived of being 'of the forest', and not 'in the forest.'" [4]

In order to convey the feeling that one has not left the site when they enter the building, the designers used the forest as an inspiration for the architectural qualities of the building. One way this is achieved is through the building's form which takes on a treelike shape, with each building component acting as an interpretation of a layer of the forest.[5] Refer to **Figures 3.5** and **3.6** for a visual breakdown of the parallels the architects drew between the building and forest.[6] The light condition achieved through the alternating rhythm of windows and CLT panels, together with extensive views outside, and the materials' tectonic character, are all qualities that collectively allow the building to blend in with the surrounding forest. These qualities combined with the heavy use of natural materials such as wood and stone contribute to the *biophilia* of the space.[7]

"We wanted to create a building that could function like a forest ecosystem, be an integral part of nature and enhance it?" [8]
- Craig Applegath, principal architect at DIALOG

The BFFSEC centre operates in such a way so as to leave as little impact on the environment as possible. Like the forest, the building relies only on the sun for energy (captured through solar panels) to fulfill all its electrical needs and more. The result is a net-positive energy building. The building also has a net-zero water use, capturing rainwater from the rooftop, storing it, and filtering it before releasing it back to the forest ecosystem.[9] Selecting wood as the main material for construction was a sustainable choice because like the forest it came from, it stores carbon; so its use helped reduce the amount of CO_2 emissions resulting from the construction process.[10] Merging the centre's operation with the natural processes of the site, helped the building blend itself harmoniously into the forest's ecosystem.[11] The result is such that it looks and functions as if it were always there.

The BFFSEC is a material inspiration for this ***project*** in the way it references its site's natural history and character to inform the material choice, architectural qualities and sustainability agenda of the building. The result is a beautiful space created through the use of innovative wood products that blends in with the natural environment and extends the "sense of place" to within the building.

It is anticipated that there may be some challenge in adapting some of these qualities to this ***project*** due to the vast difference in scale between these two buildings. A larger building with a more complex program and occupied on a daily basis, like an elementary school, will have a bigger "footprint" both in terms of the area of a site it covers and the impact it has resource wise on the site. It becomes harder to blend such a building in with the environment as it instantly has a bigger presence and is likely to cause more disruption to the surrounding ecosystem. To minimize this becomes a priority.

(opposite page)

Figure 3.5 - (top) - Highlighting elements inspired by the forest on the exterior facade of the BFFSEC building.

Figure 3.6 - (bottom) - Highlighting elements inspired by the forest on the interior of the BFFSEC building.

Summary of Sustainability Features of BFFSEC:

Net-positive energy building performance is achieved through the following strategies:

- Energy is conserved by the building's high-performance building envelope;
    - *insulated walls and roof + triple pane, argon-filled window glazing;*
- Makes use of natural light through window positioning, LED lighting
- Building is heated by radiant slab heating. The multi-purpose room contains mechanical ventilation, and heating and cooling is achieved through an air source heat pump. The rest of the building is cooled passively through windows which open/close. Heat is conserved through heat recovery units.
- Energy is generated using solar panels (roof-mounted); center produces more than it uses
- Potable water is supplied through on-site aquifers, while non-potable water is supplied through collected rainwater to achieve net-zero water. Wastewater is treated and returned to the site (biological filtration device)
- Materials used include cross-laminated timber and glulam. Both materials were FSC certified, cladding consists of recycled Douglas fir boards. All materials are from local sources.

Minimizes Impact of Building on Wildlife:

- Screen has anti bird crash pattern
- Reduced light pollution by having LED lights facing downward. Also, exterior lighting is turned off at night (for reduced impact on nocturnal species in forest)

Educational Features:

- Public is educated on the tree species located in the forest through exterior wood panels (featuring samples of the local wood)
- Screen displaying data from energy monitoring system

Biophilic Elements:

- Exterior: exterior materials used are wood and stone - which reflect the surroundings allowing the building to "blend in". The shape of the building reflects a tree.
- Interior: wood is used heavily in the interior to demonstrate sustainable use of this resource, as well as reflect the natural environment, floor has leaf impressions to remind occupants of the natural environment, ample daylighting throughout

Aldo Leopold Legacy Centre

Architect: The Kubala Washatko Architects, Inc.

Gross Floor Area: 1115 m^2

Program: Administration Offices, Multipurpose Assembly Spaces, Exhibition

Location: Baraboo, Wisconsin

Site Context: Rural

Completion: 2007

Certification Status: LEED® Platinum; certified carbon-neutral



Figure 3.7 - Exterior view of the Aldo Leopold Legacy Centre, which is made up of a series of volumes arranged around a central courtyard. Photo by Terri Meyer Boake.

The Aldo Leopold Legacy Centre serves as a precedent for the building form of this project – a form inspired by local agrarian architecture. Whereas the BFFSEC takes inspiration from the natural history of its site, the Aldo Leopold Legacy Centre references the site's cultural history in its architectural response. The design project references both aspects of the building form itself, and way that it came to be – by the architects being directly inspired by the human history of the site, which in this case was one that is closely connected to the ecology of the place.

The Centre's site in rural Wisconsin holds historical significance as being the very land which Leopold and his family worked to ecologically restore, the experiences of which are famously chronicled in his book *A Sand County Almanac.* It is this work that was the inspiration for his concept of "Land Ethic." Land ethics is born out of Leopold's understanding of the interconnectedness between humans and nature, and calls for people to have a considerate and ethical relationship with the land they occupy. The Leopold Legacy Centre was constructed as the operational base for the Aldo Leopold Foundation whose mission is to continue the work of the late conservationist: teaching people to "live on the land not only to their benefit, but to benefit the soil, water, plants, and animals that make up 'the land,' as well."[1] It was important for the building to be an embodiment of the Foundation's mission and physically demonstrate to the community how one can "live lightly on the land."[2] The result is a building that embodies this understanding through a sustainable design which combines traditional "low-tech" design strategies with new technology to reach its target goal of being a net-zero energy and carbon neutral facility.

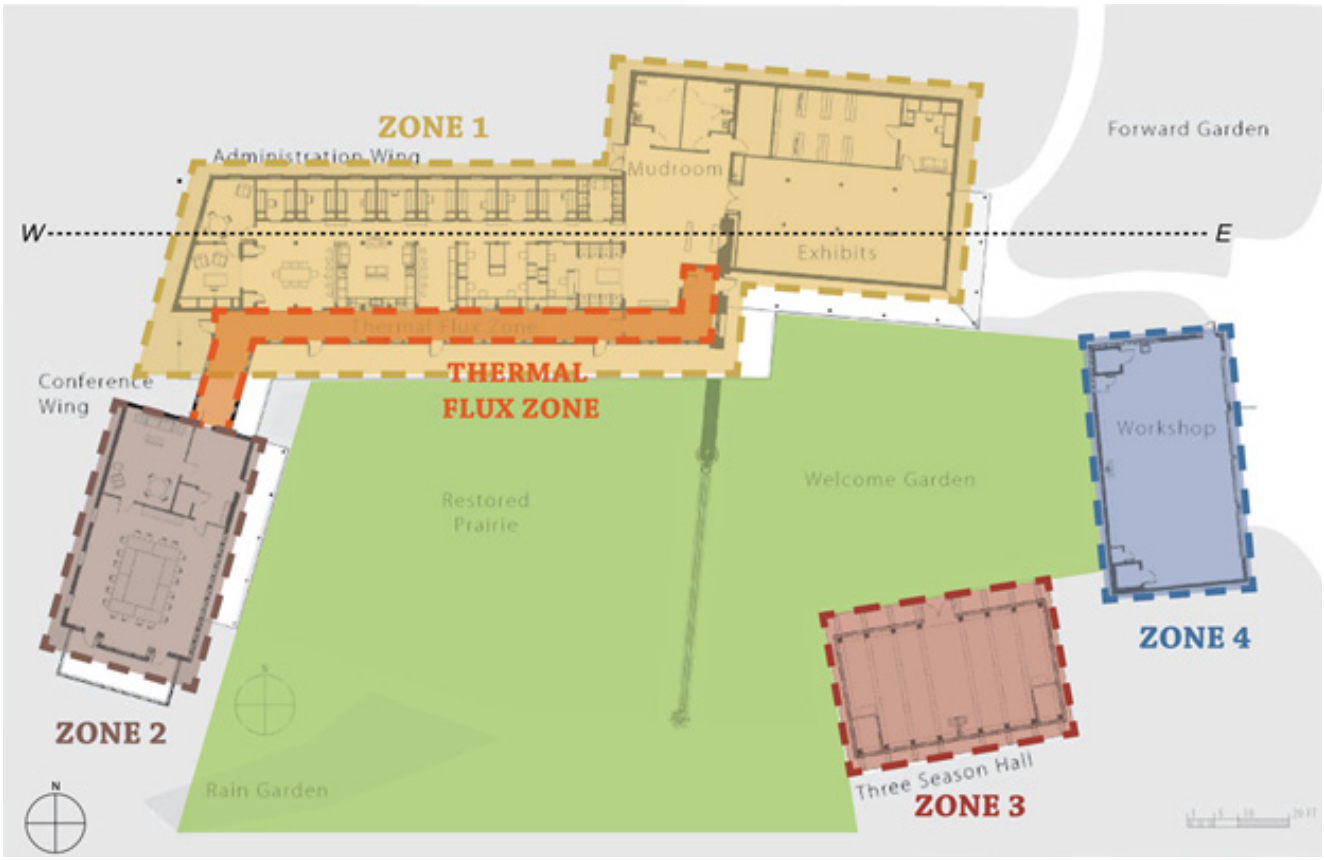







Figure 3.8 - (top) - Ground Floor Plan of the Leopold Legacy Centre, differentiating the key thermal zones in the centre. Base plan by The Kubala Washatko Architects, Inc.

Figure 3.9 - (bottom series) - Exterior photographs of the distinct building volumes that make up the Leopold Legacy Centre. Series of photographs by Terri Meyer Boake.

"The Shack was everything, and it was nothing."[3]

The architecture of the Legacy Centre building takes its cue from the simplicity of the Leopold Shack, which despite being little more than a renovated chicken coop, played a central part in the Leopold family's experiences on the land, and has endured as a symbol of their conservation efforts.[4] The Leopold Shack was truly a green building in the sense that it was fixed up using "found materials, (…) daylit and naturally ventilated, (and) used no electricity or potable water."[5] The architects tried to translate this into a building that would meet 21st century standards. Thus, the building's physical form is tied to optimizing energy performance and minimizing the building's impact on the site, rather than merely aesthetical considerations. The following aspects of the building allow it to take advantage of nature's free services, which greatly contributed to the overall 70% reduction in energy use.[6]

U-Shape Courtyard:

The program of the Leopold Legacy Centre is broken down into three separate buildings that are arranged in a U-shape around a central courtyard. The layout was developed based on a strategy known as energy programming[7] or thermal zoning[8]. Energy programming arranges building spaces into zones based on "common occupancy schedule and thermal comfort requirements,"[9] increasing energy efficiency. The spaces that are occupied on a daily basis, such as the administrative spaces and visitor exhibition area, are grouped together in one building and form the main spine of the courtyard. On the other hand, the multipurpose hall and workshop, which are not regularly in use or used only used seasonally, each form their own separate building and are located on the other end of the courtyard. All of the spaces open up to the courtyard, which helps prevent these separate programs from feeling disconnected from each other by becoming a shared outdoor common room.[10]

In terms of its relationship to the site, the courtyard configuration helps reduce the building's presence by breaking the building down into smaller parts rather than one large mass. Furthermore, it helps connect the occupants to nature – the U-shape creates an opening on one end giving each building a view towards the nature on the site (in this case the restored woodland).

Narrow Floor Plate; E-W Orientation:

To maximize the opportunities for natural ventilation, daylighting, and passive solar heating, the Leopold Legacy Centre is designed as a skin-load dominated building. This term refers to a building that has a narrow floor plate, which ensures that the occupant is "never too far from the outdoors."[11] The Leopold Centre has a floor plate that varies between 8 to 10m wide, and as a result all spaces have access to operable windows from at least one exterior wall. Orientation is also an important consideration – the Centre is placed on an east-west axis so that majority of the building envelope is oriented towards the south and north direction, maximizing winter solar gain from the southern side and diffused daylighting from the north, while minimizing openings on the east and west.[12]

"Thermal Flux Zone":

The corridor in the administration wing was designed as a buffer space that helps modulate thermal comfort. Facing south with lots of glazing, the corridor acts as a sunspace. During the day it is passively heated by the sun, whose energy it stores in the thermal mass of the concrete floor, which is then released at night. In the winter, the adjacent office space can take advantage of this heat gain through openings (sliding doors and windows) in the shared wall. Likewise, the openings can be closed to either reduce heat loss in the winter, or prevent heat gain during the summer. The apertures can also be opened to allow cross ventilation. The value of this "thermal flux zone" (as it is referred to) is that it "allows occupants to manage natural ventilation, solar gain, and glare."[13]



Figure 3.10 - The sun-filled corridors in the administration wing, also referred to as the"Thermal Flux Zone." Photos by Terri Meyer Boake.

Sloped Roof:

All three buildings in the Legacy Centre complex have a sloped roof which is climatically appropriate in regions with winter snowfall. The rooves change between a gable roof on the conference wing; a skillion and lean-to roof on the main administration wing; and a shed roof on the Seed Hall and Workshop structure. The large roof on the administration wing is sloped towards the south which provides the ideal angle and orientation to allow the centre to take maximum advantage of southern solar gain for the production of renewable energy. Thus, most of that roof is covered with a 39.6 kW photovoltaic array which produces a surplus of energy to meet all of the centre's electricity requirements.[14] This was an important piece in helping the centre meet their net-zero and carbon neutrality goals.

The roof has become a symbolic and very visible element of the Legacy's Centre's commitment to sustainable design. The rooves were constructed out of timber trusses and rafters, part of a post and beam system, the entire structure of which is made from wood harvested on-site from the Leopold Pines. This action not only connected the building to the site through the use of local material, but was of benefit to both the humans and the land. It improved the ecology of the site as the trees' health was suffering from overcrowding, contributed to reducing carbon emissions, and provided a high yield of construction material.[15] The building's frame has been left exposed and unfinished on the interior. The harvested wood was also used to clad the interior and exterior surfaces, and to construct doors and furniture.[16]

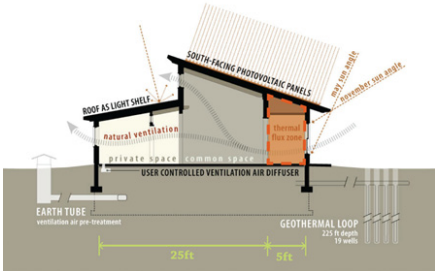


Figure 3.11 - East-west section through the administration wing of the Aldo Leopold Legacy Centre. The thermal flux zone is highlighted in orange. Base section by The Kubala Washatko Architects, Inc.

Other passive strategies such as a well-insulated building enclosure and roof overhangs sized for summer shading, contributed to reducing the building's energy demand. Complementing these passive strategies, are several active strategies – none of them however require the use of fossil fuels. Geothermal energy is used to heat, cool and ventilate the building through a radiant floor system and earth tube system. The heating is complemented by fireplaces and stoves fueled by wood (a renewable resource).[17]

On a final note, the building's design shares many characteristics to the traditional agricultural buildings typically found in this region. Some of the more direct references are the pitched roof, the exposed timber frame, open floor plan, the material palette (wood, stone, and aluminum roof, all of which are recycled), and the sliding barn doors and windows on the interior. This agriculturally-inspired appearance helps the building fit into the landscape; it connects the building to the rural community it serves by creating a building that is of the place through the use of local materials and vernacular building strategies. Similar to the approach that the Legacy Centre's design team took, the building form of the traditional barn has always been based on functionality – it is easy and inexpensive to construct, built out of the materials that were closest at hand, but able to fulfill the needs of the space.

The ***design proposal*** for the school will reference the elements that were discussed above in the design of the building form in order to optimize the building's energy performance, reduce its energy and carbon footprint, while connecting the school to its cultural history. Certain aspects will be adapted to better fit the needs of a school building. The strategy of energy programming will be applied to the organization of the school spaces. The programs of the school will similarly be organized around central courtyards, although rather than having one large courtyard it will be broken down into three individual courtyards (one to be shared by each grade division). Also, due to safety reasons the courtyards will not directly open up to the site, but will be enclosed. To take advantage of southern solar gain but avoid issues of glare and overheating, the design will employ the concept of a thermal flux zone in the classroom corridors. However, I would like the corridors to be a space that can be used as an extension of the classroom and a place to linger rather than just for pure circulation reason. This will be done by increasing the width of the corridor to 3m (compared to the ~1.6m wide ones at the Leopold Centre), and by introducing plants and seating areas. The architecture of the proposed school will similarly have features that are agriculturally-inspired as a way of connecting to the site's community. It will be gesture to the site's past and present rural identity, one which is slowly receding with the town's growth.

Urban Ecology Centre in Riverside Park

Making the Outdoors more Accessible to Everyone



Architect: The Kubala Washatko Architects, Inc.

Gross Floor Area: 1858 m²

Program: Community Center, Environmental Education Classrooms, Outdoor Recreation, Administrative Offices

Location: Riverside Park, Milwaukee, Wisconsin

Site Context: Urban

Completion: 2004

Certification Status: Did not apply for LEED due to financial reasons

The Urban Ecology Centre (UEC) serves as a precedent for this project because it shows that an environmental education centre does not have to be in a "wilderness" setting in order to effectively teach people ecological awareness. Whereas both of the previous two precedents were sited in somewhat isolated rural communities, the UEC is based in an urban park located in a downtown residential neighbourhood in Milwaukee. In this instance, the centre's urban location is to its advantage. It makes experiences in nature more accessible to the population that generally feels most disconnected from the natural environment and lacking in opportunities to experience nature in their daily lives – urban citizens. Furthermore, this project serves as a reminder that cities and ecology are not separate from each other, but that everything is interconnected.

"Many of the typical barriers to connecting with the outdoors have been greatly diminished."[1]

The Urban Ecology Centre is a non-profit organization whose mission is to educate the people in their local neighbourhood to be environmentally aware and responsible citizens; ones who will want to conserve and care for the nature in the city.[2] They aspire to do this through an "environmental education (program) that directly connects urban communities to their local ecosystems."[3]

Improving accessibility to nature is therefore of primary concern to the organization. Their environmental education program is based on the idea of making nature more accessible for children living in urban communities. How? By creating connections between the people and nature in the city.

Therefore, the building was designed to encourage these *connections* on many different levels.

Figure 3.12 - (top left) - Exterior view of the street facing elevation of the Urban Ecology Centre. Photograph by Mark F. Heffron & The Kubala Washatko Architects, Inc.

Creating a Connection to Nature

a) The building as a whole serves as "an accessible entrance" to the park.[4] It becomes a threshold between the city and natural world. Physically this is represented through the staircase/ramp that joins the street grade with the lower park grade. By increasing the ease with which the natural areas of the city can be accessed, the centre removes one barrier that may be keeping people from spending time in the park.

b) Connections to the outdoors from within the building are maximized throughout. An assortment of areas - thresholds, covered porches, balconies, an observation tower, the green roof – form spaces that can be incorporated into the building's educational programs. These spaces mediate the connection between indoors and outdoors, allowing views out onto the site while offering a sense of protection.

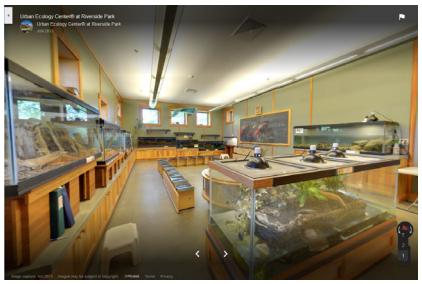


Figure 3.13 - View of the UEC's Native Species Classroom. Screenshot of Google Maps 360° view.

c) To help students and visitors develop a connection to site, the focus of the building's educational science program is the local ecology of the site. The theme of local nature is reflected in the programming of the classrooms, and through various visual features across the centre. One such space is a classroom referred to as the "Native Wisconsin Animal Room" which contains aquariums holding native aquatic species. Another room is the "Camouflage Room" which features floor-to-ceiling height murals, one for each season, within which animals are camouflaged. Other features include a local watershed map painted on the main lobby floor, a "Habitat Playground," and the use of natural materials such as raw wood for furniture and railings.



Figure 3.14 - View of the UEC's main lobby which serves as the "city's living room." Photograph by Mark F. Heffron & The Kubala Washatko Architects, Inc.

d) The centre's relationship to city becomes as important as its relationship to nature. A connection to city is created through a main lobby that acts as the city's "living room."[5] The building's proximity to the urban environment invites everyone to come visit – young and old and anyone in between; not just outdoorsmen and nature enthusiasts; in this sense it becomes a true community centre. Architecturally this idea is reinforced through the open main lobby. It is the first space that people encounter as they walk in the building, and it is designed to be welcoming with a central seating zone gathered around a wood-burning stove, and multiple other seating and working spaces distributed throughout the open room. The staff areas are not isolated but right off of the main lobby, where they are able to interact with visitors.

e) Connection through programming and education – The centre's focus audience is children, and one of its main mission goals is to provide opportunities for children in urban areas to experience hands-on outdoor environmental education on a regular basis. This is based on the understanding that repeated contact with a piece of land helps develop ecoliteracy.[6] This led to the development of the NEEP (Neighborhood Environmental Education Project), a partnership with local schools that allows nearby schools to visit the center multiple times within the school year. The schools incorporate the programs offered by the center into the science curriculum, supporting what is studied in the classroom with hands-on experiences in nature. The NEEP program is where the center concentrates most of its programming efforts and it serves a source of income for the UEC to support its operation. Other programs offered by the center include after-school programs, opportunities for volunteering, and collaborations with local university students, all which help make the UEC an environmental community centre.

IslandWood

A School in the Woods



Architect: Mithun Architects

Gross Floor Area: 6503 m²

Program: Multipurpose Assembly Hall, Dining Hall, Classrooms and Labs, Administrative Offices, Overnight Accommodations, Greenhouse, Outdoor Pavilions

Location: Bainbridge Island, WA

Site Context: Rural

Completion: 2002

Certification Status: LEED® Gold

The project takes inspiration from IslandWood, as it is a precedent in how an entire site can be utilized as a "laboratory for learning."[1] IslandWood is an environmental education centre located on a small island whose site is an incredibly rich oasis of wilderness. The centre takes advantage of its unique location to offer to students from elementary schools in the area a chance to learn about nature, science and sustainability through an overnight program at its campus.

The project's response to the site in terms of occupation is to minimize its impact on the site and make the natural area of the site accessible so that it could be utilized as an educational resource. The facility consists of a collection of buildings and small outdoor pavilions that are distributed across the site. The campus is an example of sustainable land use, as the designers chose to place the main buildings of the centre on a location which minimized impact on the ecosystems and limited the area of development to previously logged parts of the site, thereby leaving undisturbed areas untouched. Designed as a LEED® Gold certified building, the building minimizes its impact on the natural ecosystem by connecting to it through a passive building design that harnesses elements of nature – the sun, wind, rainwater, plants & organisms – to help it operate.

- SUN – Due to the forest location, solar meadows had to be created in order to harvest energy through solar panels and let natural light to reach buildings. The solar orientation of building allows for solar gain, solar panels provide energy for classrooms, and moveable awnings provide shade for rooms. The centre is oriented for optimal natural lighting reducing dependency for electricity, allowing light in through windows and installed skylights.
- WIND - No air conditioning is provided in the centre, instead natural ventilation is used (through windows and skylights which can open up). Fans which run on solar-power provide air movement.

IslandWood's experiential educational curriculum is based on a study that was conducted in 1998 by the name of 'Closing the Achievement Gap' that "examined models of learning in children and showed that by taking children outside the classroom, by focusing on actively doing rather than reading or being lectured to, children's academic performance goes up in every discipline. In math and science scores went up by over 90%, and discipline problems decreased while attendance increased."[5]

Figure 3.15 - Exterior view of the main building which holds the welcoming centre, administrative offices, and large assembly hall. All photos of IslandWood are by Terri Meyer Boake.



Figure 3.16 - Exterior view of the science classroom building at IslandWood.



Figure 3.17 - View of interior spaces within IslandWood campus; clockwise from left: science lab, dining hall, guest cabin.



Figure 3.18 - On-site pavilion within the forest on Bainbridge Island.

- RAINWATER - Rainwater is collected and stored in on-site cisterns. Collected rainwater is used to water gardens. Waste water is treated on-site through the Living machine and wetlands. Water is heated through solar energy.
- LIVING MACHINE - To treat wastewater on-site a biologically-based filtration system called the Living Machine is used. Wetlands were created and used for additional wastewater treatment.

The building not only teaches sustainability by demonstrating it but by also allowing it to be experienced, as students explore concepts of sustainability and environmental stewardship integrated throughout the site and building.[2] Students observe how the building functions and participate in operating it during their stay on the island. Art features and interior design details are incorporated throughout the spaces to teach about the history of the site and bring notice to the sustainable components of the building.[3]

The building design helps bridge the indoor and outdoor environment, through the use of interior biophilic features which help reinforce the building's connection to the site, as well as teach students about its natural history. The material palette of the building is inspired by the site and contains natural materials such as wood and stone which were sourced locally and/or reclaimed. For example, when the solar meadows were created, the wood from the trees that were removed was used as building material. To teach children about sustainable materials different flooring materials including rubber, cork and bamboo and different countertop materials, such as a recycled yogurt container composite plastic, are used in science lab classrooms. Straw bales are another natural material, and were used to form the exterior walls of the Art Studio. Recycled products such as tires, carpet, tiles and reclaimed wood were used throughout the campus.[4] Each building is conceived slightly differently in terms of its interior finishes and architectural expression, but the landscape of buildings is connected to and related to one another through the common use of a wood structural system.

The proposed school design of this thesis project similarly deals with a collection of distinct building programmes, and though they are not spread out over as large a site as at IslandWood, they require to be distinguished from each other while remaining connected, to identify them as belonging to the same school. This precedent inspired the approach to dealing with this situation through the use of a common material palette that consists mainly of natural materials (wood, strawbales, plaster) and is connected to the natural features of the site.

3.3 - On-site Wastewater Treatment

The Living Machine® and Constructed Wetlands

The Living Machine® is an alternative wastewater treatment technology that cleans water by pumping it through a series of closed and open tanks that are filled with a variety of plants, microorganism and bacteria.[1] The concept was invented by Dr. John Todd of John Todd Ecological Design, Inc. and treats wastewater through biological processes instead of using chemicals such as conventional systems like wastewater treatment plants or onsite septic systems do. The system simulates the natural filtration processes of wetlands, creating a miniature ecosystem in these tanks, which supports itself by feeding on the nutrients in the incoming waste. The treatment system takes advantage of this, using the bacteria and microorganisms growing on the plant roots and soil medium to break down the waste solids in the water and consume them, thereby filtering and cleaning the water. The treated water is then re-used for greywater purposes such as for flushing toilets again and landscape irrigation.

An example of ecological design, the Living Machine harnesses the free services of natural systems and applies them to wastewater treatment.[2] The process has many benefits over conventional wastewater treatment systems. By treating all wastewater onsite, the system reduces the load on the municipal water treatment services (centralized sewage treatment system) which while able to treat large volumes of water, is an energy intensive process. The Living Machine also cleans water with zero chemicals, unlike conventional treatment systems which rely on harmful chemicals to treat water, and produce by-products of sludge. Generally, Living Machines enable a much more energy efficient process, as much of the treatment work is done by the organisms, and electricity is only used to pump the water between tanks.[3] The Living Machine is also generally a more cost-effective process to operate.[4] Furthermore, any water that is released back to the environment will be safer as it is almost free of all nutrients like phosphorus and nitrogen as the Living Machine process is capable of removing these.[5] The process is silent, emits little odour, reduces a building's potable water use as it allows for the reuse of black water, all achieved in a relatively compact footprint. Some drawbacks are that it is more prone to technical issues, such as not having enough solid waste to process, and therefore requires careful monitoring and maintenance of conditions that allow for the biological processes to occur. For a school however, its ultimate advantage is that the Living Machine offers environmental education opportunities as it demonstrates alternative methods of wastewater treatment, and gives visibility to biological processes at work.[6] Students are able to incorporate the system into lessons on biology, and sustainability with emphasis on learning about how important water is as a resource.

Living machines are functional, beautiful, and educational, in alignment with meeting all three pillars of a "green school." The steps and sequence are able to take many forms but the main component, and the most aesthetically defining one of this process, is the open aerobic reactors. [7] The aerobic reactors are generally

"Microscopic bacteria consume the nutrient-laden organic matter from the wastewater and con-vert toxic ammonia to nitrite and nitrate, which creates suitable food for plants like duckweed. Algae growing on the sides of the tank consume abundant nutrients and grow rapidly. Snails and zooplankton feed on the algae. The zooplankton are then eaten by fish, such as striped bass, tilapia and minnows, etc.—and on and on churns the natural food chain cycle of an ecologically engineered system, purifying the waste-water with each step."[8]
–Dr.John Todd

a cell or tank that is several feet deep that contains a diverse selection of tropical plants. These plants are supported by a metal rack, and their long roots which extend deep into the water form a habitat for the digesting microorganisms. The open aerobic tanks are usually placed in a greenhouse to provide the ideal temperatures and light levels required to support the health of the plants. This makes them a very visible part of the process and an aesthetically pleasing one at that. The following pages briefly present three existing Living Machine systems, looking at the key components of their system, which served as precedents for the design of the biological wastewater treatment system integrated into the project's proposed school design.



Figure 3.19 - The aerated hydrponic reactors located in the greenhouse at IslandWood. Photograph by Terri Meyer Boake.

IslandWood

The Living Machine at the IslandWood campus is housed in the on-site greenhouse. It serves as tertiary wastewater treatment process, cleaning the wastewater from the toilets so that it is clean enough to reuse for flushing toilets and for subsurface irrigation. It was installed at the campus because not only was it a more cost-effective solution to wastewater for the island than having to install pipes all the way to the mainland to connect to the municipal sewage system, but also because it is in line with the centre's sustainable education curriculum. The system is incorporated into students' lessons, and the greenhouse is host to a variety of activities. The steps in the process are:

1) Septic Tank/Anaerobic Reactor – Located outside, but adjacent to the greenhouse, this is where the wastewater collects, settles and starts to break down into a liquid so that the affluent can be filtered through the system with more ease.

2) Textile Filter Boxes – A closed environment, this is where bacteria begins to digest the solids.

3) Aerated Hydroponic Reactors – Consisting of three tanks that are six feet wide

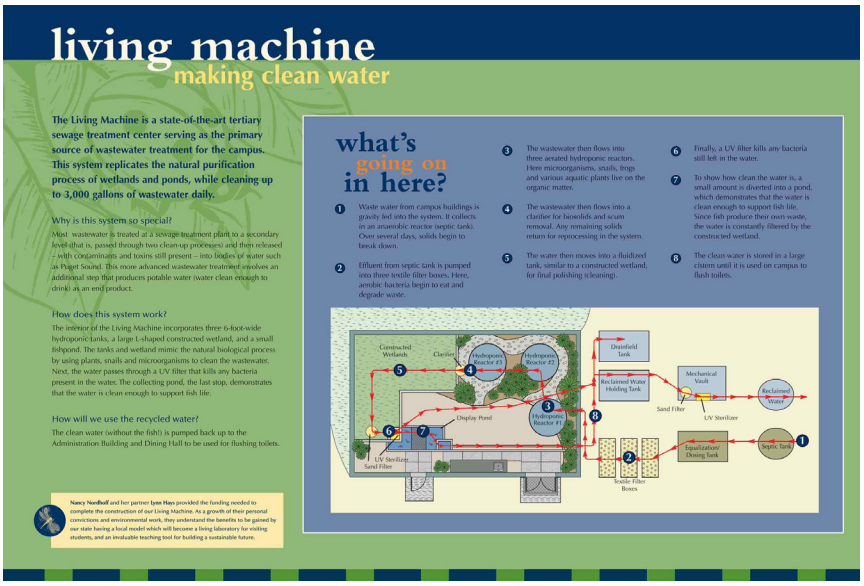


Figure 3.20 - Signage inside the greenhouse explaining the steps of the treatment process. Signage designed by Lehrman Cameron Studio.

and located in the greenhouse, the reactors are overflowing with tropical plants species such as canna lilies, taro, umbrella plants, Egyptian paper reed and irises among many other.[9] They create a habitat for microorganisms and amphibious small animals such as snails, frogs which feed on the waste solids.

4) Clarifier

5) Ecological Fluidized Bed – A small L-shaped constructed wetland, where the water is polished for the final time.

6) UV Filter – to rid the water of any leftover bacteria

7) Collecting Pond – The cleanliness of the water is showcased in the pond the water in which is now clean enough to be inhabited by small fish.

8) Reclaimed Water Holding Tank – Stores cleaned water for later use

In the proposed design, the Living Machine and its components will be arranged differently than in the IslandWood precedent. Within the proposed design, the main components (the aerobic tanks) will be spread throughout the campus rather than being concentrated solely in the Greenhouse, as they are at IslandWood. This helps the system feel more incorporated into the everyday life of students, and will be visible to them whenever they come and go rather than hidden away in the Greenhouse. As part of this design intention, the design will locate parts of the system outside. This means that the Living System design must address the cold climate of the site which differs from the temperate climate of Seattle where IslandWood is located.

To answer the question of whether a biological wastewater treatment such as this one would work in a cold climate, two other precedents based in the same climate zone as the project site were looked at. How the filtration steps can manifest in various architectural expressions/ landscape design features was also explored.

Centre for Alternative Wastewater Treatment (CAWT)

The CAWT, an educational facility and research institute affiliated with Fleming College in Lindsay, Ontario utilizes an onsite constructed wetland wastewater treatment system to clean the building's wastewater for reuse. Its other purpose is educational – the treatment system provides the necessary onsite infrastructure for the centre to conduct its research on a range of projects concerned with innovative water and wastewater systems. It is used as a testing field for research and incorporated into the student's lessons providing them with hands-on experience as they observe and manipulate the treatment system.[10]

While the treatment process is based on the same principles as the Living Machine at IslandWood, what differs with this project's biological wastewater is that majority of the components of the wastewater treatment system are situated outdoors within the courtyard of the building. Instead of using indoor open aerobic tanks, the CAWT utilizes two types of constructed wetland cells, where the waste is broken down by microorganisms and absorbed by plants as nutrients. The steps in this wastewater treatment process are: 1) Solid Settlement Tank, 2) Cell #1: Horizontal Flow Wetland Cell, 3) Cell #2: Vertical Flow Wetland Cell, 4) Cell #3: Horizontal Flow Wetland Cell, 5) Polishing Pond.[11] Pumps are used to transfer the water between the cells, while a windmill is used for the aeration of the water in the finishing pond. The terms "horizontal flow" and "vertical flow" refer to the direction the affluent is pumped, flowing across the cell in the first, and flowing downwards in the latter.[12]

Due to the cold climate of Ontario, the system is designed to ensure that it functions properly throughout the year, even during the winter. This is achieved by installing two sets of pipes at different depth levels below the ground. The higher level of pipes are utilized during the summer and placed nearer to the surface. The winter level pipes are buried deeper in the ground, and thus kept warm by the thermal mass of the earth which is at a warmer temperature than the above ground temperature.

This project's proposed Living Machine will utilize this same strategy of installing two level of pipes for the outdoor components of its treatment system.

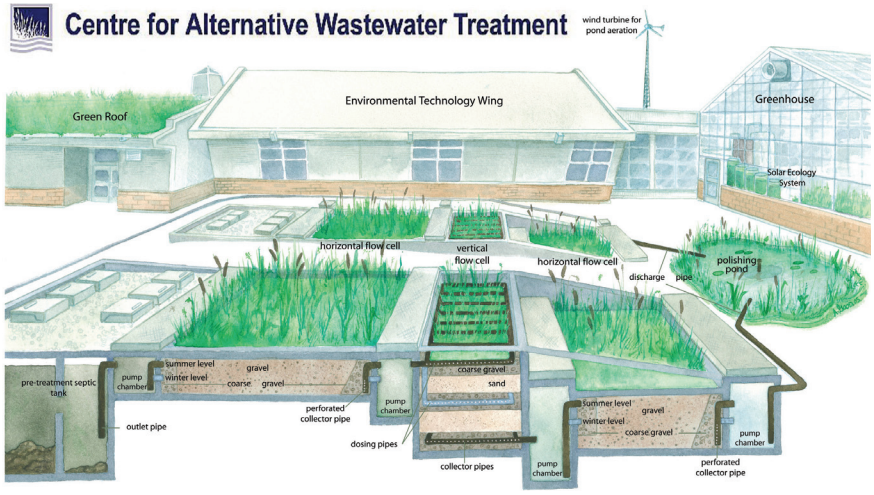


Figure 3.21 - Section through the constructed wetland cells located in the courtyard of the CAWT facility. Image by Centre for Advancement of Water and Wastewater Technologies.

Omega Centre for Sustainable Living

The biological wastewater treatment system at the Omega Centre for Sustainable Living in Rhinebeck, New York, which is referred to as an Eco Machine, serves as the third precedent because it combines both of the strategies of the previous two projects, by placing filtration components in both the inside and outside of the building, in addition to be situated in a cold climate. The Omega Institute utilizes the system to treat wastewater (from toilets, sinks and showers) for the entire campus, so that it is clean enough to be safely discharged back into the environment.[13] The steps in the wastewater treatment process are as follows: "1) Solid Settlement Tanks 2) Equalization Tanks 3) Anoxic Tanks 4) Constructed Wetlands 5) Aerated Lagoons 6) Recirculating Sand Filter, and 7) Dispersal Fields."[14] The two most important stages in this process, where majority of the solid breakdown occurs is the constructed wetlands located outside of the building, and the aerated lagoons which are located in a greenhouse-like environment inside the building.

Constructed Wetland Cells: At the Omega Centre, a series of four wetland cells, each about three feet in depth and filled with wetland vegetation, provide the primary waste treatment. The cells are positioned down the slope of a hill, so that the force of gravity can help move the water through the system. The benefit of placing the first filtration phase outdoors is that it helps manage odours, as by the time the water flows inside it will have been significantly cleaned by that point.[15] The winter climate is addressed in two ways: the plants in the outdoor constructed wetland are prevented from freezing by using native plants such as cattails and bulrush[16], which are hardy enough to withstand the cold winters of upstate New York. The second strategy is the use of a mulch layer at the top of the water which helps insulate the liquid below the surface. Snow that collects around the plants helps to further insulate the water below, and so while the plants lay dormant during the winter, the bacteria on their roots are still able to treat the water.[17]

Aerated Lagoons: From the wetland cells, the wastewater flows indoors to the open aerated cells which consists of four cells that are each ten feet in depth, and serve as host to a variety of tropical plants suspended in the lagoons and beneficial microorganisms growing in the water on their roots. The benefit of having a filtration component on the inside in addition to the outside is that it makes the space more beautiful. People use the space for activities like yoga and art classes. The institute utilizes the system along with its LEED Platinum- certified building "as a teaching tool in its educational program designed around the ecological impact of its campus."[18]



Figure 3.22 - View of the exterior component of the Eco Machine at the Omega Centre, the constructed wetland. Photo by Andy Milford.



Figure 3.23 - View of the interior component of the Eco Machine at the Omega Centre, the aerated lagoons. Photo was taken when the plants were just beginning to get established in their indoor habitat. Photo by Andy Milford.

3.4 - The Classroom Module

Sprout Space Classroom

In this precedent I am exploring what a "green" classroom looks like. The Sprout Space, a 1008 square foot[1] portable classroom designed by Perkins + Will Architects was developed as a more sustainable alternative to the modular classrooms on the market. Designed to enhance student's learning, the three driving concepts of the design are improving the health, sustainability and flexibility of the classroom space. These three concepts are what makes the Sprout Space a 21st century classroom.[2] Using a portable classroom as a precedent is beneficial to the study as it narrows in specifically to the classroom level. The following key design features and concepts were derived from the Sprout Space:



Figure 3.24 - Aerial view of the Sprout Space classroom, installed on the site of the National Building Museum in Washington as part of its 2013 green school design exhibit.

Healthy - One big focus of the design is on improved comfort and wellbeing within the classroom space. In the Sprout Space classroom this was achieved through ample natural daylighting provided through the clerestory windows, natural ventilation, acoustical ceiling panels, and the use of healthy non-toxic and low-emitting materials. Providing a visual and physical connection to the outdoors is also part of this and is achieved through three glazed bi-folding doors that open the classroom up to the outdoor deck.

Sustainable – Integrated systems allow the Sprout Space to function as a net-zero energy building and so that it can be self-sustainable. The classroom produces its own energy through a 4kW rooftop solar panel array, and harvests rainwater through its butterfly roof which it stores in the connected cistern and uses to flush its toilet and water the garden. The systems that make the indoor environment comfortable are energy efficient and include an energy recovery ventilation system and dimming interior LED lights that adjust through sensors to the available daylight levels.

Flexible – The space is designed for flexibility through the floor plan layout which conceives the classroom not as one big space, but as a collection of many smaller zones that are able to accommodate different styles of learning and teaching. The Sprout Space also provides multiples types of outdoor spaces which help make the outdoor environment more accommodating to classroom activities. Provided are a covered vestibule entry, an outdoor classroom with whiteboards on the wrap-around deck, and an allotted space for growing an educational garden. Flexibility is further enhanced through mobile furniture that allows for various classroom arrangements and with the provision of marker boards and cork boards on all four sides of the classroom.

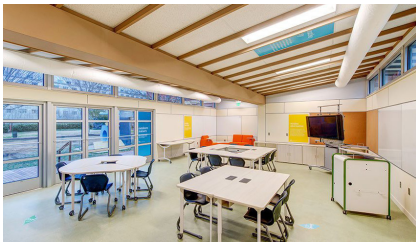


Figure 3.25 - Interior view of the Sprout Space classroom.

The L-Shape Classroom Module

"The classroom is the most visible symbol of an educational philosophy. It is a philosophy that starts with the assumption that a pre-determined number of students will all learn the same thing at the same time from the same person in the same way in the same place for several hours each day."[1]

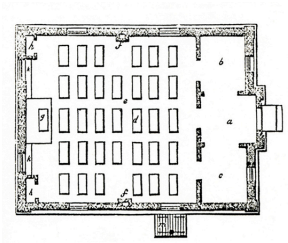


Figure 3.26 - Plan of a one-room school house built in 1872 in Markham, Ontario.

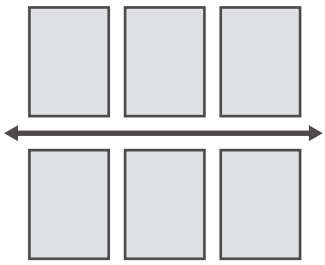


Figure 3.27 - The "factory model" with rows of classrooms arranged linearly on either side of the corridor.

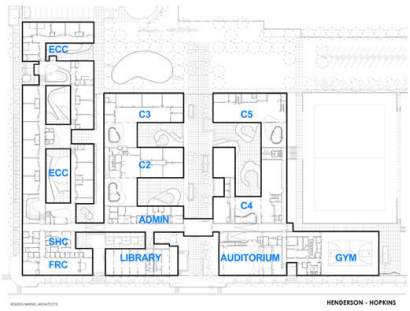


Figure 3.28 - Floor plan of Henderson-Hopkins School, a present-day iteration of the open plan school.

Since the days of the one-room schoolhouse, the classroom has been the basic building unit and main learning space within a school. The design of most schools is based on a typology that emerged during the Industrial Age, known as the "factory model"[2] or "Ford model,"[3] and is the form people are most familiar with. This traditional classroom consists of a rectangular room with rows of desks arranged linearly all facing the blackboard with the teacher positioned at the front of the room. Learning in this space primarily takes place in a lecture style where the teacher shares their knowledge to the class, and the students passively receive it. The classrooms are arranged linearly along both sides of the corridor, and students move along the corridors in a horizontal route from class to class, in a fashion similar to moving along a factory line.[4] The benefits of this traditional model are that it allows for ease of control and supervision, with the classroom being designed as a controlled space that is centered around the teacher. The limitations of the factory model of the classroom is that it lacks the flexibility necessary to allow for the adaptation of a more active curriculum where different modes of learning and teaching styles can occur.[5]

As flexibility has been identified as an important quality to a 21st century classroom, it necessitated the exploration of different ways of introducing it into the space. The open-concept school model is one way which this has been achieved in the past, and is one re-emerging design trend for new schools being built today.[6] There was a period in the 1960's and 1970's where many schools experimented with an open plan school layout that eliminated small individual classrooms and instead organized the school into several large rooms that were used simultaneously by the many classes. Functioning much like open plan offices the open school is meant to encourage a more creative and collaborative learning process where learning is more student-led than teacher-led. However there were issues that arose with this layout related to noise, acoustics and a reduced ability for students to concentrate on their work that led to the schools eventually putting walls back up and reverting to the traditional classroom model. [7] Present-day iterations of the open plan school have had mixed levels of success, with many such as the Henderson-Hopkins school by Rogers Partners in East Baltimore as one example, having encountered similar issues with high noise levels, distracted students and frustrated teachers. For the Henderson-Hopkins school, these issues lead the school to renovate only three years after construction, putting permanent walls up in its open classrooms.[8] Considering the problems this has created in the past with issues related to the wellbeing and comfort aspect of a school, the proposed design decided to maintain the concept of an individual classroom.

Instead, the classroom will be made more flexible through the adaptation of a layout known as the "L-Shaped Classroom. First proposed by James A. Dyck as a design pattern, the term refers to a floor plan where the room "takes on the form of the capital letter 'L', in which both legs are nearly of equal length and depth."[9] The benefit of the floor plan, according to researcher and designer Peter Lippmann, is that its shape allows for the formation of several activity zones within the space while maintaining a degree of separation between them thereby allowing students to work in small groups without distracting each other. The layout offers the teacher the option of reorganizing the classroom furniture so that it can support both "individual, one-to-one, small group, and large group activities."[10] Furthermore, it allows students to work more independently while remaining in the teacher's field of vision who is nearby to help guide the students.[11]

The L-Shape classroom is not a new idea, and has been adapted successfully in many projects around world. The previous precedent – the Sprout Space – utilized a modified version of the L-shape classroom with the breakout space being articulated as a way of introducing flexibility in to the space. Two of the most famous examples of the L-Shape plan are the Crow Island School built in 1940 in Illinois by Perkins + Will Architects and Eero Saarinen, and the Montessori School in Delft designed by Herman Hertzberger in 1960. The following pages will briefly examine those projects as successful iterations of the layout.

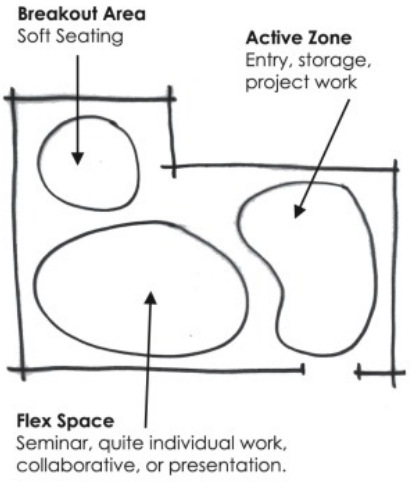


Figure 3.29 - Diagram of the potential zones for which an L-Shaped classroom allow the creation of. (Source: P. Nair and R. Fielding, The Language of School Design)

Crow Island School

This elementary school utilized a modified version of the L-Shape classroom to divide each classroom space into two activity zones: a large central instructional area and a smaller more private project space. Each zone forms one of the legs of the L-shape, though they are not equal in size. The void space between the two legs is designed as a private outdoor classroom, one for each class that is separate from the larger shared outdoor play area. The main classroom space connects to the outdoor courtyard through large exterior glazed walls with window seats under them and a door leading to the patio. The project space/workroom holds a long counter at children's height which overlooks the outdoor courtyard. It also contains a washroom, sink and storage space making the classroom a self-sustainable unit.[12]

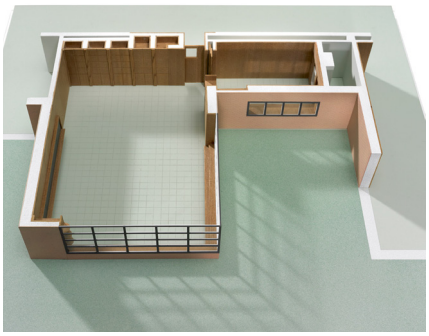


Figure 3.30 - Bird's eye view plan of the classroom unit at Crow Island School.

Montessori School in Delft

Herman Hertzberger designed the classroom as an L-shaped unit, whose configuration allows for flexibility, that is a wider range of learning scenarios to take place than is possible in a rectangular classroom. To have a variety of spaces for students to learn in is important in Montessori education. This is an example of architecture being shaped by the curriculum. Montessori education is child-centered and so correspondingly the classroom should not be centered on the teacher. The education adapts to a child's individual needs, and so in a typical Montessori classroom many activities are taking place at the same time. The L-shape allows for different zones to be designated to which a different activity is attached. In order to help minimize the opportunities for distraction, Hertzberger used the L-shape and sunk one area of the classroom in order to reduce children's visibility of each other.[13] The narrower leg of the L is oriented towards the corridor and the void forms a pocket of space that allows the corridors to be used as more than just a space for circulation, but as a common area by the school. Referred to as the "learning street"[14] a variety of activities take place in the hallway: there is a library, sitting area, stage and spaces to work. By staggering each classroom, Hertzberger created a transition space between the corridor and classroom where students can hang about between classes and store their coats.

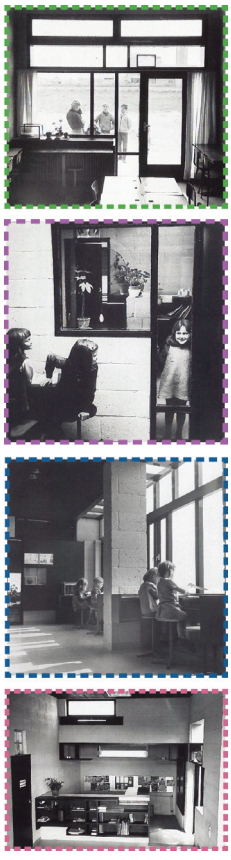


Figure 3.31 - Photos of the various work zones in the classroom unit. The coloured border correlates to the area of the classroom floor plan that it is located on.

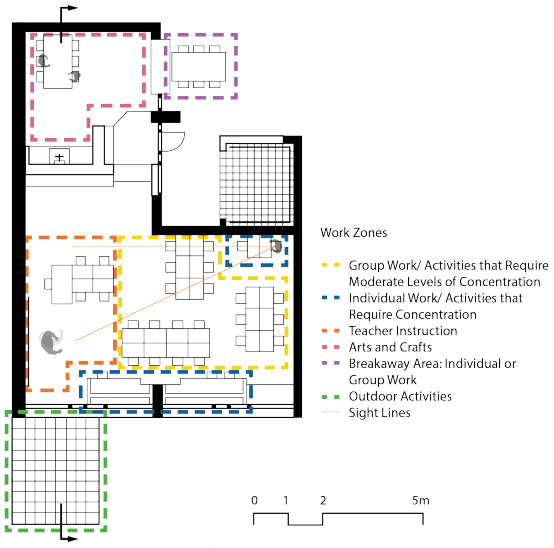


Figure 3.32 - Classroom floor plan of Montessori School in Delft, highlighting the various work zone areas within the plan.

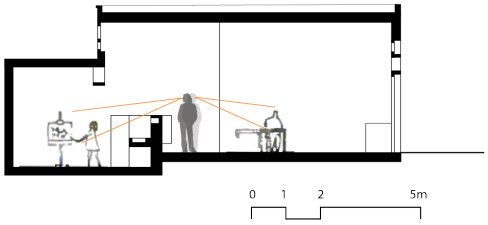


Figure 3.33 - Cross-section through typical classroom at the Montessori School in Delft. Section illustrates the teacher's open field of vision.

We're gonna do a little test. Alright!



OLIVER: Who knows what this is?





Potato. So, you think these are potatoes? Not potatoes, though.





Do you know what this is? No?

Who knows what tomato ketchup is? Yeah. That's what it's made out of.







"Immediately you get a really clear sense of *"Do the kids know anything about where food comes from?"*

And if the kids don't know what stuff is, then they will never eat it."

3.5 - Food Education

Jamie Oliver's Food Revolution – "Teach every child about food"

As a result of the disconnect from nature in modern-day life, the basic natural processes that support life have become an abstraction for many people. One area where this disconnection is quite noticeable is in our relationship with the food we eat. At a time when the distance between where we live and where our food comes from is greater than ever before, many people have lost basic knowledge about food and its source.[1] For the children who have only participated in the food system as consumers – this can mean that they grow up knowing very little about what they eat.

There is a well-known scene in one of the first episodes of British chef Jaime Oliver's 2010 show *Jamie Oliver's Food Revolution* that illustrates the lack of basic knowledge that many children have about food. In the scene, Oliver visits a first grade classroom at an elementary school in America to test them on their familiarity with common fruits and vegetables. He proceeds to hold up a vegetable – tomatoes, a cauliflower head, an eggplant, beets – and asks the class to identify it. The children are unable to, and genuinely do not recognize the vegetables in their raw form. Oliver has had similar experience in classrooms all across America and Britain. He believes that this is a result of how little we teach children about food.[2]

"My only wish is for every child to be taught about food – where it comes from, how it affects their body, and how to cook it."[3]

To make "food education a priority in education"[4] is part of the *Jamie Oliver Food Foundation's* mission to improve the health of children everywhere in the fight against the growing obesity epidemic.[5] As the current North American "landscape of food" that children grow up in does little to support their healthy eating habits, he regards schools to be in the position to help fix these issues by starting a "food revolution."[6] Oliver's foundation has started campaigns that aim to help schools do just this by: 1) Improving the quality of school lunches so that instead of serving processed and fast foods, lunches are cooked out of fresh food , ideally from a local food source.[7] 2) Integrating food education into the curriculum so that children leave school having learned firsthand how to cook.[8]

Instructing kids in how to cook teaches them important life skills that they will carry with them for the rest of their lives. Historically many educators have shared that same position on teaching children life skills such as cooking from an early age. Friedrich Froebel, considered the founder of kindergartens, believed that children should be encouraged to take risks and be given responsibilities. He taught a curriculum where they actively learned through play with activities such as gardening, cooking and taking care of animals.[9] Montessori education similarly incorporates the development of practical life skills such as preparing food into the curriculum as way of allowing children to participate in daily life alongside adults.[10]

Figure 3.34 - (opposite page) Scene from the 2010 show where Oliver visits a first grade classroom and quizzes students.

Endnotes for Chapter 3

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Urban Ecology Center in Riverside Park

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CHAPTER 4:

SITE & CLIMATE

4.1 - Site Context

The Town of Milton

The site of the proposed project is located in Milton, Ontario, a town located in a region that is experiencing rapid population growth, that is very quickly transforming from an area that was for a long time predominantly rural (since the town's inception as a farming community in 1800's) into a suburban residential community. This places the project within a background context consisting of a set of diverse conditions.

The Town of Milton has emerged as one of the fastest growing municipalities in Canada. Since 2001, the town's population has more than doubled going from 31,471 residents in 2001[1] to a population of 101,715 in 2016,[2] and it is expected to only continue increasing, with a projected population growth of 230,000 within the next 15 years.[3] The town's proximity to the city of Toronto has been a large factor in driving this rapid population growth. The unaffordability of living in Toronto, combined with a lack of space in the city and the relative ease with which people can commute from the suburbs to the city (which is due to the existing transportation infrastructure such as the Go Transit system and provincial highways), is attracting people to move to Milton. Young families in particular make up a major demographic group[4], attracted to the town due to the family-friendly lifestyle that is more possible in Milton than in a large city such as Toronto. But being the fastest growing community in Canada comes with its problems. These challenges are related to providing the necessary housing, services and infrastructure to support an ever-increasing population. One such challenge is the need for new schools to be constructed to accommodate the town's large population of young children, as the existing schools are at an overcapacity and struggle to accommodate high enrollment number.[5]

However, Milton isn't only known for its rapid growth. It has strong ties to nature being the home of significant natural features, and has long held an identity shaped by its natural heritage. Overlooking the town are the cliffs of the Niagara Escarpment, a unique geological feature that dominates the skyline of the town. Within the escarpment are several large conservation areas that "are an oasis of unspoiled wilderness and open green space."[6] While the conservation areas are at some distance from the developed urban areas, associated with these lands is a green network of forests, wetlands, rivers and valleys that support a diverse range of plants and animals extending into the urban areas of the town. One of these fragments of urban wilderness is the Sixteen Mile Creek which runs through the town accompanied by pockets of woodland areas, making up one of the Halton region's many Natural Heritage Systems. The large amount of close by natural areas are one of the factors that makes Milton an appealing town to live in as these natural areas provide many recreational opportunities for its residents and as well as those of nearby cities. The abundance of green space creates the perception that the town is a healthy place to live and raise a family.

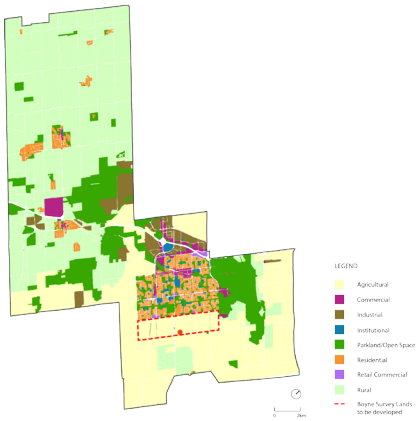


Figure 4.1 - Current land use pattern of Milton. Most of the residential areas (orange) are part of the large cluster near the downtown area. The lands that are going to be developed next will be the current agricultural lands (yellow) in the south-east part of Milton where the project site is located. The north-west half of Milton is still relatively rural, likely due to the barrier of the Niagara Escarpment which makes construction more difficult.

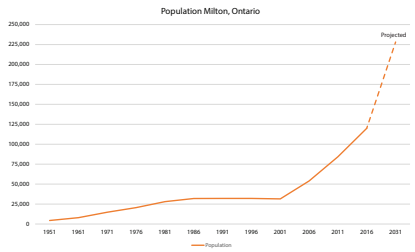


Figure 4.2 - Graph of the expected population growth that is predicted to take place in Milton by 2031, based on the current population growth trends.



Figure 4.3 - Aerial images of site showing the extent of urban growth that the town has undergone in the last 15 years. Image Source: Google Earth.

Local Nature as a Special Theme

It is the dichotomy between these two conditions – the rapidly growing suburban areas and the significant natural features that positions the Town of Milton as an ideal site for a school whose mission is to develop environmental stewardship and ecological literacy.

While pristine sites of wilderness are often where environmental education centres are constructed, as was demonstrated by the precedent the 'Urban Ecology Centre" in Milwaukee, environmental education can also take place effectively in urban environments that have access to semi-wild natural features, such as parks, forests, greenways, urban creeks and rivers. Existing research on effective approaches to environmental education continuously concludes that ecological stewardship behaviour is formed through repeated and frequent contact with nature during childhood.[7, 8, 9] Having this contact with nature occur on a piece of land that is locally-based and near home has been found to be more effective as not only are experiences in nature made more accessible, thereby increasing their frequency of occurrence, but experiences with local nature helps students relate what they are learning to their everyday lives.[10] Furthermore an environmental education approach that focuses on local nature helps students develop a connection to and knowledge of the unique characteristics of their local neighbourhood, which helps them develop a "sense of place," that leads to caring about the place they live, and makes them more likely to want to protect it.[11]

It is these conditions of the site that form a special theme for the school. The proposed school will offer an environmental education curriculum that focuses on local nature in the town as a way of reinforcing to students the idea that cities and ecology are not separate from each other but that everything is interconnected, and that rich ecosystems are found within their own backyard. Students learn about the development taking place in relation to its impact on the natural ecosystem, focusing on the interactions between the human and natural community. This theme is especially appropriate as a reminder to the growing city that sustainable development is important in order to minimize the negative effects of urbanization on natural ecosystems. The school can play a role in educating the whole community on being environmentally aware and responsible citizens, thereby contributing to helping the community maintain the health of its rich natural systems.

A more detailed site analysis report titled "Town of Milton Ecosystem Report" was completed and included in ***Appendix D*** of this document. The report utilized the "A,B,C,E's" mapping technique which looks at the abiotic, biotic, and cultural factors as well as the flows of energy within the ecosystem found on the proposed site. This was a useful tool in helping me gain a better understanding of the site in terms of both the natural and human communities that the project will be serving and occupying the same site with. This also helped in developing an understanding of the special qualities of the site, which allowed for the design project to be able to communicate a sense of place more effectively.



Figure 4.4 - Aerial view of the project site (approximate boundary is outlined). Image Source: Google Earth.

The Project Site

The proposed project is situated in the south-east part Milton, Ontario, on a plot of presently undeveloped land, approximately 100 acres in size that is positioned at the intersection of Britannia Road and Regional Road 25. It is located at the edge of the Sixteen Mile Creek valley, a Natural Heritage System that cuts across the centre of the Halton region from its source up in the Niagara Escarpment to where it joins Lake Ontario at its mouth. The specific lot of land that serves as the site of the proposed project is positioned at the crossroad between the town's suburban and rural communities. On the south-west edge of the site is a large residential neighbourhood consisting of recently constructed townhouses and

single-family homes. Britannia Road which defines the south-east border of the site marks the beginning of the south rural part of the town. The site's immediate neighbour on the other side of that road is a vast open crop field and a small farm consisting of several agricultural buildings and a single-family home.

The site was selected based on it meeting the following criteria:

1) The first step was identifying the areas of the town that are in the process of being developed and/or where new residential development has been proposed, as this is where new schools would be most needed as infrastructure to support the growth. Locating schools close to and within the neighbourhood where students live allows them to practice sustainable behaviour by walking or biking to school, decreasing their dependence on having to be driven to school by parents.[12] It also allows the school to connect more easily to its community by creating the opportunity for it to share its facilities afterhours with the community.

2) The second very important criteria for the project site was that it be situated in close proximity to or have a connection to significant natural features. This would allow for the proposed school to utilize the natural areas as an educational resource, supporting what is learned in the classroom with hands-on experience in nature. Ideally the nature would be within walking distance, making it more accessible from the school and thereby increasing the frequency of experiences in nature.

3) The third criteria was that the selected site complied with the LEED site development credit "Sensitive Land Protection," that seeks to minimize "the development of environmentally sensitive lands," by constructing new buildings on previously developed land,[13] thereby protecting ecologically-rich and sensitive areas from damage. "Environmental Site Assessment" is another LEED category that is a prerequisite for the construction of new schools, is that sites that contain environmental contamination are avoided or remediated.[14]

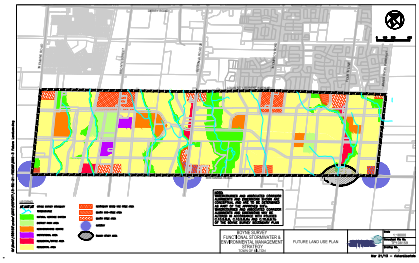


Figure 4.5 - Proposed land use plan for the lands within the Boyne Survey. A larger version of this plan is available in ***Appendix D***. (Source: Town of Milton)

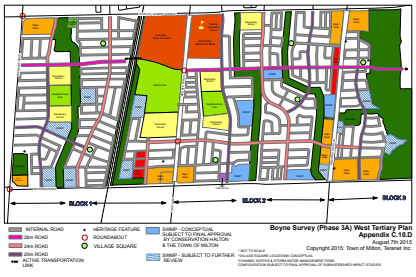


Figure 4.6 - Proposed plan of Boyne Survey Phase 3A, showing a higher level of detail such as proposed roads, community nodes and parks. A larger version of this plan is available in ***Appendix D***. (Source: Town of Milton)

The chosen project site is currently an agricultural field, but it is next in-line to be developed as a residential neighbourhood, as it is situated within the Boyne Survey Secondary Plan. The Boyne Survey defines the areas that makes up the third phase of residential development as part of the Town of Milton Urban Expansion plan. Phase 3A consists of three blocks, the second of which is nearly completed, with construction soon to begin on the final phase and planned to be completed by 2021.[15] This site which is located within the third block, was selected as it is representative of the changes that the town of Milton is undergoing, and on a larger scale the whole region of the Greater Golden Horseshoe, as formerly rural areas are embracing growth and development.

Within the areas where new development was proposed, several small fragmented greenways run across diagonally in the south-east to north-west direction, but only one stood out as significantly larger and more in-tact than the rest; that is the Sixteen Mile Creek and its associated riparian and upland valley corridor. Thus, the area of the Boyne Survey through which the creek cuts across was chosen

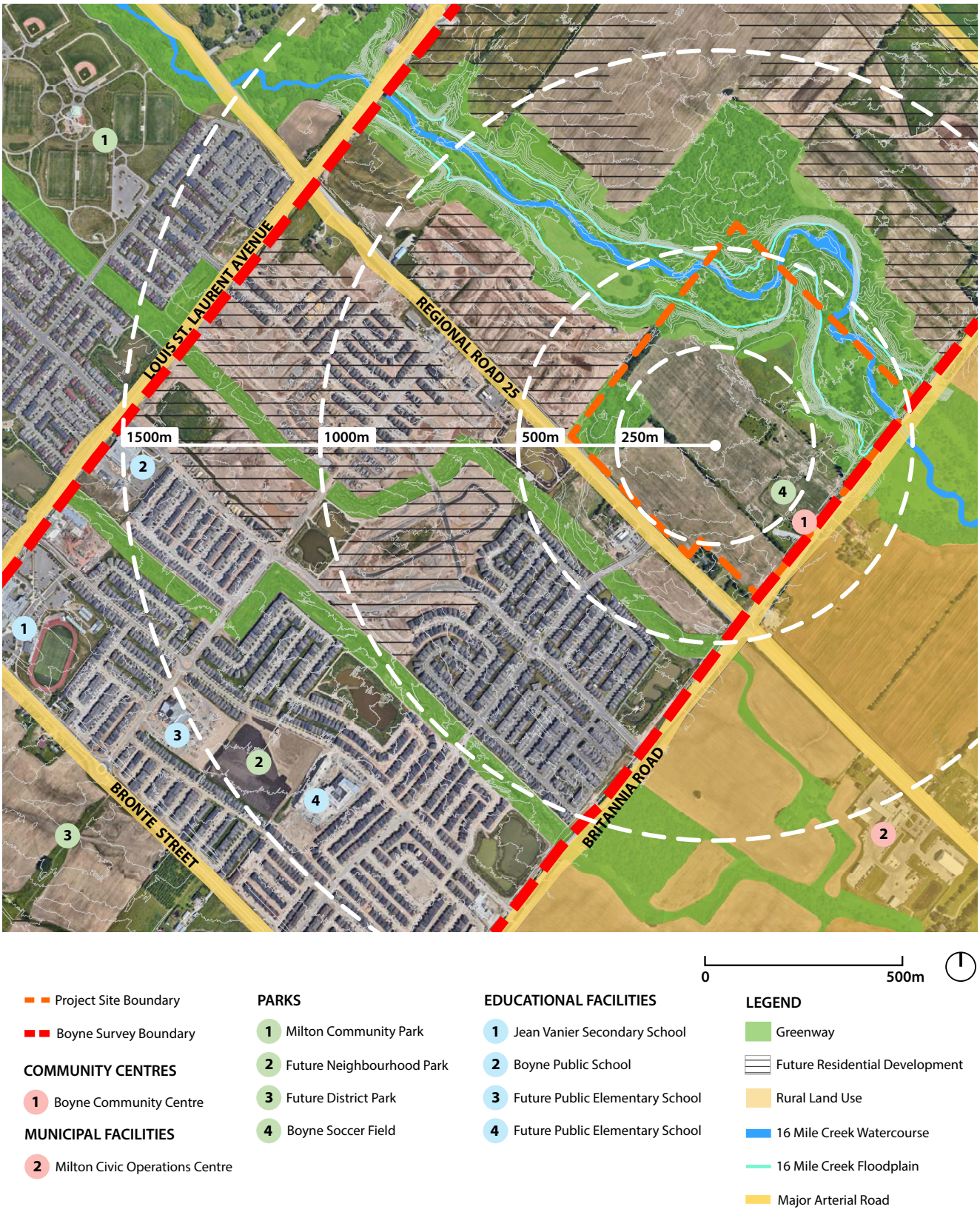


Figure 4.7 - Site plan of existing conditions of proposed site.

as the project site, as it allows for the proposed school to be ideally situated to significant natural features. The site encompasses a collection of distinct natural ecosystem: a deciduous forest, pockets of deciduous thickets, cultural meadows, small wetland areas such as a deciduous swamp, and the aquatic ecosystem of the creek.[16] The woodland ecosystem marks the border of the Natural Heritage System surrounding the Sixteen Mile Creek as well as coinciding with the floodplain boundary. The woodlands, which consist primarily of deciduous species such as "bur oak, shagbark hickory, (and) sugar maple,"[17] cover the surface of a steep ravine that forms the valley and separates the upper meadow from the riparian zone surrounding the corridor. The ecosystems immediately surrounding the corridor consists of an open meadow, pockets of swamp thickets, and forest cover, alternating depending on the portion of the creek. These patches of woodland define the north and north-west boundary of the site. The upper part of the site which comprises approximately two third of the site consists of an expansive meadow and agricultural fields, that gradually slope towards the woodland. The meadow consists of a variety of indigenous prairie grasses and wildflowers such as Canada Golden Rod, New England Aster and Field Thistle. The meadow is quite open with little shade save for that provided by a few hedgerows, single trees and shrubs scattered across this area.

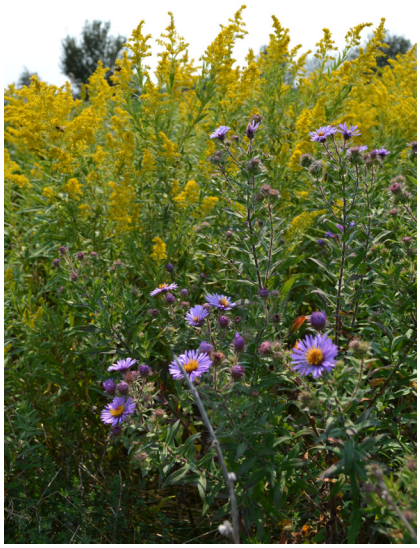


Figure 4.8 - Native species of wildflowers and grasses dominate the cultural meadow area of the site.

The proposed school is situated on the upper field/meadow part of the site, avoiding development in the flood-plain zone by not building past it. Rather the thesis proposes that a network of trails and a small pavilion near the creek would be constructed to accompany the proposed school facility and help make the site more accessible, but nothing beyond that so as to preserve the site. The edge of the greenlands that are part of the Sixteen Mile Creek Natural Heritage system would not be under pressure from the proposed design, helping protect the ecologically sensitive parts of the site. The proposed school would however still be able to be built in close enough proximity to the creek and surrounding ecosystems, to allow for the school's students to engage with this fragment of urban wilderness on a daily basis, thereby utilizing it as a hands-on resource to support the environmental education curriculum. The school would thus be located both "close to home and close to nature,"[18] teaching students that nature in one's own backyard is just as much a complex ecosystem.

The site complies with the LEED site development credit as the upper meadow part of the site had been previously developed/disturbed. The site used to be the location of a horse stable (boarding/riding) that operated until sometime in 2014, and consisted of several smaller agricultural structures, a single-family home, and paddocks. The structures were demolished sometime in 2015 or 2016 judging by Google Street View. (Refer to **Figure 4.9** for view) Since the structures have been demolished the majority of the site is used as a crop field, filled with a leafy green crop during the summer, which is mowed down in autumn. The site also used to serve as a small community centre and public soccer field. The soccer field is no longer in use, the nets have been take down, and it has been allowed to be overgrown by meadow grasses. The lot still holds the related amenity spaces - a change room and small paved parking surface. As the site had only been used for agricultural and recreational land uses, it is not environmentally contaminated.



Figure 4.9 - Google streetview image from July 2009 of the previous building development on the site consisting of a collection of barns, a single-family home, and paddocks.



Figure 4.10 - At the present the existing human development on the site is limited to a small community centre, and parking lot off of Britannia Road. Image of site was taken in the winter of 2017.



Figure 4.11 - Barn located across the street from the site; an example of the vernacular agricultural architecture of the region.



Figure 4.12 - Image of the newly completed residential neighbourhood across the street (Regional Road 25) from the site. The development forms Block 2 of Phase 3A.

Though the city has a proposed plan in place for the site, as the site is not currently developed and will not be until 2021, this project utilizes it as a case study site, imagining what this site could be as an alternative to the town's proposed plans. The official plan drawings show that the town of Milton has proposed that the southern-most portion of the lot be utilized as a "major node area" and that the upper half of the lot be an extension of the residential neighbourhood further north-east of it.[19] This thesis takes the position that this pocket of land has value to the community due to its natural features, and can be better utilized as a resource for the community when occupied by a school. The proposed school design will not cover the whole site, leaving open areas of the land to be utilized as a park space by the community. This proposal would be more in line with a previous version of the master plan from June 2010 (refer to **Figure 4.13**) where the town had allocated the lands in block 3 to be retained as a "community park area," before that was revised in the current master plan.[20] Schools have traditionally occupied a central place within communities, making the proposed school well-suited to function of a community center. The school with its special curriculum could act as an environmental education centre for the community, and take on the role of stewarding this specific piece of land. In this sense the school would become a symbol of sustainable urban development; an opportune role when located in one of the country's fastest growing cities.

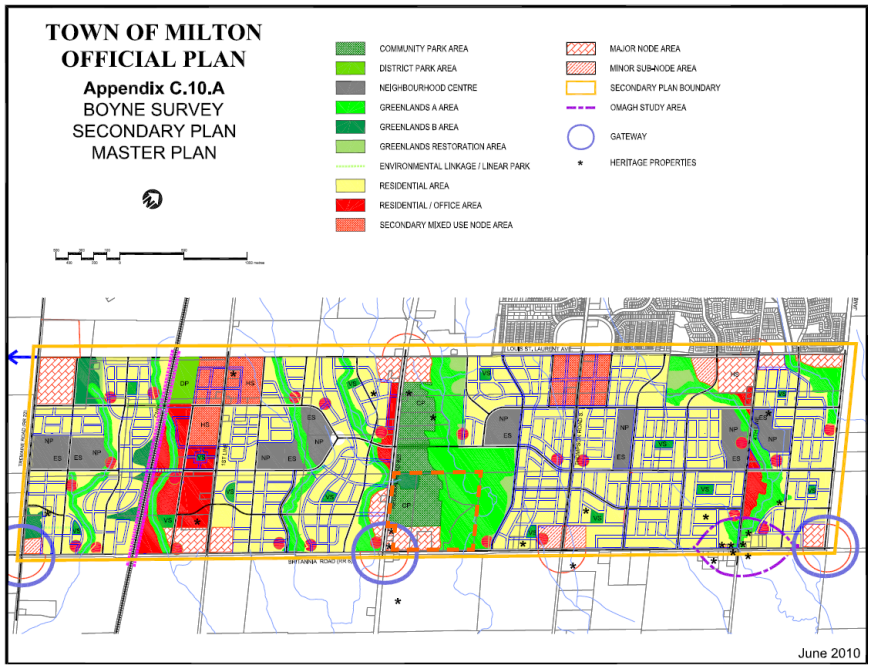


Figure 4.13 - Previous version of the master plan for the Boyne Survey, dated June 2010. (Source: Town of Milton)

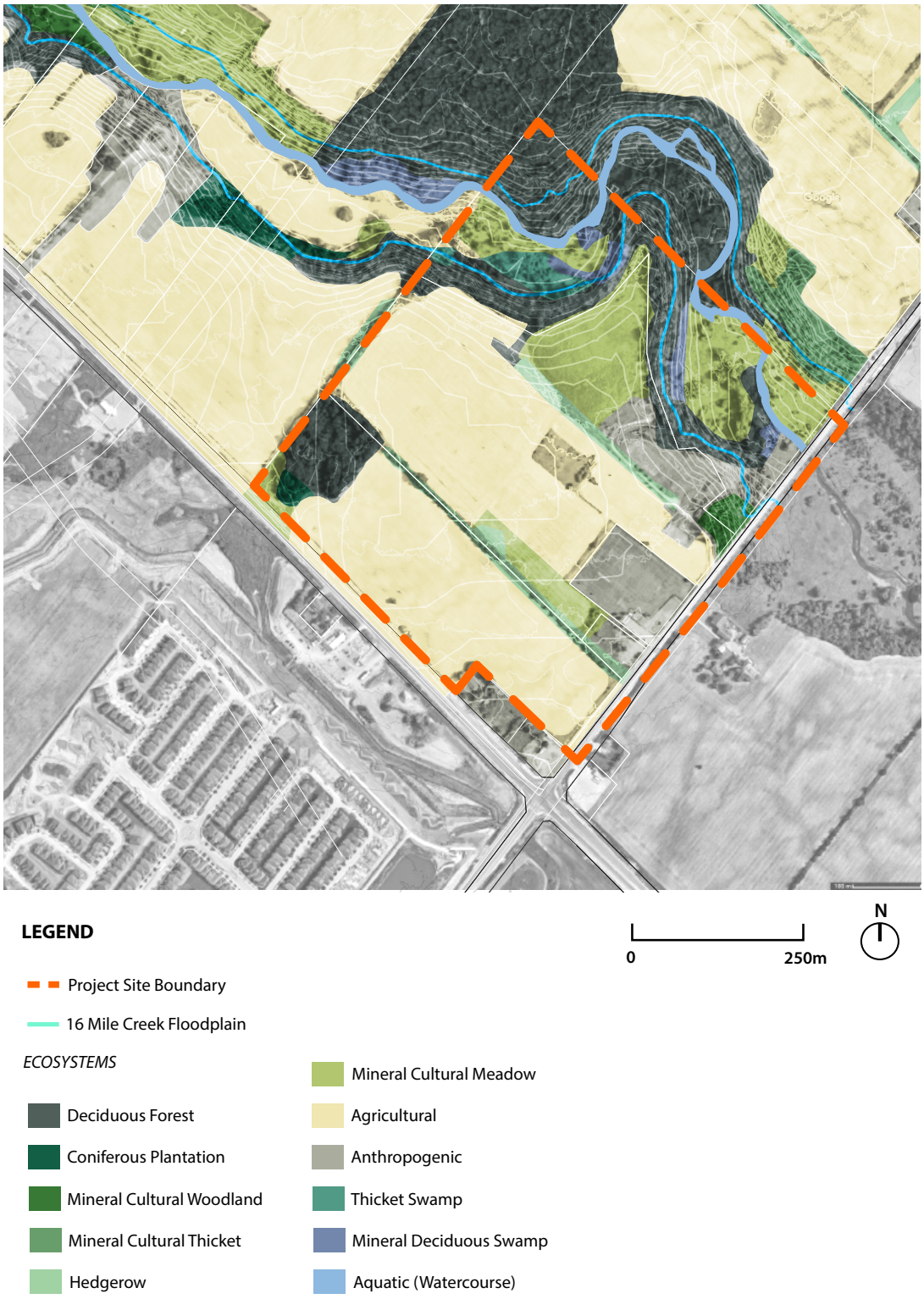
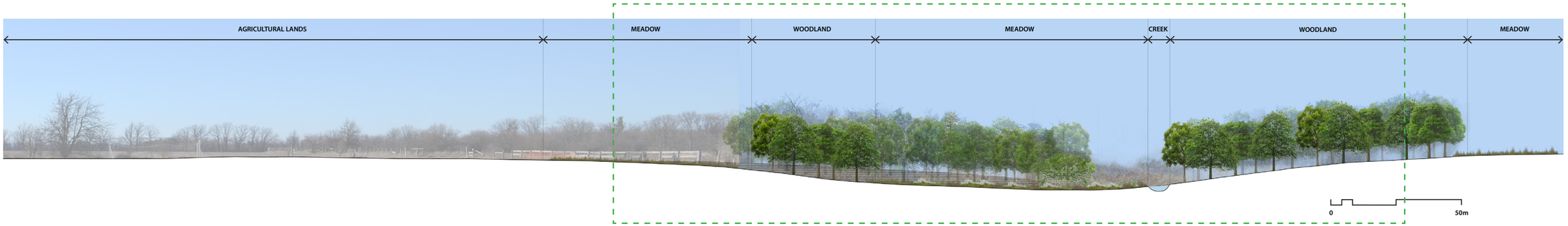


Figure 4.14 - Diagram of ecological communities found on the proposed site.







KEY PLAN

Figure 4.15 - Longitudinal cross section through site. Bottom drawing is a zoomed in portion of the section at the top.

SITE WALKTHROUGH

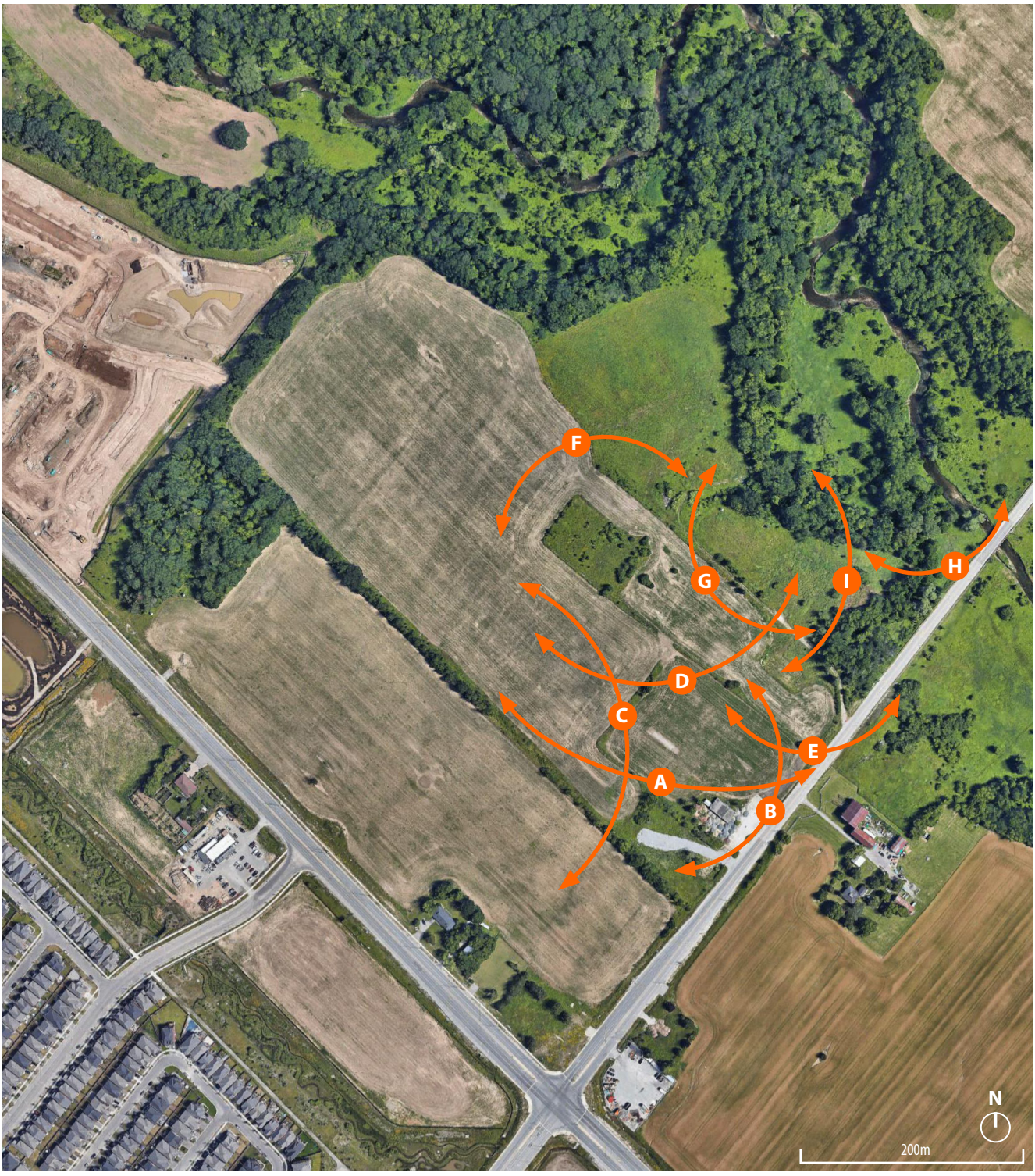


Figure 4.16 - Aerial photograph of site marking out the locations of the panoramas on the next page.



Figure 4.17 - Photograph of the open field part of the site where the proposed school will be primarily situated. View looks from the former soccer field towards the woodland surrounding the creek and defining the boundary of the site.



Figure 4.18 - View standing from the edge of the site (along Britannia Road) and looking towards the part of the site that was previously utilized as a soccer field. The change rooms of the community centre are visible to the left.



Figure 4.19 - View looking from the open field part of the site to the newly constructed residential neighborhood across from Regional Road 25.



Figure 4.20 - View of the agricultural field part of the site during the summer.



Figure 4.21 - View across the agricultural field towards the woodland part of the site. View taken from the edge of the site, next to Britannia Road. This is the area of the site which was previously developed (buildings which have since been demolished).



Figure 4.22 - View towards the agricultural field area of the site from the far north-west corner of the site. Crops have been mowed down in the autumn.



Figure 4.23 - View of the cultural meadow which consists of a wide variety of grasses and native wildflowers. This part of the site is very open and unsheltered from the elements. The structure visible of the site are a two Barn Swallow nesting structures that currently exist on the site.



Figure 4.24 - View taken from the north east edge of the site, looking across the cultural meadow towards the opposite edge.



Figure 4.25 - View of the hillside that connects the upper and lower meadow, and is currently the most accessible route to the creek.

SITE FEATURES



Figure 4.26 - Aerial photograph of site marking out the locations of the photographs on the opposite page.

A - Cultural Meadow Ecosystem on Upper Part of SIte



Figure 4.27a - Existing meadow at the top of the ravine; in winter.



Figure 4.27b - Existing meadow at the top of the ravine; in summer.



Figure 4.27c - Existing meadow at the top of the ravine; in fall.

B - Trail Running between Cultural Meadow and Agricultural Field



Figure 4.28a - Existing trail adjacent to the creek valley; in winter.



Figure 4.28b - Existing trail adjacent to the creek valley; in summer.



Figure 4.28c - Existing trail adjacent to the creek valley; in fall.

C - Hillside that Connects the Upper and Lower Meadows



Figure 4.29a - Existing meadow directly adjacent to the creek; in winter.



Figure 4.29b - Existing meadow directly adjacent to the creek; in summer.



Figure 4.29c - Existing meadow directly adjacent to the creek; in fall.

D - The 16 Mile Creek Watercourse



Figure 4.30a - The 16 Mile Creek, portion next to Britannia Road; in winter.



Figure 4.30b - The 16 Mile Creek, portion next to Britannia Road; in summer.



Figure 4.30c - The 16 Mile Creek, portion next to Britannia Road; in fall.

E - Meadow at the Bottom of the Valley and Adjacent to Creek



Figure 4.31a - Existing meadow at the bottom of the ravine; in winter.



Figure 4.31b - Existing meadow at the bottom of the ravine; in summer.



Figure 4.31c - Existing meadow at the bottom of the ravine; in fall.

F - Deciduous Forest Cover and Steep Slope of the Valley



Figure 4.32a - Existing deciduous forest; in winter.



Figure 4.32b - Existing deciduous forest; in summer.



Figure 4.32c - Existing deciduous forest; in fall.

4.2 - Climate Analysis

TEMPERATURE

The town of Milton is located in the Great Lakes region of Southern Ontario. The site of the proposed school is situated near the south-eastern border of Milton at latitude 43˚29' N and longitude 79˚50' W, and at an elevation of 187m above sea level.[1] The region of Southern Ontario has a cool but humid climate. It is located in category *Dfb* according to the Koppen-Geiger climate classification system[2], or in zone 5A according to ASHRAE International Climate Zones[3].

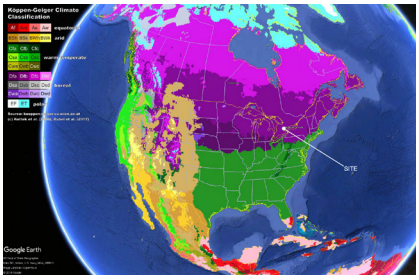


Figure 4.33 - Koppen-Geiger climate zone classification map. Site is marked on the map. Image retrieved from Google Earth data file.

Southern Ontario experiences four distinct seasons. The mean annual temperature is 7.1˚C.

Winters are cold, though milder than in Central and Northern Ontario. Winter usually lasts from December to late March, some years up to mid-April. The average seasonal temperature is -3.8˚C, with temperatures generally ranging between 0˚C and -10˚C. Most winters there is a period or two of severe cold that lasts for a few days up to a week as result of an arctic air system that enters the region, and a record extreme temperature of -33˚C[4] has been recorded in the Halton region.

Spring is often a short season, its length dependant on the time it takes to transition from winter to summer. Spring in Southern Ontario begins in late-March when temperatures begin to rise above 0˚C. Early spring days are cool, as are nights. The seasonal temperature average is 8.7˚C[5]. By May the days are warmer, but nights continue to be cool. As the earth begins to thaw, vegetation begins to grow again.

Summer starts around mid-June and ends in late September. Summer temperatures are warm with temperatures on average in the low to mid-20 both during the day and at night. There are regularly periods of hot and humid weather, when heat waves hit the region; an extreme temperature of 37˚C[6] was recorded one year in July in the Halton region. Though it is generally a warm month, by September the temperature begins to slightly cool down with a greater difference between daytime and nighttime temperature.

Fall, like spring is a shorter season, lasting from late September to the end of November. The daytime temperatures as the season progresses transition from warm to cool, with increasingly cool nights. The average daytime temperature hovers around or under 15˚C, though the seasonal average is calculated at 8.7˚C.[7] The first frost takes place in the fall. There are some years when following the first frost, the region experiences a brief return of warm summer-like temperature.

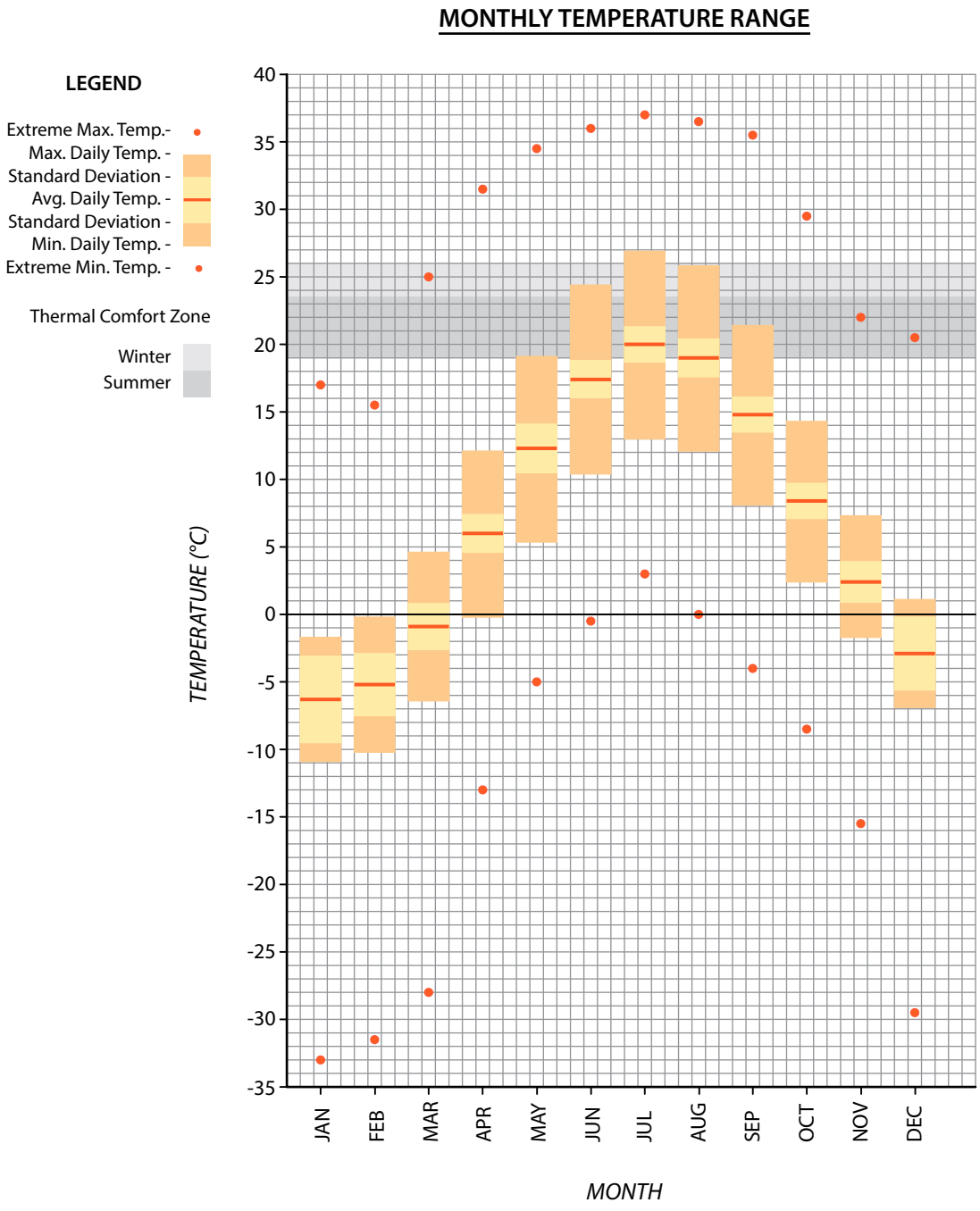


Figure 4.34 - Minimum, Maximum and Average Monthly Temperatures for Milton, ON.

PRECIPITATION

The area annually receives an average precipitation total of 877.4 mm, rainfall accounting for 741.5 mm and snowfall for 135.9 mm of the total.[8] Precipitation is quite evenly distributed between the seasons (there is no period that is considered extremely "wet" or "dry"). During the summer the region usually experiences slightly higher amounts of rainfall than at other times of the year. Most of the annual snowfall occurs from December to March, with smaller amounts snow occasionally falling in late November or early April.

HUMIDITY

The region has a consistently high level of humidity throughout the year. The mean annual relative humidity in the morning is 81.3%, and 61.3% in the afternoon. The relative humidity is at its highest during the summertime and in early fall.

WIND

The earth is divided into 6 zones, three on each hemisphere, based on the global wind pattern which they are influenced by. The zone between latitudes 30°N and 60°N, in which a large portion of Canada lies is under the influence of the wind pattern called the "prevailing westerlies." In this zone air moves predominantly in a direction from east to west. For this reason, the prevailing wind direction in Milton for much of the year is the west. The average wind speed throughout the year is 15 km/h. [9] The winds are strongest in the winter and early spring, and at their lightest during the summer months.

Southern Ontario is affected by several air masses which are responsible for bringing changes to the weather. During the winter the region is predominantly influenced by air masses originating from the Arctic or ones that developed above the Pacific Ocean. The Continental Arctic air mass comes in from the north bringing cold, dry air that causes temperatures to drop and is responsible for the periods of extreme cold in Southern Ontario during wintertime. The air masses that develop over the Pacific and Atlantic Ocean are cool and moist, and often cause clouds and precipitation.[10] Similarly, the periods of tropical weather that occur during the summer are caused by air masses formed over the Caribbean Sea that bring hot and humid weather to Southern Ontario.

However, the region sits along a major storm track through where contrasting pressure systems often collide bringing frequent changes to the weather in this region, so periods of extreme weather rarely last longer than a few days.[11]

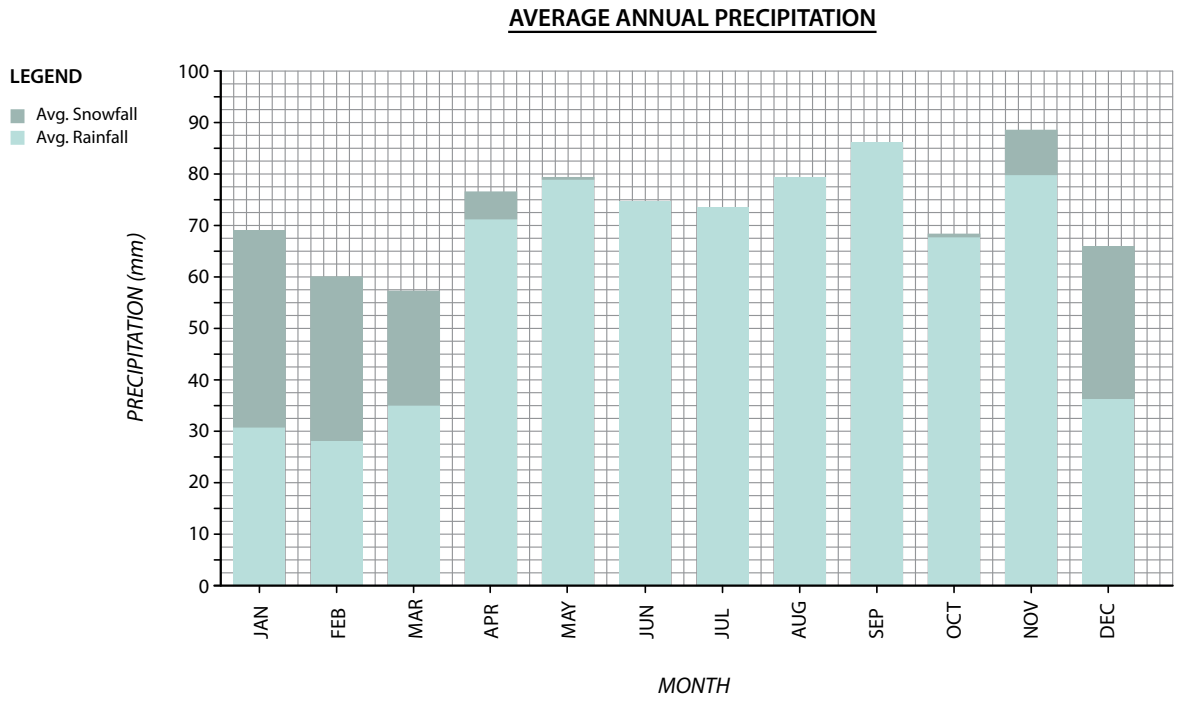


Figure 4.35 - Average Monthly Precipitation for Milton, ON.

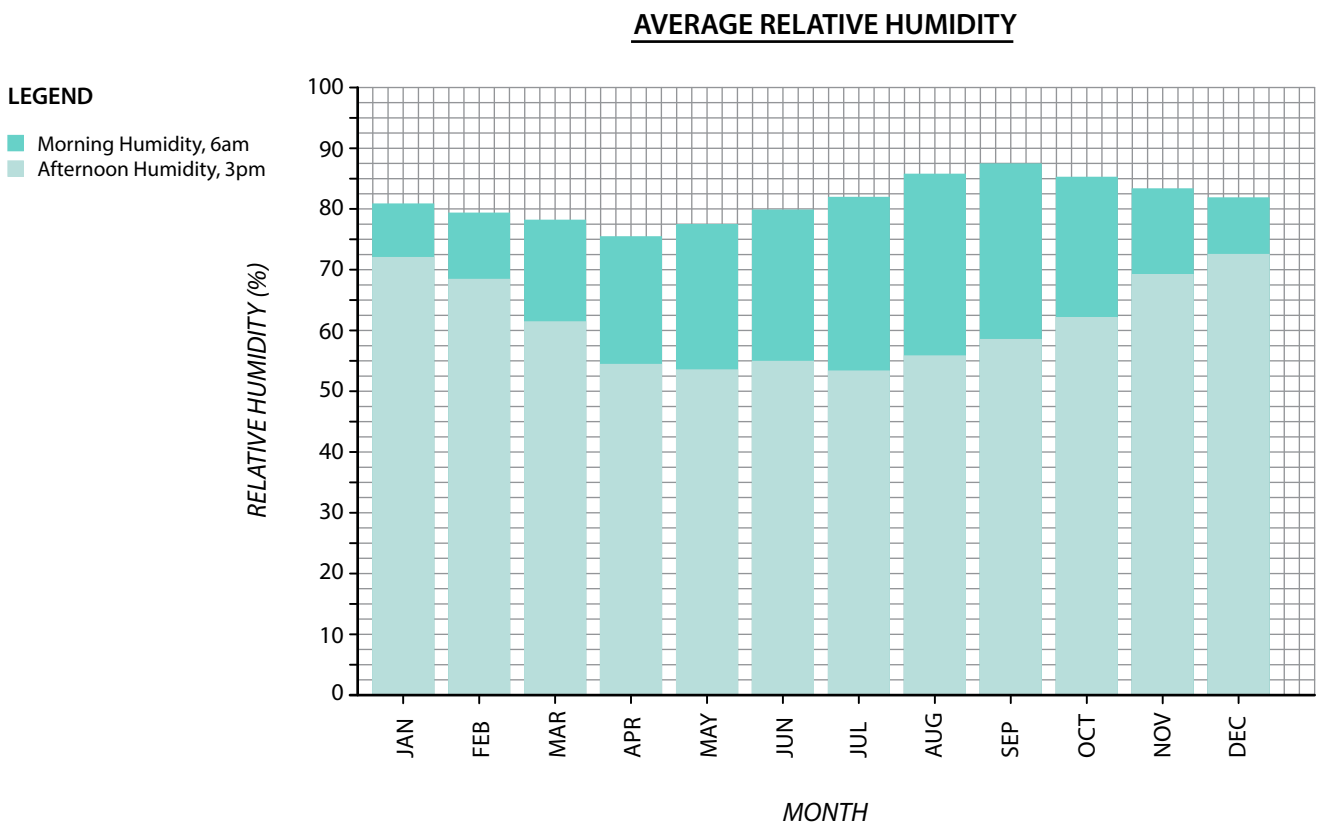


Figure 4.36 - Average Monthly Relative Humidity for Milton, ON.

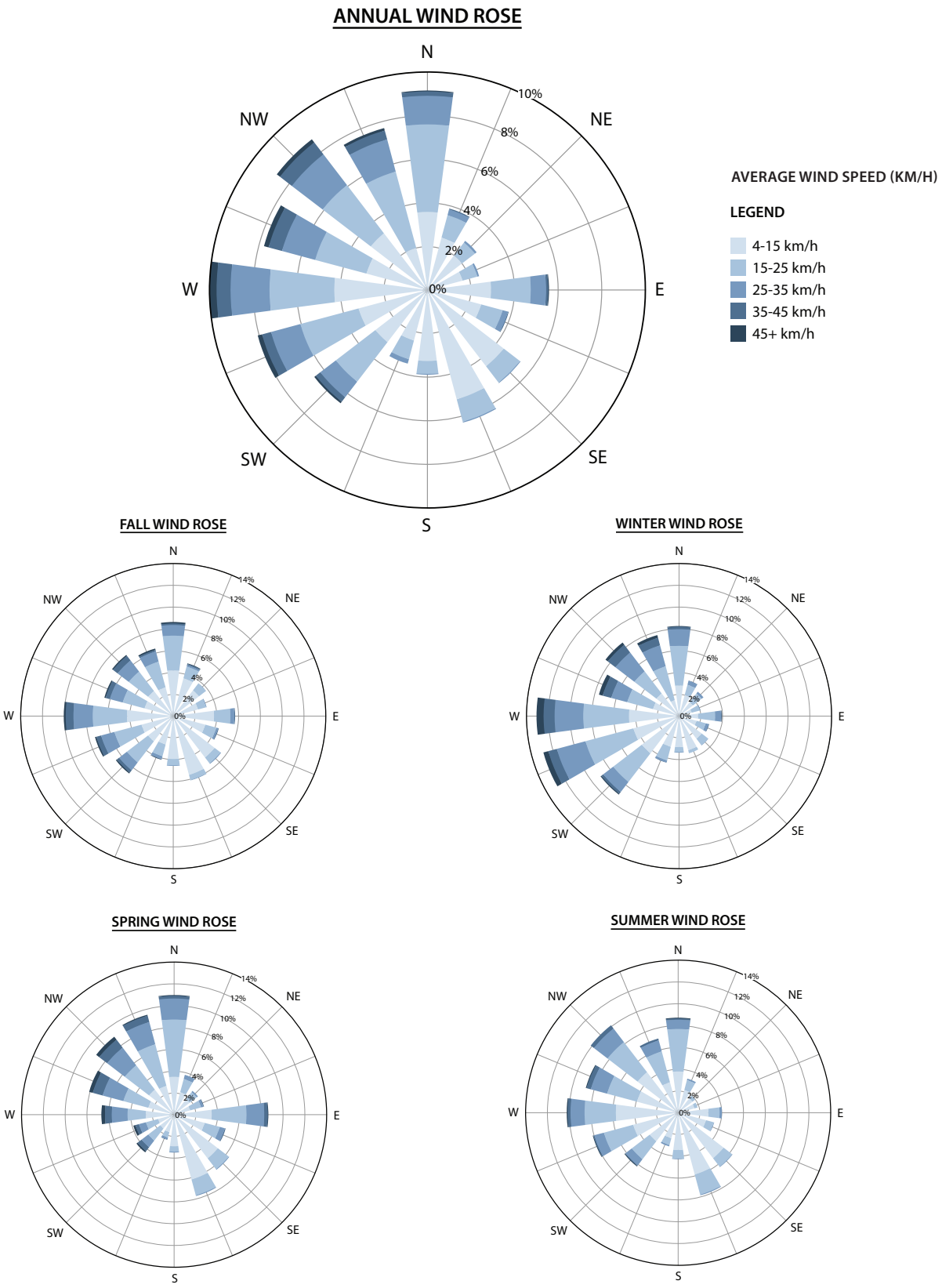


Figure 4.37 - Annual and Seasonal Wind Roses, for Greater Toronto Area.

DAYLIGHTING

The angle at which the sun's rays strike the surface of the Earth varies throughout the year, resulting in different amounts of daylight and solar heating from season to season. This difference, as well as the seasons themselves, occurs due to the 23.5° tilt of the Earth's axis. Canada experiences spring and summer when the face of the Earth on which the Northern Hemisphere lies, is tilted towards the sun. During fall and winter, the Northern Hemisphere is tilted away from the sun.

During the summer the sun is at its highest altitude in the sky and more directly overhead of the land. Sunlight strikes the earth's surface at an angle that is closer to a right angle than in other seasons. Its solar radiation is stronger as the sun ray travels a shorter path through the atmosphere and its illumination is focused on a smaller area (cosine law), warming the earth more effectively.[12] During the summer there are also more daylight hours, as the sun rises earlier and sets later than at other times of the year. The longest day of the year, known as the summer solstice, occurs on June 21st in the Northern Hemisphere. On noon on this day, the sun is at its highest altitude of the year.[13]

The cold temperatures of winter are a result of the sun's low position (altitude) in the sky and the short daylight hours. During the winter the sunlight which the earth receives is weaker due to the low angle at which the rays hit the surface. The land absorbs less solar radiation, because low angled light must travel a longer path through the atmosphere (giving up energy to the atmosphere along the way through absorption and reflection), as well as spreading out its illumination over a larger surface of land.[14] As winter approaches, the days get shorter, as the sun rises later and sets earlier. The shortest day of the year is the winter solstice which occurs on December 21st in the Northern Hemisphere. At noon on this day, the sun is at its lowest altitude of the year.[15]

The fall and spring equinox are two days in the year when day and night are equal in length. In the Northern Hemisphere the spring equinox occurs around March 21st, and the fall equinox occurs around September 21st. On these days the sun rises and sets at exactly 90° east and west of south.[16] The solstice dates illustrate the conditions of the "extremes of the sun's position", while the equinox dates give an idea of the "average sun position."[17]

The sun's position in the sky varies not just by season, but also changes according to the time of the day. The sun is low in the sky as it rises in the morning. The period between 9am and 3pm is called the "solar window" and is when the sun's radiation is the strongest[18]; and happens to correspond with the school hours. Around noon the sun is at its most powerful as it reaches its highest altitude point, shining from the southern direction. In the late afternoon the sun starts to get weaker again, as its position in the sky lowers, before eventually setting at dusk.

Using a vertical sun path diagram, the position and angle of the sun on the site was calculated at different times of the school day.

Seasons	Time of Day									
	8 AM		10 AM		12 PM		1 PM		3 PM	
	Altitude	Azimuth	Altitude	Azimuth	Altitude	Azimuth	Altitude	Azimuth	Altitude	Azimuth
Spring Equinox (March 21)	21°	68° E of S	39°	40° E of S	46°	0°S	44°	21° W of S	31°	56° W of S
Summer Solstice (June 21)	37°	87° E of S	58°	60° E of S	69°	0°S	66°	36° W of S	48°	76° W of S
Fall Equinox (September 21)	21°	68° E of S	39°	40° E of S	46°	0°S	44°	21° W of S	31°	56° W of S
Winter Solstice (December 21)	3°	52° E of S	17°	28° E of S	23°	0°S	21°	15° W of S	11°	41° W of S

Figure 4.38 - Seasonal Solar Angle for Milton, ON.

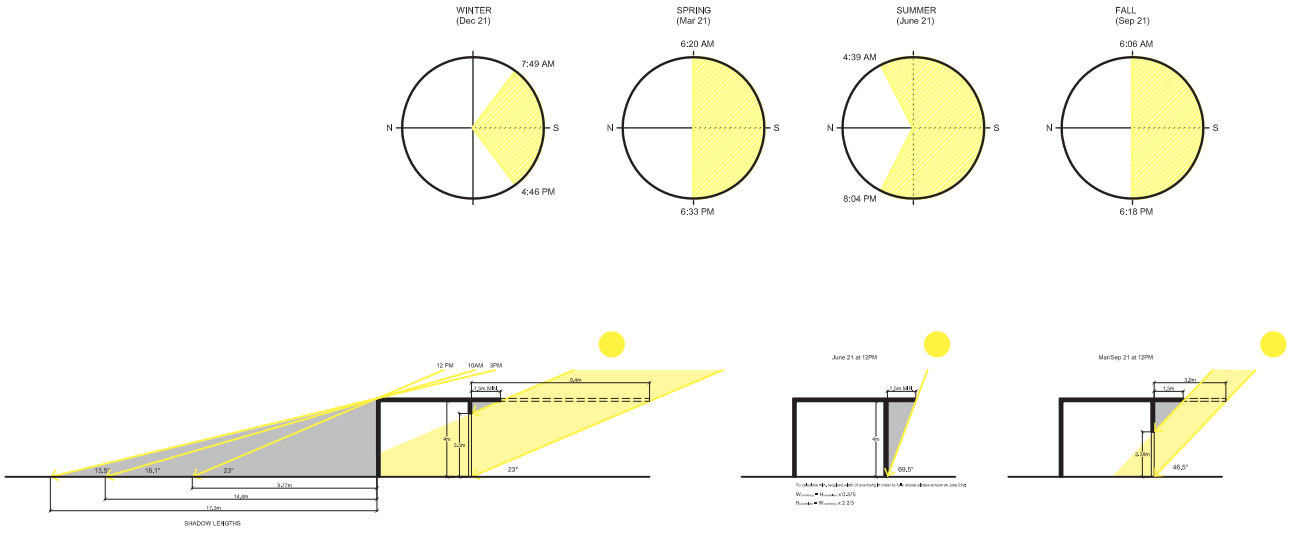


Figure 4.39 - Dayligthing study diagrams for project site. The lower diagram illustrates the length of the shadow the building would cast over the courtyard (assuming a 4m building height), and the required depth of the overhang to fully shade the window during the summer. The top diagram illustrates the direction of solar access according to season.

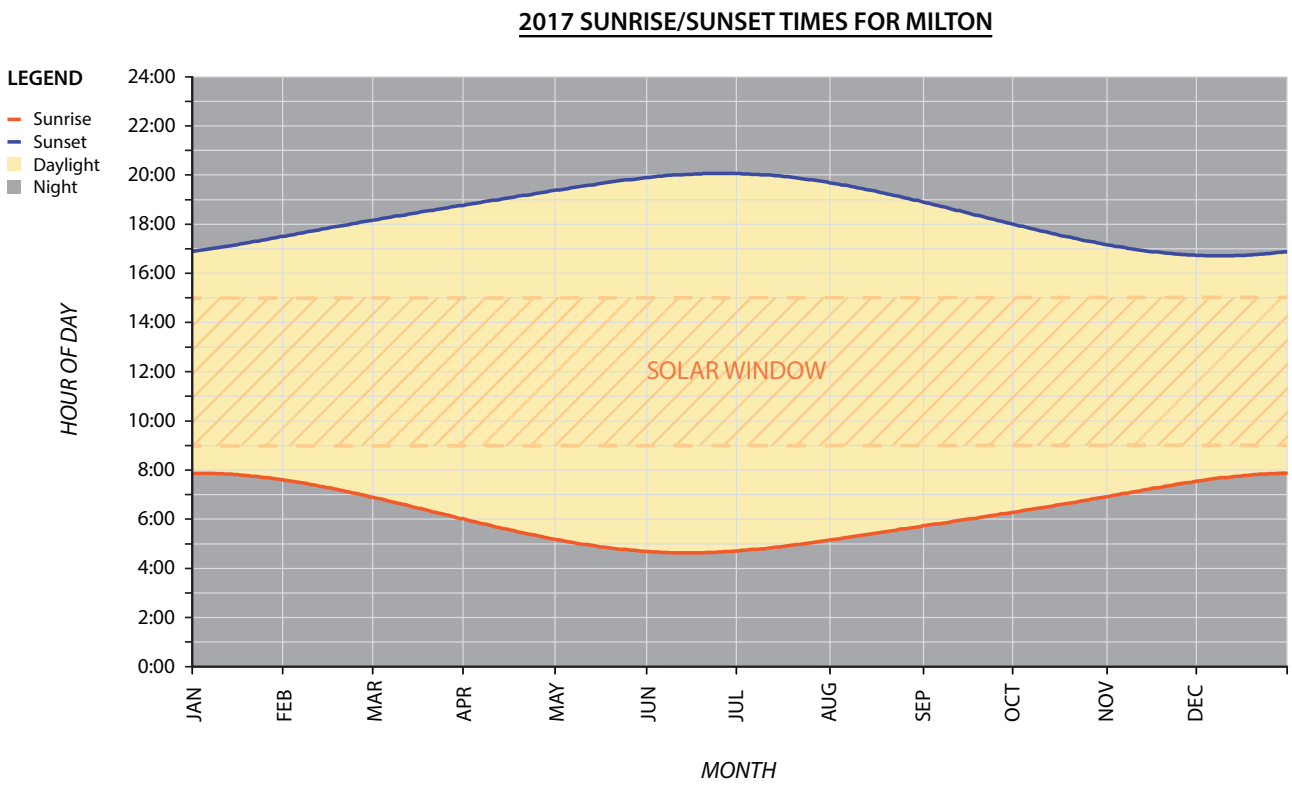


Figure 4.40 - Graph of sunrise and sunset times, and hours of daylight by month for Milton, ON.
The "solar window" which is the period of the day that the sun's radiation is strongest, occurs between 9am and 3pm year-round, aligning perfectly with the regular hours of operation of schools. This suggests that passive solar heating strategies would work well in meeting environmental comfort needs for the school, as solar radiation is available to be harnessed.

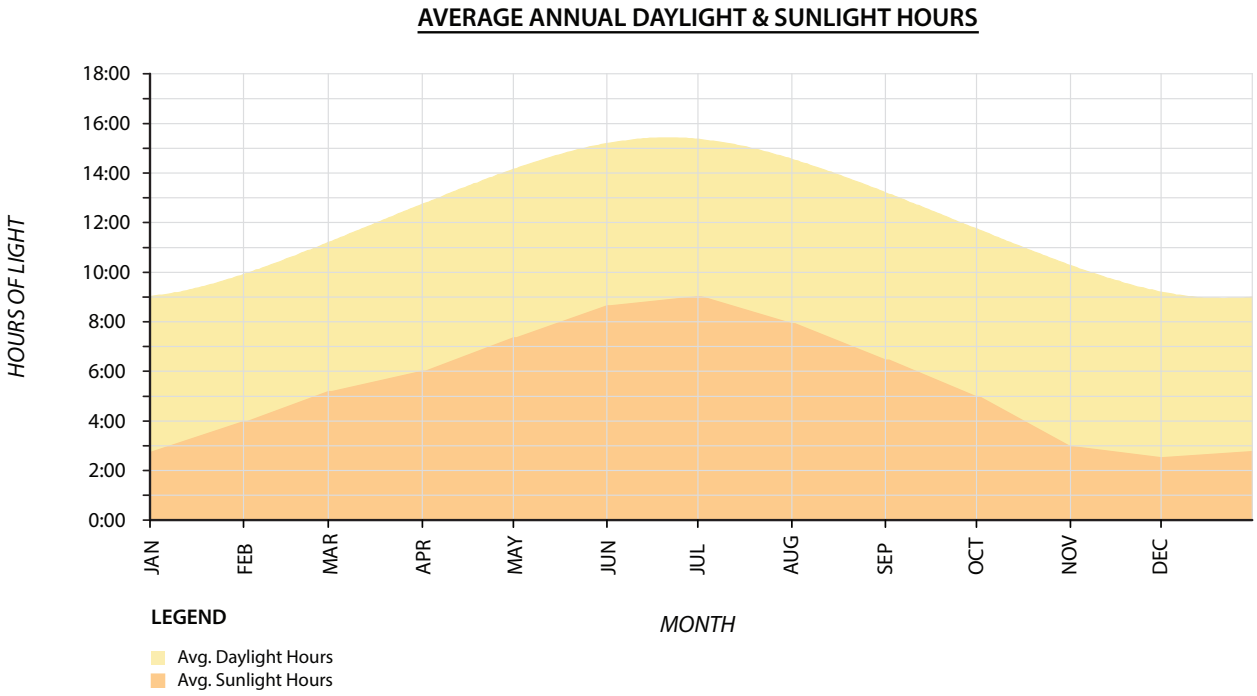


Figure 4.41 - Average Monthly Hours of Daylight and Sunlight for Milton, ON.

MICROCLIMATE DUE TO GEOGRAPHY

Besides the constantly moving air masses, geographical features such as topography and large bodies of water can also influence the climate of adjacent regions. Milton is located near the western shore of Lake Ontario, whose presence along with that of the other Great Lakes has a large climatic effect on all of the regions that are within the Great Lakes Basin. The lakes "moderate the climate" by "reducing temperature extremes"[19] which results in a milder climate in surrounding areas. This means that it generally feels warmer beside the lake in the wintertime than in areas that are inland, and alternately a little bit cooler in the summer. Known as the "lake effect," this occurs due to two factors: a) the difference between the thermal properties of land and water, and b) the large size of the lakes and the immense volume of water they contain which gives them a greater capacity to act as a heat sink or heat source, depending on the season. It takes a longer period of time to heat or cool the temperature of a body of water with a volume as large as Lake Ontario than it does to change the temperature of the land surrounding it. This results in a significant temperature difference between the lake and the adjacent lands throughout much of the year.[20] During the winter months the surface temperature of the water is warmer than the air and so the lake acts as a heat source, releasing its energy to the air that passes above it. Alternately during the summer, it is cooler than the surrounding land and acts as a heat sink.



Figure 4.42 - Lake Ontario, one of the largest freshwater lakes in the world. Photo by Valentina Hucik.

The lake effect is felt for a distance of about 48km from shore.[21] The project site is 15km inland from the shore of Lake Ontario, so its microclimate is affected by the lake effect.

The microclimate that Lake Ontario creates provides the ideal conditions for growing fruits, and agriculture in general, and is the reason for the strong agricultural history of the site's region. The late springs and long mild fall weather in the region affects the growing season in such a way that crops are less susceptible to frost damage than elsewhere in the province.[22] [23] Given its inland location and distance from the moderating effects of both the Pacific and Atlantic Ocean, without the presence of the Great Lakes the region of Southern Ontario would have a climate that is more "extreme continental"[24] similar to that of the Prairies region of western Canada, with colder winters and drier, hotter summers.[25]

As a large body of water, the Great Lakes have an influence on the amount of precipitation that occurs in the region. During the winter, they cause a phenomenon known as "lake-effect snow" that results in areas near the lakes to be hit with large amounts of snowfall in a short period of time. Lake-effect snow usually affects the cities around the eastern ends of the Great Lakes, as the prevailing wind direction in Ontario is west; these areas are called the snowbelts because they receive the greatest amounts of annual snowfall in the region. The GTA region is rarely affected by lake-effect snow as it is on the west end of Lake Ontario, and too far east for snowfall formed over Lake Huron to reach it. In fact the GTA often gets less snowfall than anywhere else in the province. [26]



Figure 4.43 - The Niagara Escarpment, a prominent natural feature of the region. View taken from the limestone cliffs of Rattlesnake Point, looking towards Mount Nemo.

The most dominant land form in the Halton region is the Niagara Escarpment. With its cliffs reaching "a height of only 200 to 300 feet"[27] the Escarpment is not tall enough to have a significant impact on the climate of adjacent regions, like mountains do. However, the Escarpment's interaction with the Great Lakes amplifies the lake's moderating effect on the climate[28], as well as having some effect on precipitation levels in the area. The Escarpment causes what is known as the "rain shadow effect," where the areas on the downwind side of its elevation receive less rainfall than the areas on the windward face. The project site is located in the part of Milton that is on the east side of the Escarpment and so is in the rain shadow.

CLIMATE STRATEGIES

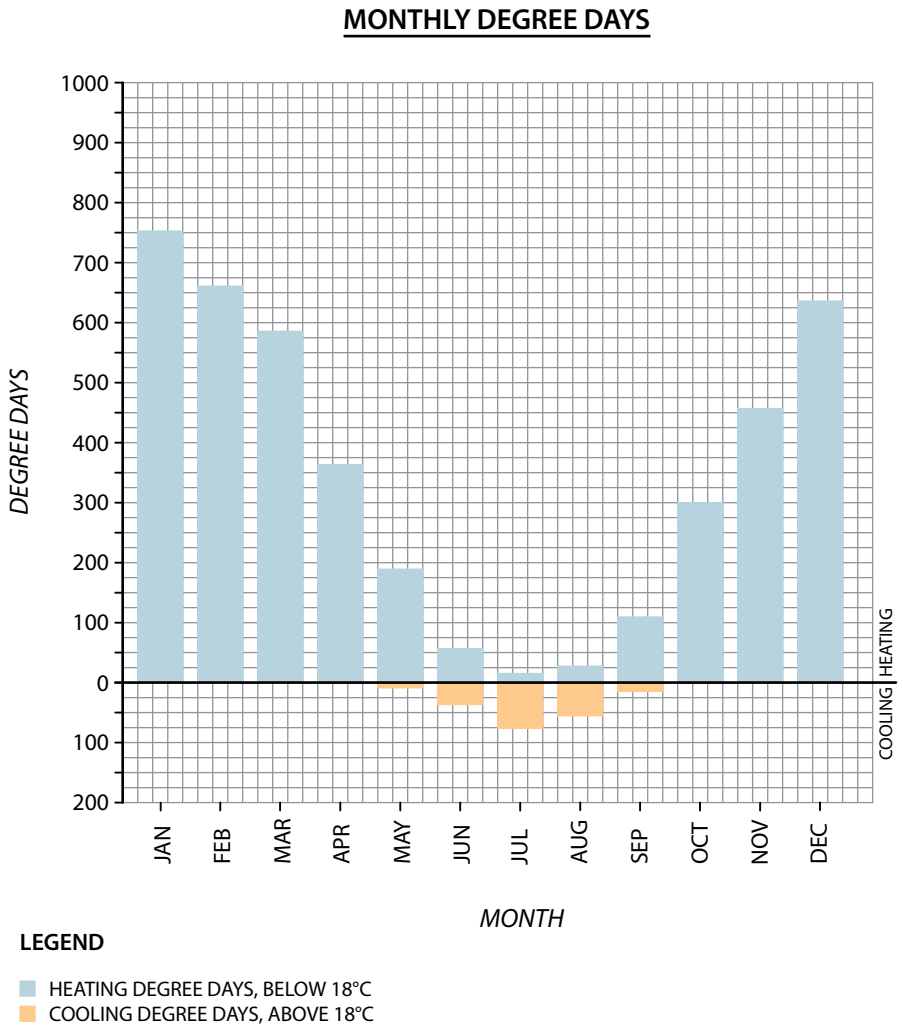
The cool climate of the Halton region results in thermal conditions that are below the human comfort level for the larger period of the year. It feels too cold outside more often than it feels too hot or even comfortable.

Thermal comfort is formally defined as "that condition of mind in humans which expresses satisfaction with the thermal environment."[29] The temperature that is considered comfortable varies depending on the person, their level of activity and the amount of clothing one is wearing, as well as being influenced by environmental factors such as humidity, internal heat gains from surrounding occupants and equipment, and air speed.[30] However there is a temperature range that has been found to generally be considered comfortable by the majority of people. Based on the recommendations of ASHRAE Standard 55, the CSA Guideline for Office Ergonomics suggests that the ideal indoor temperature range is between 20-23.5˚C during the winter, and 23-26˚C in the summer (when the humidity is at 50%), for occupants in an office environment where their level of activity is lower (e.g., sitting or reading) and they are wearing indoor clothing corresponding to the season.[31]

One method of measuring quantitatively how cold or hot it is at a certain part of the year is *degree days*. Degree days are used primarily to calculate how much energy will be needed to heat or cool a building, providing an estimate of consumption based on the difference between the recorded outside air temperature and a set indoor temperature. However, they are also "a good indicator of the severity of winter and summer"[32] typically experienced by a region. There are two types of degree days calculated for buildings: heating degree day and cooling degree days. Heating degree days are related to the building's heating requirements and refer to the period and amount by which the outdoor temperature was below the set base temperature. Cooling degree days are the opposite and measure how much the outdoor temperature was above a given temperature.[33]

Calculated using a base temperature of 18˚C (a fairly comfortable temperature), the Halton region annually experiences on average 4153.3 heating degree days, and 192.7 cooling degree days.[34] Halton's annual total of 4153 heating degree days is less than 5500, the minimum number of days that areas considered to have severe winters experience[35]; this is consistent with the fact that southern Ontario has cold winters, but are milder compared to those of central and northern Ontario. As for cooling degree days, any annual total below 500, as in the Halton region's case, signifies an area with a generally short and mild summer.[36] These numbers indicate that this is a climate where the heating of a space is a priority for the greater part of the year; and cooling is a lesser priority and only becomes important for a small period in the year.

In the 21st century, the heating and cooling requirements of a building can be achieved through mechanical systems and equipment. But to maintain indoor comfort through mechanical means requires that high amount of energy are consumed. The dependence on these systems as well as the energy load put on them can be minimized, or in some cases even eliminated, through a building design that architecturally responds to its climate.



Total # of Heating Degree Days per Year: 4153.3
Total # of Cooling Degree Days per Year: 192.7

Figure 4.44 - Average Monthly Heating and Cooling Degree Days for Milton, ON.

Norbert Lechner in "Heating Cooing Lighting" lists the following as the "climatic design priorities" for this climate zone in which Southern Ontario is located. Greater importance is placed on heating in this climate, and so the winter energy needs are the first priority. In order of importance:

1) Retain heat and minimize heat loss.

2) Block and shelter from prevailing winter wind direction

3) Maximize solar exposure/access

Of lower priority, for summer cooling design to:

4) "Protect from the sun" to minimize overheating

5) Allow for natural ventilation [37]

Daylighting is important to the environmental quality of a building and should be a design priority regardless of the season. The building design should allow access for daylight from the sun to enter the building so that rooms receive sufficient amounts of lighting. Daylighting is supplemented with artificial lighting where or when it is required. The amount of daylight however needs to be controlled so that it does not become uncomfortable for occupants, and to avoid glare.

A building can be passively heated, cooled or day lit by designing the building in relation to the sun and wind present on the site. Depending on the season, the design priorities outlined by Lechner, can be achieved "by appropriately admitting or blocking the sun and wind."[38] Based on the exposure to sun and wind, design decisions can be made related to the orientation and placement of the building on the site, as well as the size of the building and its openings. The programming and layout of rooms in the building can be developed based on the energy requirements and occupancy of the spaces, and located in zones with rooms that have similar heating, cooling, daylighting needs.[39] The same strategies can be applied to the design of outdoor spaces, as to indoor rooms. Outdoor rooms that are located in relationship to the building, and to the sun and wind directions on the site, can experience comfortable outdoor conditions for extended periods of the year.[40]

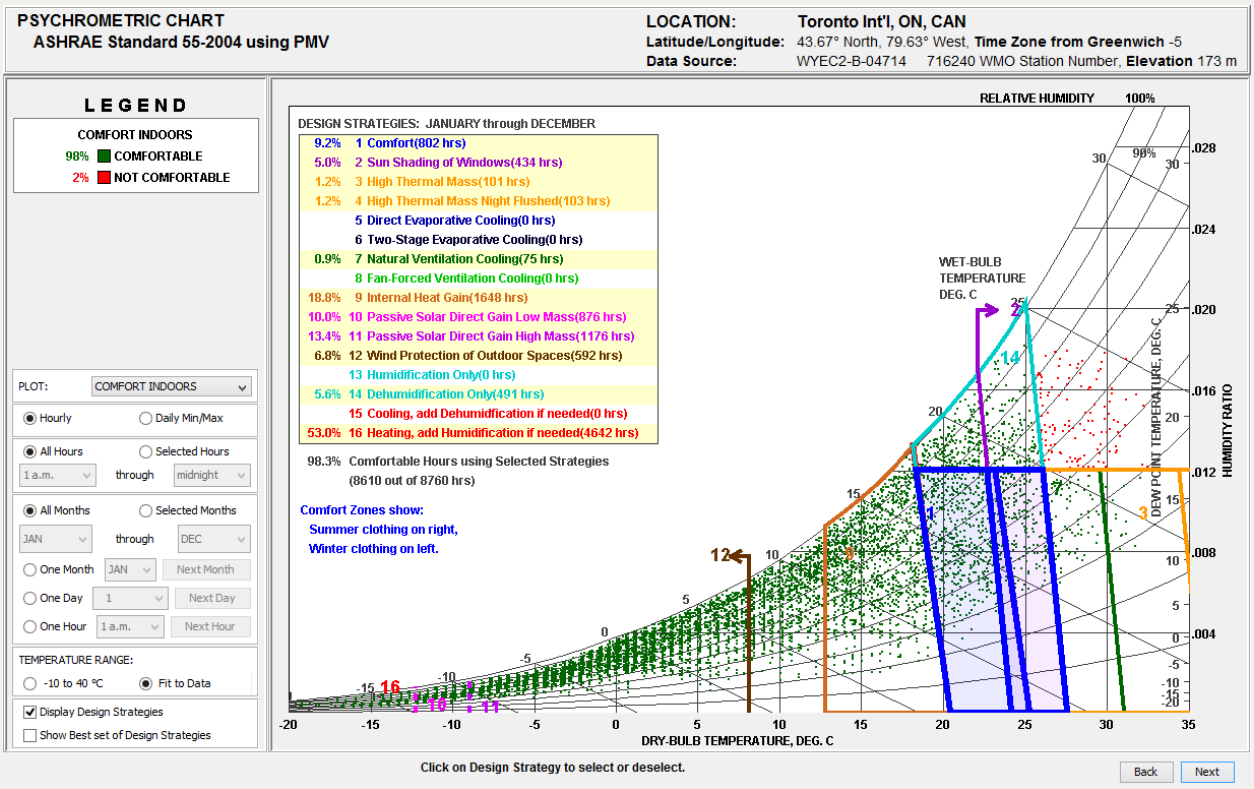


Figure 4.45 - Psychrometric chart for Toronto, Ontario generated through Climate Consultant 6.0.

The psychrometric chart generated by the software Climate Consultant 6.0 was a useful tool for exploring the effect of various design strategies (both passive and active) on thermal comfort. By selecting the different strategies from the list, the program shows what percentage of the total hours in a year the building would be comfortable when relying on just that group of strategies. This is displayed on the chart in terms of temperature and relative humidity.

- In the climate region of Toronto, just 9.2% of the total hours of the years would be considered comfortable without any active or passive heating/cooling strategies.

- Selecting only relevant passive heating and cooling design strategies, results in 40% of the year being comfortable. This suggests that active strategies will be required for some periods of the year, as otherwise the building will be too cold for much of the year as the left side of the chart remains red.

- With the addition of mechanical space heating (design strategy #16), the total number of comfortable hours rises to 93%. The addition of active cooling (#15) causes the number to rise to 94.7%, only improving the period of comfort by 1.7%. Fan-forced cooling (#8) similarly only increases the period of comfort by 48 hours. This suggests that an active cooling system is only needed for a small portion of the year, but confirms that heating is indeed a priority in the climate of the project site. It can be concluded from this chart that for the proposed building, designing an efficient heating system will be important.

- By removing active cooling strategies, and replacing them with dehumdification (#14), the hours that are comfortable rises to 98.3%. This suggests that dealing with humidity is more important to this climate than active cooling of the indoor space. This lines up with what is generally known about the southern Ontario climate – that it has a short period during the summer when it can get quite humid.

SITE MICROCLIMATES

Within the site there are areas where the climatic conditions slightly vary from the general climate of the site. These spots are modified by factors present on and adjacent to the site, and form microclimates on the site. A site walkthrough helped identify the existing microclimates on the proposed site off of Britannia Road.

The Sixteen Mile Creek and its forested valley on the north-eastern part of the site are natural features that modify the climate on the surrounding environment. The following factors influence how it feels to be on this part of the site compared to the upper field area.

a) Topography: The land begins to slope gradually on the northern ends of the fields, becoming steeper at the forest, and gradual again as the hill evens out at the creek. The creek and the fields next to it make up the lowlands of the valley. On the other side of the creek, the land begins to gradually slope upwards again. The low-lying part of this valley feels a little cooler than the rest of the site, because cold air sinks down into it, collecting at the bottom near the creek. Rainwater and melting snow from the site also drains down the slope, pooling at the bottom of the valley. As a result the soil along the creek is often wet and oversaturated particularly in the spring.

b) Water: The creek adds moisture into air above it, increasing the humidity in the valley. The moist air in combination with the cool air at the bottom of the valley often leads to fog forming in the 16 Mile Creek Valley in the evening and early morning.

c) Forest: The tall trees that grow on the forested hillside have some influence on the site. The dense growth of trees on either side of the creek shelters the valley from wind. The trees act as a wind break forcing the wind to rise over them and reducing its speed. Thus, at the bottom of the valley (the creek and meadow) it feels less windy than in the open fields at the top of the hill. The forest canopy creates shadows on the ground beneath it, not allowing much sunlight to reach the understory and for the soil to absorb its radiation. Consequently, it feels cooler within the woodland parts of the site, particularly during the summer when the branches have leaves. The forested slopes are credited with helping in "maintaining (the) surface water quality" of the creek by shading the water and thus keeping the surface cool.[41]

The conditions on the south-western part of the site are opposite to those of the valley. This area is at a higher elevation, and consists of meadows and agricultural fields. The south-western part of site is open with almost no trees to act as windbreaks or offer shading protection from the site. Consequently this part of the site feels warmer than the end with the valley. On a sunny day the ground heats up quickly, and can feel uncomfortably warm in the afternoon. There is an existing hedgerow on the western edge of the site which acts as a windbreak for westerly winds, but its distance from the east edge of the site is too large for it to protect any area but the most western end of the field.

Currently, the site is still considered a rural area and most of the adjacent land is farmland, thus it is not affected by the urban heat-island effect.

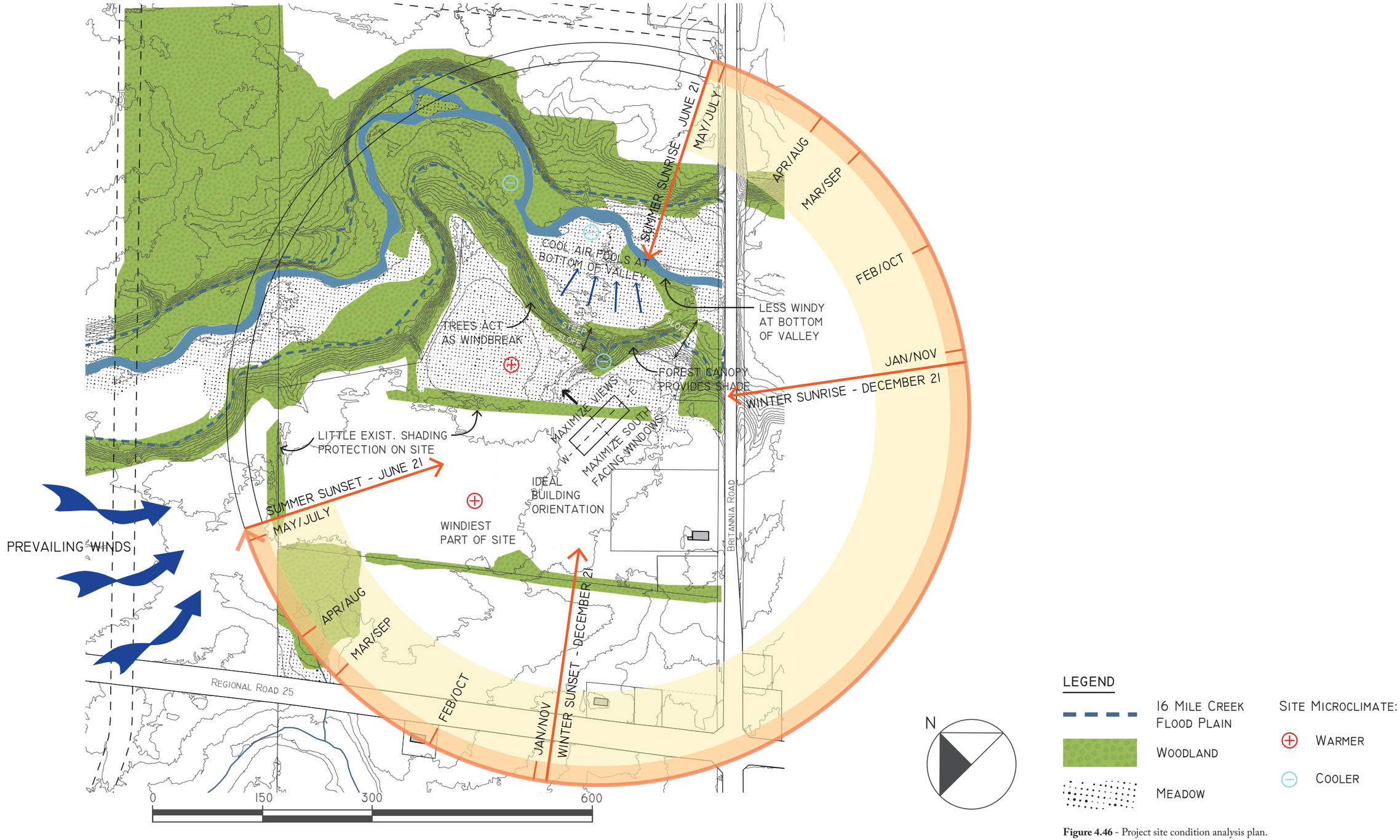


Figure 4.46 - Project site condition analysis plan.

Endnotes for Chapter 4

4.1 - Site Context

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CHAPTER 5:

DESIGN PROPOSAL

CREEKSIDE VALLEY ECOSCHOOL

5.1 - Overview of Design Proposal

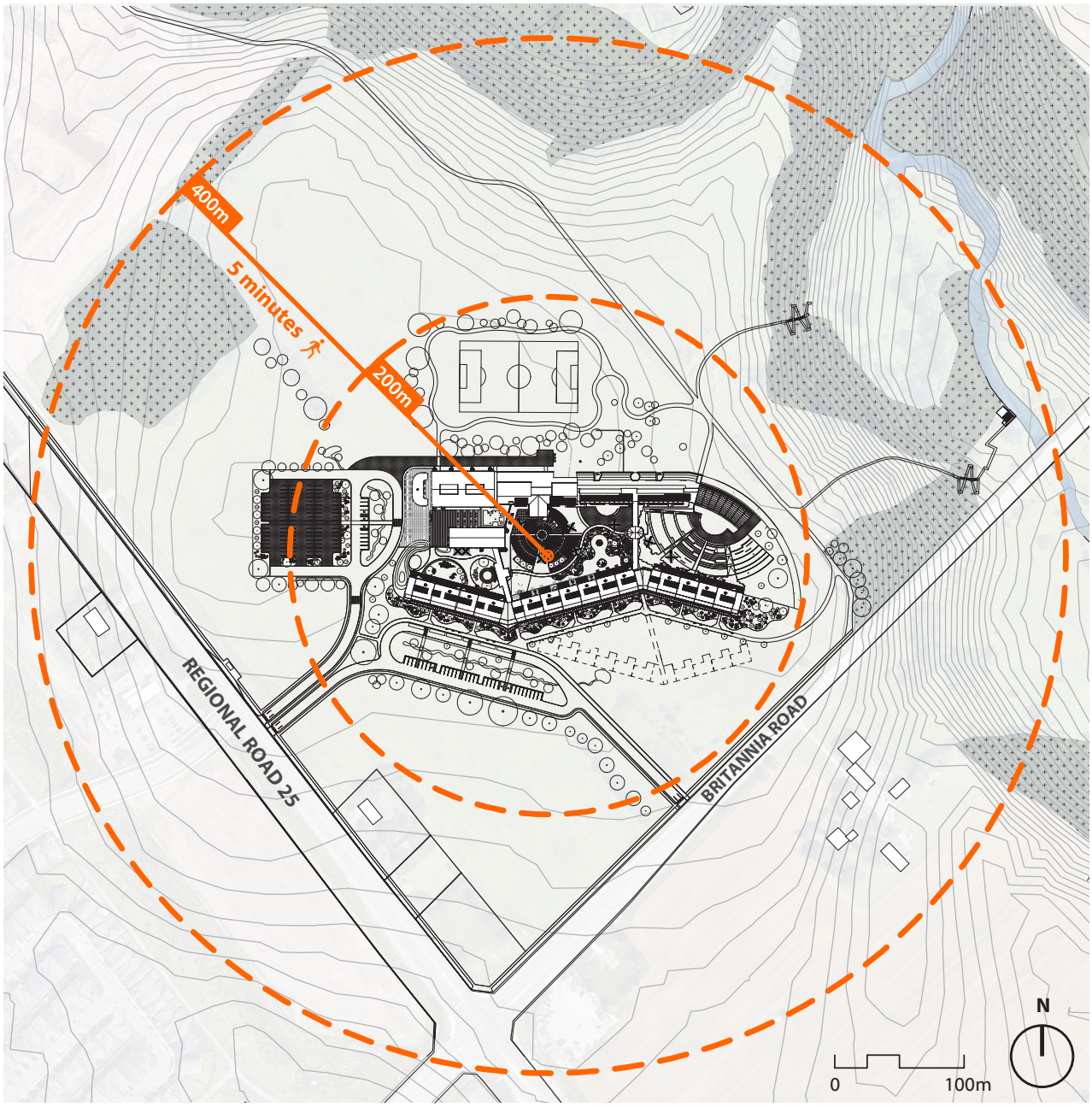


Figure 5.1 - 1:5000 Site Plan

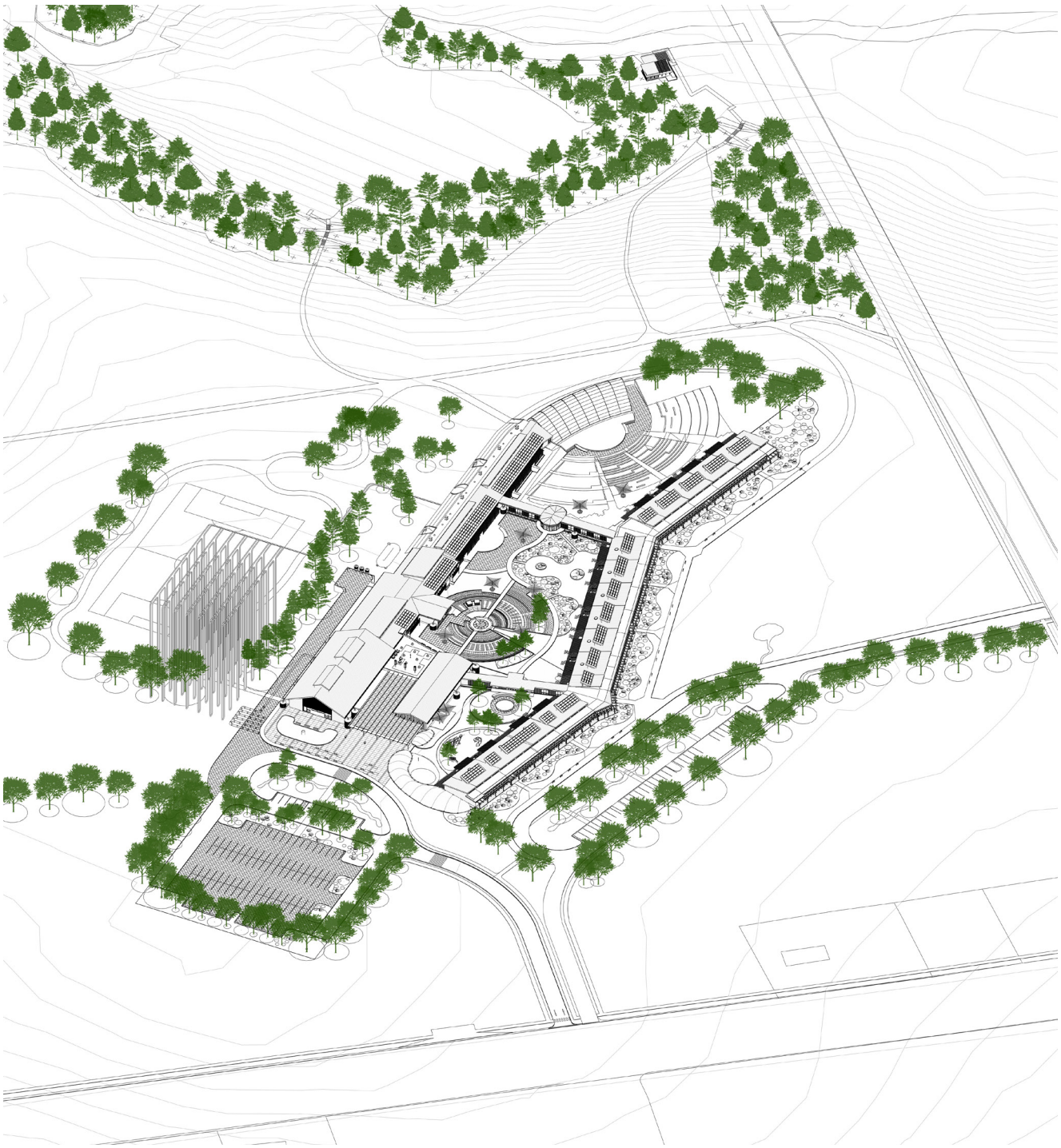


Figure 5.2 - Aerial perspective view of the Creekside Valley School campus.

Building Parti and Programme

The school is located in the middle of the vast site in the Boyne lands of the town of Milton, where it is positioned amidst the tall grass of the open meadow and within walking distance to the creek and woodlands. Here it reoccupies the previously developed part of the site, while respecting and protecting the rich natural habitat by not building past the natural heritage system boundary line.

The parti of the school developed out of response to the vastness and relative wilderness of the site. The parti is based on the biophilic design attribute of "prospect and refuge," which refers to two ways of experiencing and inhabiting spaces that people have a biological inclination to prefer. Prospect denotes the clear long views out into one's environment and refuge responds to people's inclination to seek out these views from a sheltered and enclosed space. Together they help people feel secure and at ease in their environment.[1] This concept of "prospect and refuge" inspired the building's form and is a metaphor for its role on the site as a shelter, providing protection from the elements on the exposed site while maintaining a physical and visual connection to the outdoors.

Out of this concept evolved the school's courtyard typology. The building program is divided into two wings which are arranged on opposite sides of each other around a series of three central courtyards. These two wings frame and define the central courtyard space, offering a sense of protectiveness to the outdoor space. The courtyards serve as shared gathering spaces for the school, helping foster a sense of community while maintaining privacy and security from the expansive site beyond. The courtyard allows for the experience of "prospect and refuge" by creating an enclosed and sheltered outdoor area that allows for views of nature from the building interior from both sides. Along the inner perimeter of the courtyards the experience of prospect and refuge is further promoted through an assembly of decked outdoor classrooms, deep roof overhangs, trellis screens, pergolas and canopies that provide a degree of enclosure when outdoors.

The programmatic spaces are broken down according to two levels of division. The first division is based on the public accessibility of the spaces. The programme is divided into two wings based on the concept of private versus public. The south wing consists of the homeroom classrooms which are considered private and not accessible to the public. The south wing is further broken down into three bars based on age divisions (kindergarten, primary, and upper grades) and are alternatingly rotated to create more interesting pockets of outdoor space.

The north wing contains the more public spaces that are shared by all members of the school during the daytime, and are equally accessible to the public community for use afterhours. While the classrooms serve as the main instructional area, the spaces contained in the north wing are shared amenity and instructional spaces that support the specialty environmental education curriculum of the school. The second level of division breaks down the north wing into key program areas: Administration, Entry Foyer, Gymnasium, Cafeteria, Library, Science Classrooms,

ITERATIVE DESIGN PROCESS

An iterative design process was used during the design development stage of the project. Several different typologies were considered and tested on the site, before arriving at the final form of the design.



Figure 5.3 - The Cluster Plan: defined by many individual courtyards, grades divisions are grouped together into small communities and separated by open courtyard spaces. Aldo van Eyck's Amsterdam Orphanage was an important precedent to this iteration due to its use of interstitial outdoor spaces and the staggering of rooms.



Figure 5.4 - The Fingers Plan: A variation on the cluster plan, in this arrangement classrooms are grouped together in long bars, and separated by grade levels by larger courtyards. These courtyards are open to the site, and the advantage of this plan is a view towards the forest from each class.

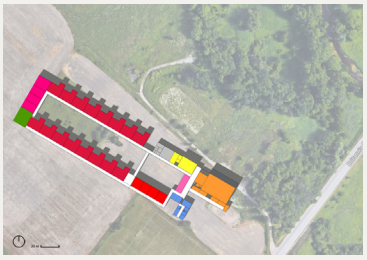


Figure 5.5 - Central Closed Courtyard: The gesture of the courtyard remains in this arrangement, but the numerous smaller courtyards are merged into one big courtyard that is shared by the whole school. The benefit of a larger courtyard is the increase of space which permits a greater variety of activities to occur, as well as increased brightness – improved daylighting conditions. In this plan the courtyard is closed off from the site, and classroom are arranged around the perimeter. This plan meets the safety concerns of a school



Figure 5.6 - Parti Diagram: Prospect & Refuge

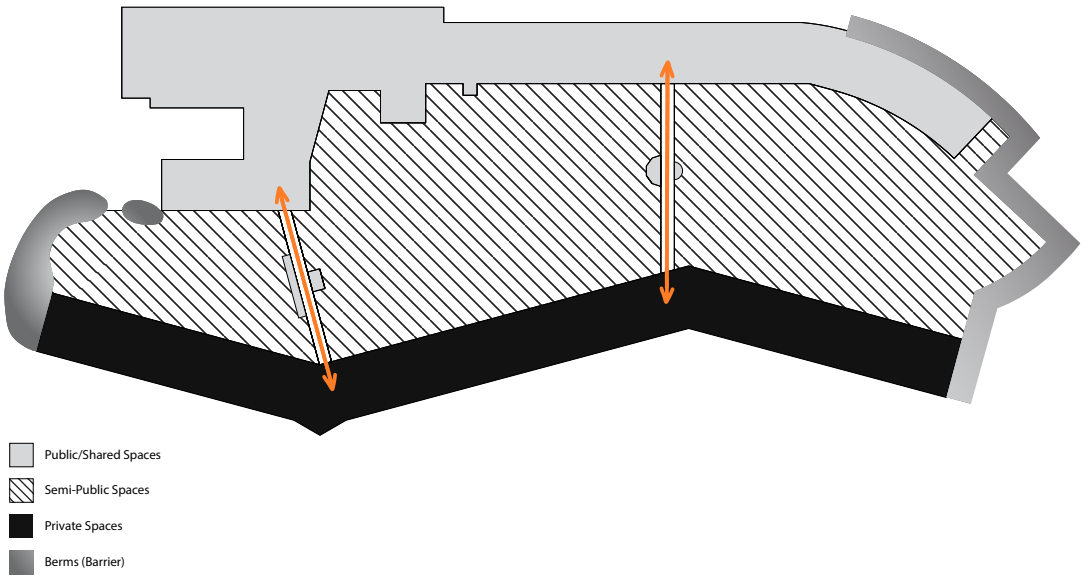
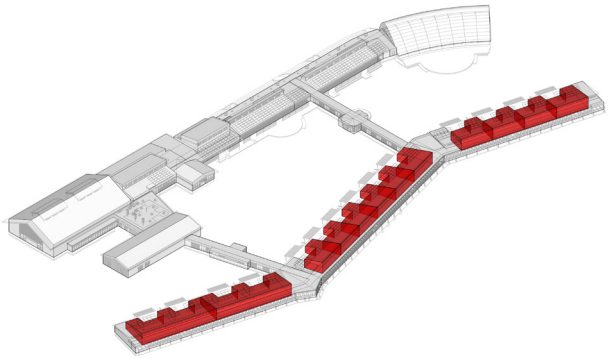


Figure 5.7 - Parti Diagram: Public vs. Private

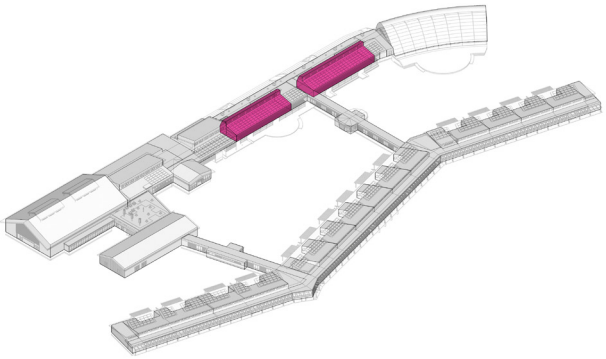
and the Greenhouse. The programmatic spaces are expressed as an assembly of volumes connected on the interior through corridors and open common spaces. The north and south wings are connected to each other through two glazed breezeways that create the courtyard divisions.

The building is expressed as a single story building for several reasons:

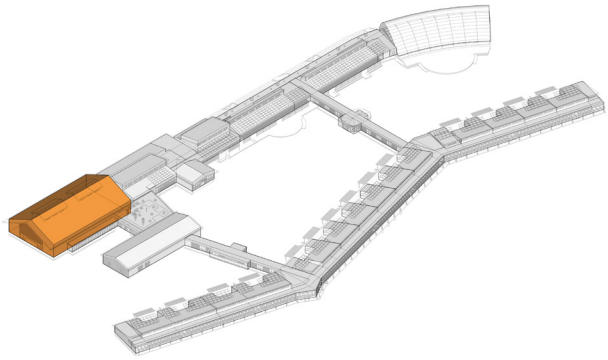
- It gives the building a presence on the vast site by spreading its footprint out, but still maintaining open space through the formation of the internal courtyard.
- The one story reduces the size of the shadow that the building casts on the inner courtyard and on the site, which improves the thermal comfort level of the outdoor spaces.
- It addresses the need for barrier-free design in a public building, allowing the building to be wheelchair accessible.
- The one-story layout allows for direct access to the outdoors from all regularly occupied rooms of the school. This serves to connect to indoor spaces to the outdoors.



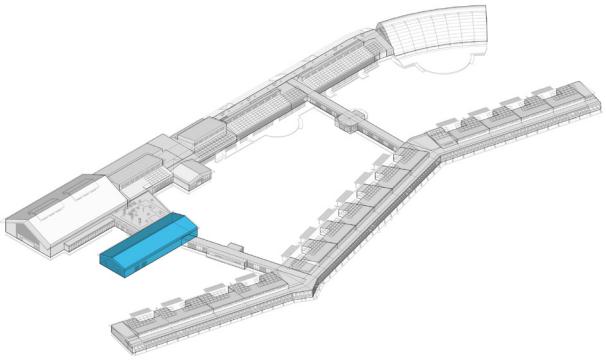
Homeroom Classrooms



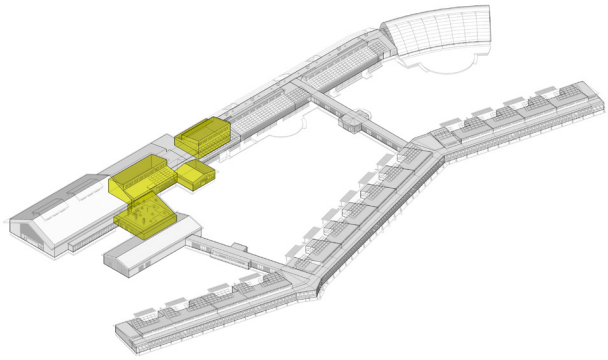
Science Laboratories



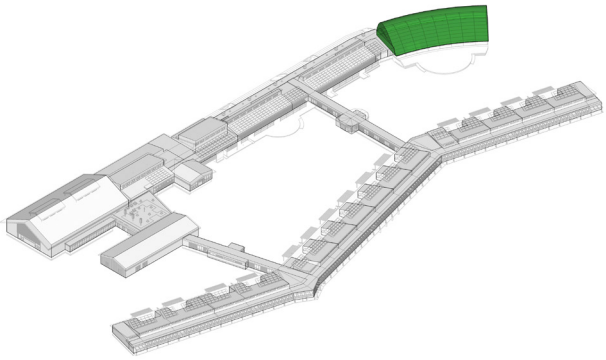
Gymnasium



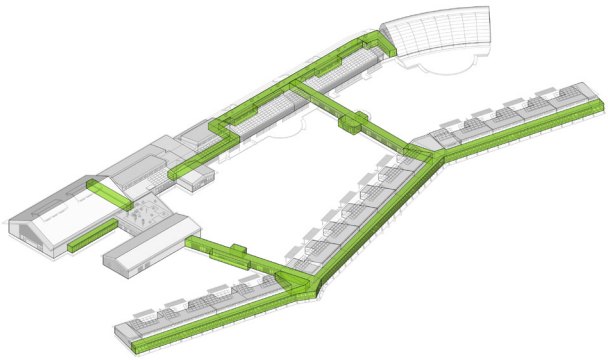
Administration



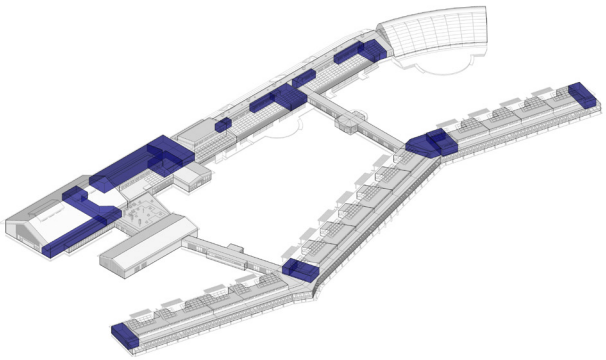
Shared Amenity & Instructional Spaces



Greenhouse



Circulation



Service Spaces and Mechanical Rooms

Figure 5.8 - Programmatic Massing Diagrams



Figure 5.9 - Perspective view of the exterior front entry face, looking across to the covered courtyard of the main entry to the school.

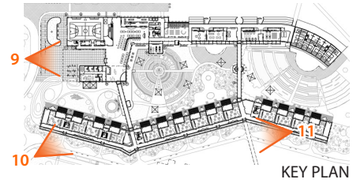




Figure 5.10 - Perspective view of the exterior of the classroom wings on the south side of the building. Classroom wings have their own entrances to reduce travelling distances. View is taken from the bioswale garden next to the bus drop-off and parking lot.



Figure 5.11 - Perspective view of the exterior of the classroom wings on the south side of the building, near the entrance.

Building Program

Table 5.1: Gross Floor Area (m^2) of Building Program Chart

PROGRAM SPACES	# OF ROOMS	AREA (m^2)	TOTAL AREA (m^2)
CLASSROOM WING (SOUTH)			
CLASSROOM (Grade 1-8)	10	145	1450
KINDERGARTEN CLASSROOMS	4	/	724
MAIN CLASSROOM SPACE	4	154	616
MEZZANINE	2	24	48
TEACHER PREP SPACE	2	19	38
KINDERGARTEN WASHROOMS	2	11	22
BREAKOUT SPACE	1	90	90
CIRCULATION	N/A	897	897
WASHROOMS	2	72	144
STORAGE	2	18	36
OUTDOOR STORAGE	2	12	24
MECHANICAL ROOMS	3	VARIES	216
			3581
NORTH WING			
ADMINISTRATION			
FRONT DESK AREA	1	206	206
MAIN OFFICE	1	/	307
PRINCIPAL'S OFFICE	1	24	24
VICE PRINICIPAL'S OFFICE	2	18	36
COPY ROOM	1	17	17
HEALTH ROOM	1	17	17
CONFERENCE ROOM	1	28	28
STAFF ROOM	1	108	108
STAFF CHANGE ROOM	1	8	8
STAFF B/F WASHROOM	1	8	8
CIRCULATION	N/A	61	61
FRONT LOBBY	1	288	288
FRONT VESTIBULE	1	7	7
			808
GYMNASIUM			
GYMNASIUM	1	665	665
CHANGE ROOMS	2	41	82
STORAGE	2	VARIES	86
MECHANICAL ROOM	1	93	93
CORRIDOR	N/A	97	97
MEZZANINE/BLEACHERS	1	297	297
			1320

PROGRAM SPACES	# OF ROOMS	AREA (m^2)	TOTAL AREA (m^2)
CAFETERIA			
DINING HALL	1	690	690
CAFETERIA KITCHEN	1	/	259
SERVERY & COOKING LINE	1	85	85
KITCHEN PREP AREA	1	92	92
DISH WASHING	1	30	30
PANTRY	2	VARIES	20
FREEZER ROOMS	2	6	12
KITCHEN OFFICE	1	7	7
KITCHEN STAFF WASHROOM	1	4	4
KITCHEN CHANGEROOM	1	9	9
SERVICE AREA	1	/	123
OPEN SERVICE SPACE AND CIRCULATION	N/A	100	100
RECEIVING ROOM	1	14	14
LAN ROOM	1	5	5
JANITOR'S CLOSET	1	4	4
WASHROOMS	1	/	65
GIRL'S WASHROOM	1	17	17
BOY'S WASHROOM	1	17	17
B/F WASHROOM	1	8	8
COMMUNAL SINKS	1	23	23
LEARNING KITCHEN	1	/	153
KITCHEN CLASSROOM	1	128	128
PANTRY	1	25	25
			1290
LIBRARY			
LIBRARY	1	278	278
LIBRARY WORKROOM	1	17	17
SEED LIBRARY	1	10	10
CORRIDOR	1	N/A	105
			410
SCIENCE LAB WING			
LAB #1 - ENERGY LAB	1	116	116
LAB #2 - MAKER SPACE	1	133	167
WORKSHOP	1	26	26
WOOD STORAGE ROOM	1	8	8
LAB #3 - WET LAB	1	140	168
NATIVE SPECIES ROOM	1	28	28

Table 5.1 (continued):

PROGRAM SPACES	# OF ROOMS	AREA (m^2)	TOTAL AREA (m^2)
LAB #4 - DRY LAB	1	140	140
PREP & STORAGE ROOM	4	VARIES	100
BREAKOUT SPACES	2	36	72
WASHROOM	1	9	9
MECHANICAL ROOM S	2	VARIES	177
CIRCULATION	N/A	392	392
			1340
GREENHOUSE			
GREENHOUSE	1	664	664
OTHER			
ENCLOSED BREEZEWAY #1(CIRCULATION)	1	149	149
ENCLOSED BREEZEWAY #2(CIRCULATION)	1	183	183
			332
TOTAL GROSS FLOOR AREA (m^2):			**9745**
EXTERIOR AND PARKING			
OUTDOOR CLASSROOMS	17	/	919
CONNECTED TO CLASSROOMS	14	58	812
CONNECTED TO SCIENCE LABS	3	VARIES	107
COURTYARD #1 (KINDERGARTEN)	1	2290	2290
COURTYARD #2 (MIDDLE GRADES)	1	6340	6340
OUTDOOR STORAGE	1	16	16
CHICKEN COOP	1	186	186
COURTYARD #3 (UPPER GRADES)	1	6540	6540
			16089
PARKING SPACES - IMPERMEABLE SURFACE	42	/	/
PARKING SPACES - PERMEABLE SURFACE	96	/	3827
BICYCLE PARKING SPOTS	82	/	/

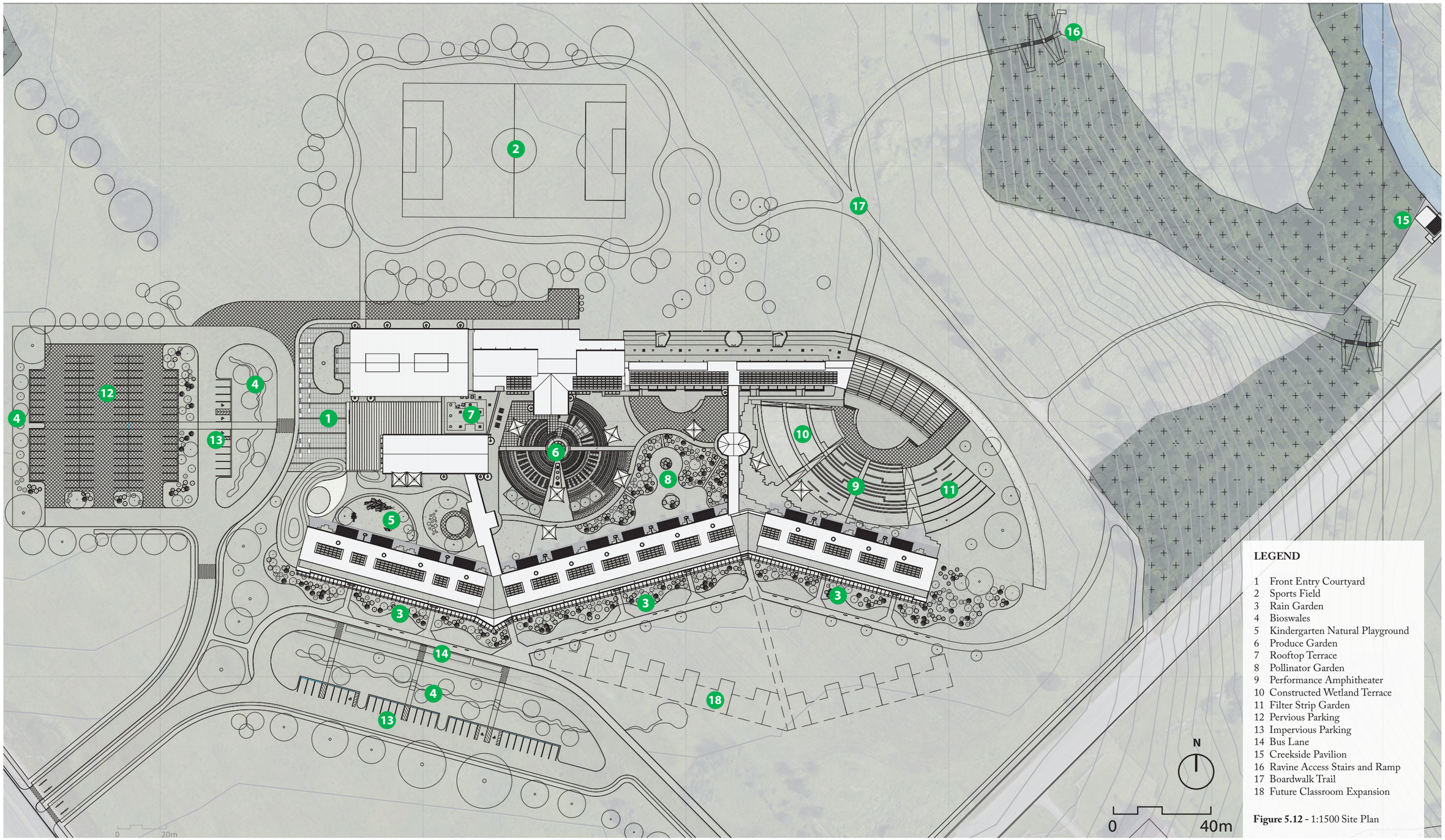
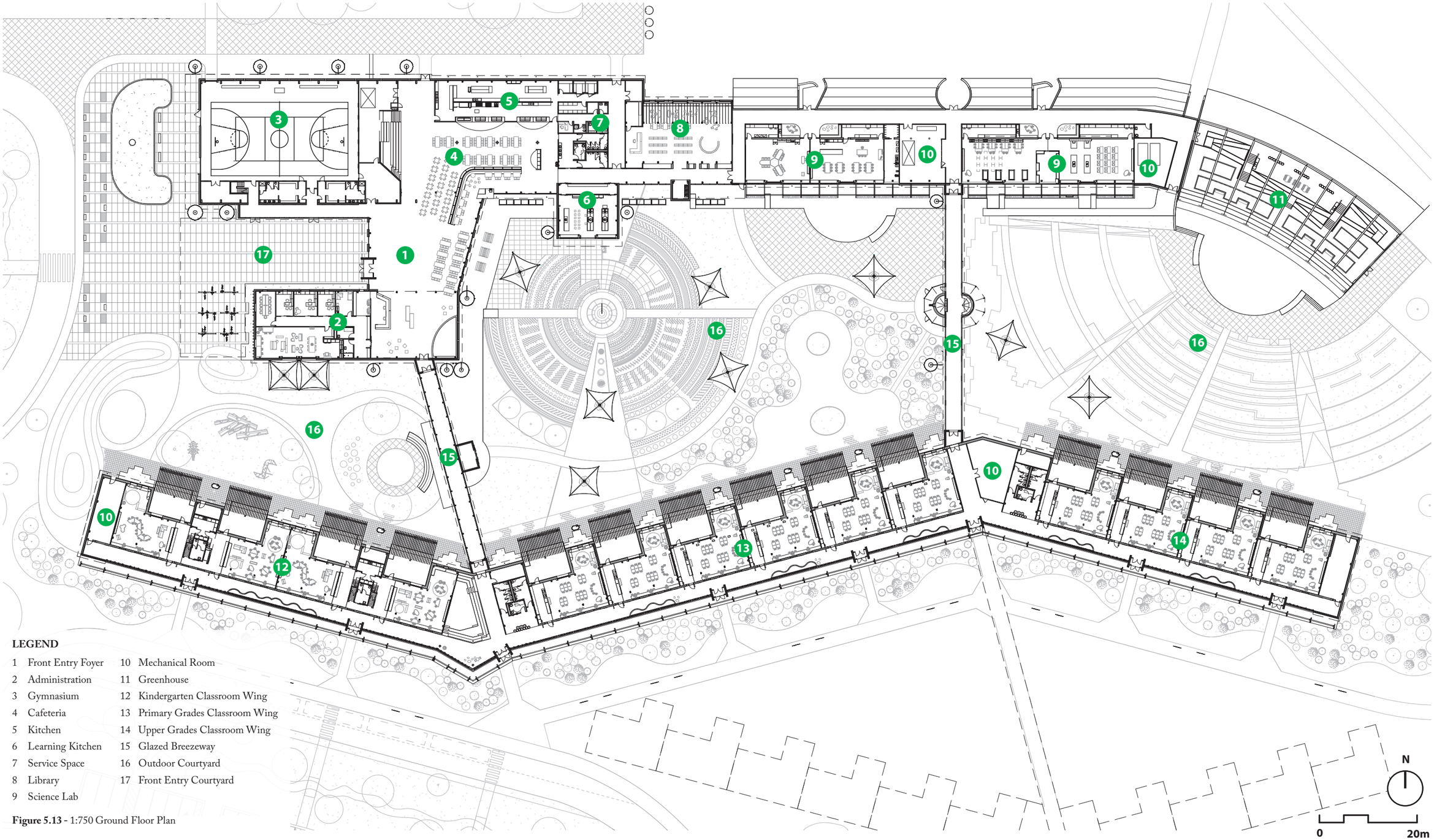


Figure 5.12 - 1:1500 Site Plan



LEGEND

1	Front Entry Foyer	10	Mechanical Room
2	Administration	11	Greenhouse
3	Gymnasium	12	Kindergarten Classroom Wing
4	Cafeteria	13	Primary Grades Classroom Wing
5	Kitchen	14	Upper Grades Classroom Wing
6	Learning Kitchen	15	Glazed Breezeway
7	Service Space	16	Outdoor Courtyard
8	Library	17	Front Entry Courtyard
9	Science Lab		

Figure 5.13 - 1:750 Ground Floor Plan



Figure 5.14 - 1:750 South Elevation



Figure 5.15 - 1:750 Interior Courtyard North Elevation



Figure 5.16 - 1:750 Interior Courtyard South Elevation



Figure 5.17 - 1:750 North Elevation



Figure 5.18 - 1:750 West Elevation



Figure 5.19 - 1:750 East-West Longitudinal Section

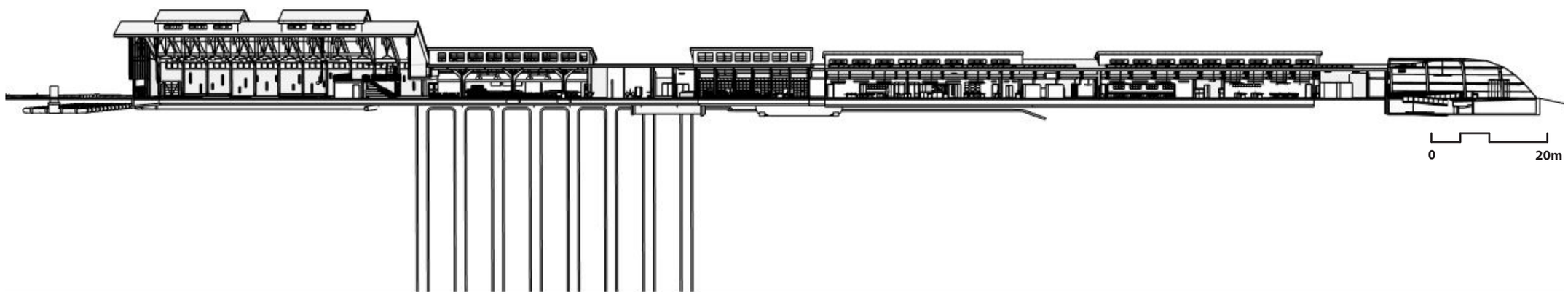


Figure 5.20 - East-west sectional perspective through north wing.

5.2 - Design Materiality

Overview

The materials for the construction of the project's structure and building envelope were selected based on how successfully they meet all three pillars of the green school design framework[1]. The materials were considered based on how they contribute to the school's overall goals of:

1) Reduced Environmental Impact

- Appropriateness to Region's Climate – In response to the cold climate of this project, the focus was on selecting materials that have a low thermal conductivity, high thermal insulative properties, and/or high thermal storage capacity. Materials were also considered based on their response to the elements: their ability to shed rain/or water, their ability to let in sunlight, etc.

- Local Availability - Selection of materials that are readily available in the region, so that majority of the materials are able to be sourced locally (within 500km to 1000km from site)[2] so as to reduce transportation distance and emissions, which in turn reduces the overall carbon footprint. Furthermore this contributes to the development of the local economy.

- Life Cycle Analysis[3] – Involves the consideration of a materials' environmental impact over the course of its life, starting from the raw material extraction and continuing through each stage from manufacturing, construction, occupancy and demolition. The embodied energy involved at each stage in the lifecycle of the material or product is of significant consideration. This is weighed against the materials' durability. What happens to the material at the end of its life, whether the material can be recycled or is compostable, were also considered.

- Reduction of Quantity of Material – Evaluating material systems based on the quantity of raw material they require. Can the material serve more than one purpose – for example such as both structural and building envelope? Choosing systems that can be left unfinished, thereby reducing the need for finish materials, and the labour associated with it.

- Further the building's connection to the site ecosystem and natural processes.

2) Improved Health and Wellbeing

- Avoiding the use of harmful construction materials that are toxic and harmful to human health and pollute the environment. Refer to the Living Future Institute's "Red List" of the worst materials that are to be avoided. This list include materials such as volatile organic compounds (VOC's), metals like lead and mercury, carcinogenic materials such as PVC and formaldehyde, many traditional wood treatments and paints, among a long list of others.[4]

- Aesthetic considerations of the materials connections to site. How do the materials reflect the site's colours, textures and tectonics? Do they connect to the site's natural and cultural history?

- Biophilic Properties of the Material – How well does the material enhance people's innate sense of biophilia?

3) Increased Environmental and Sustainable Literacy

- Potential for pedagogical connections were considered in regards to "transparency." Considering how or whether the material can be made visible, or how its presence can otherwise be communicated to occupants.



Figure 5.21 - Project Material Palette
The material's selected reference the site, in terms of its colours and textures.

Materials: Structure

Structural Wood Use

Mass timber was selected as the primary structural system for the proposed school building. Mass timber is a term used to refer to large prefabricated or engineered wood products – such as cross-laminated panels (CLT) and glue-laminated timber (glulam) members – that are used as the primary load-bearing structure. [5]

In this project engineered wood products are used to construct a structural system composed of: 1) Glulam and Parallel Strand Lumber (PSL) beams which hold up the roof and form its structure, 2) glulam and PSL columns that support and carry the load from the roof structure and transfer it to the foundation 3) CLT wall panels that are primarily used to provide lateral bracing for the glulam frame. This structural system is used throughout the entire school, with variations on how the structure is architecturally expressed depending on the program of the space. Due to the manufactured nature of engineered wood, products like glulam can be shaped into curved forms allowing for a variety of configurations.[6] The design proposal showcases the formability of glulam by slightly modifying the structure to give each space a distinct character and identity.

Classrooms:

The structure of the main classroom module consists of glulam portal frames braced with beams for lateral stability. As the classrooms are designed as a repeated module, this portal frame is repeated through the whole length of the classroom wing, spaced at 3000mm. 3-ply, 144 mm thick CLT panels form the east and west interior partitions between classrooms, acting as shear walls to provide lateral resistance. The structural strength of engineered wood reduces the size of the beams required, so there is no need for large bulky beams. The portal frame carries the entire load, eliminating the need for load-bearing interior partitions, which helps maintain flexibility within and allows for an open central teaching space within the classroom. It also allows the classroom to have high ceilings which are beneficial for daylighting and give the space a sense of openness.

Variations on this frame are repeated in other areas of the school of the school. The cafeteria structure showcases a glulam portal frame with one main modification: replacing the central columns that otherwise support the upper roof beam with curved glulam columns shaped to give them a tree-like form.

Gymnasium:

The structure responds to the programmatic needs of the gymnasium for high ceilings and a clear span with a glulam beam frame braced with a steel tie-rod truss. The beams rest on glulam columns located on the perimeter of the external walls. The enclosure of the gym is entirely constructed out of CLT wall panels that are attached to the glulam frame helping brace it.

Benefits of Using Engineered Wood Products

- Engineered wood products have a stronger performance and with reduced thickness of material than conventional lumber. This is due to their manufactured origin which generally involves bonding smaller individual wood pieces together with an adhesive. The wood products are more efficient because the increased strength allows for smaller beam sizes to be specified, and the member is able to span greater distances. The strength and stability of the structure approaches that of other structural systems, but is able to be achieved with a more lightweight structure, which has the benefit of a lower weight bearing on the foundation, thus decreasing the amount of concrete required to support the structure.[7]

- Engineered wood products require a bit more energy to manufacture but can be made using smaller pieces, thus younger trees are required, faster grown. The product does not need to rely on old-growth trees for material.[8]

- Engineered wood products allow for a more efficient construction process. Products like CLT and glulam can be manufactured to size in a factory, so once the material arrives on site the structure is erected quickly. This minimizes site disturbance and is more cost-efficient.[9] Furthermore, the efficiency of the process reduces material waste, as each structural member is preplanned, and the chance of error is reduced.

- The high degree of precision in the manufacturing of mass timber products results in a tighter fit between member joints. Products such as CLT, which come in large solid panels, due to their size can reduce the number of pieces required, which means the building envelope will have less transitions, and less thermal bridging. As a result a more airtight, energy efficient envelope is able to be achieved.[10]

- Increased fire resistance and seismic performance[11]

Spaces use same material language but have a distinct character based on the way the structure is expressed.

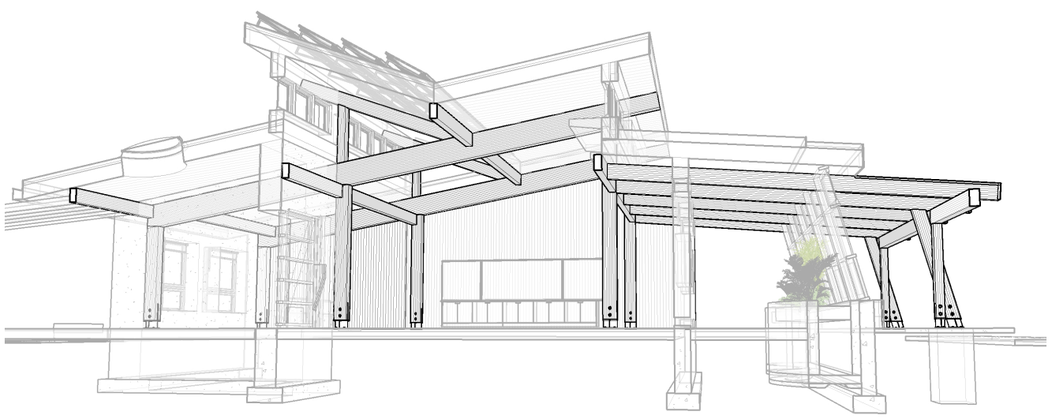


Figure 5.22 - Classroom Structural Frame

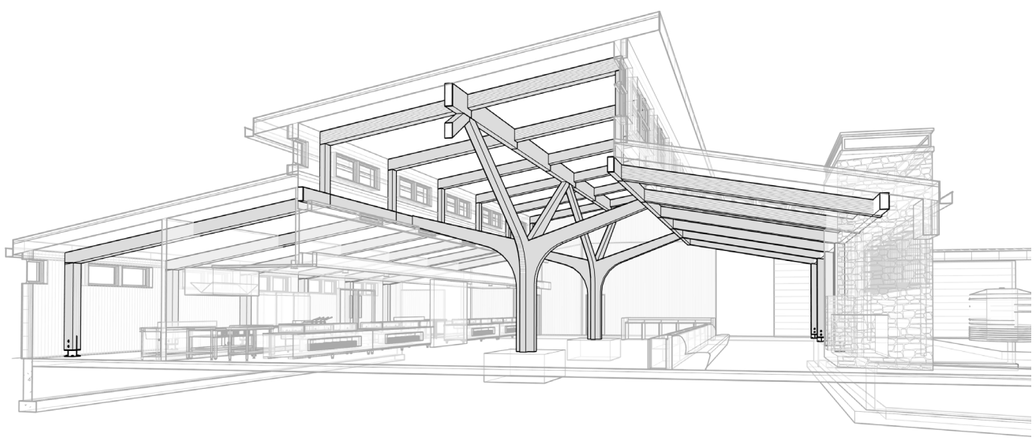


Figure 5.23 - Cafeteria Timber Structure

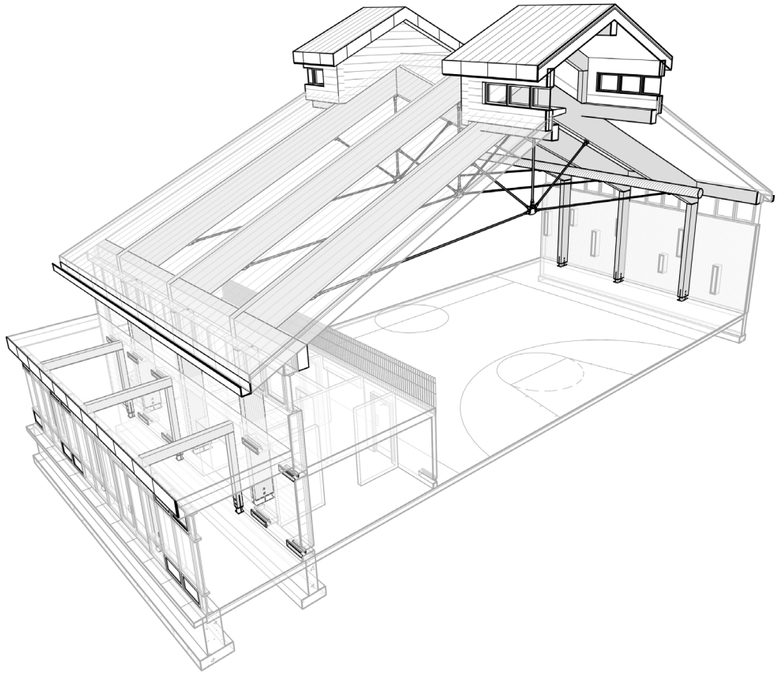


Figure 5.24 - Gymnasium Structure

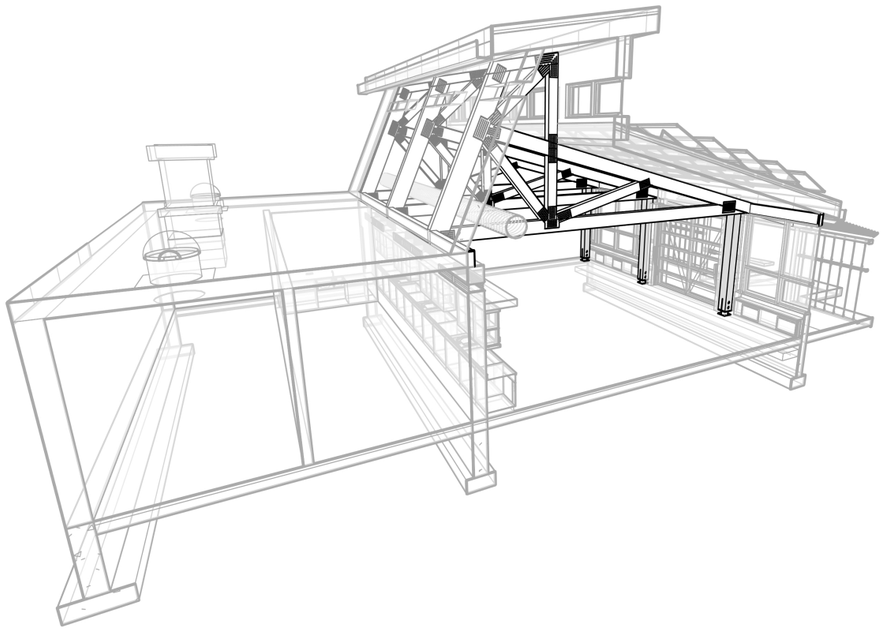


Figure 5.25 - Roof Truss System in Science Lab wing constructed out of parallel strand lumber.

Parallel Strand Lumber (PSL)

Parallel Strand Lumber replaces glulam in the science lab wing. The use of PSL was based on the desire to showcase the application of multiple wood engineered products, and it was chosen for this area of the campus for both aesthetic and functional reason. PSL is a product manufactured by bonding vertical wood strands with an adhesive glue which gives the wood a higher strength and stiffness than regular wood beams of the same size.[12] It allows for greater spans which made it a good choice for the construction of the open ceiling trusses in labs, which were designed for increased daylighting in the space. Furthermore, PSL has a unique unfinished appearance due to the striped texture of the wood strands alternating with glue lines, which suits the experimental and messy nature of the activities that take place in the science labs, and differentiates the lab spaces from the homeroom classrooms. PSL is a sustainable material because it can be manufactured from smaller (younger) trees and scrap wood, rather than relying on old-growth trees allowing for faster forest regeneration cycles.[13]

Why Wood?

Wood was the ideal choice for the structural system of the project. It was chosen due to its sustainability as a material, its strength and durability, its aesthetic qualities, its connection to the project's site, and its positive impact of on the wellbeing of the building's occupants.

Wood is arguably the most sustainable structural system that is readily used in construction. It is a renewable material, is recyclable and/or compostable, has a lighter carbon footprint and has less embodied energy than steel or concrete, among other benefits. It is locally available and can be sourced from nearby to reduce its carbon footprint. Wood is also an appropriate material to the climate of the region. Refer to sidebar for more detail on why wood is considered a sustainable building material.

A wood structural system supports the flexible programme needs in a school. The structure makes it easier for the school to adapt its building to accommodate changes in population and teaching styles. The wood structure allows for flexibility within the floor plan because load bearing wall are minimized in number as the weight of the roof is carried by the beams and column frame, making renovations easier. Wood is also a durable material with a long life cycle that can be expected to last for the school's life. With the average service life of school buildings in Canada being at around 40 years[14], and mass timber structures are designed with projected lifecycle of 90 to 100 years[15], the structure will increase the project's service life.

The aesthetical considerations of the building heavily favoured the use of wood. Its natural beauty and warm appearance is universally appealing and is generally considered to have a positive effect on its occupants, due to its biophilic properties. The wood structure in this project is left exposed to allow it to be seen, touched, studied and enjoyed. Exposing it also eliminates the need for interior finishes. The wood is left unfinished, except for a clear, protective zero-VOC emissive coating.

Why is Wood a Sustainable Material?

- In Canada, wood is a widely available building material, as the country is resource rich in it. Canada has 347 million hectares of forest which covers approximately 35 percent of the country[16], making it one of the countries with the largest forest areas in the world. Canada has the most forest area per capita in the world, at 9.74 hectares per person.[17] Wood has been a plentiful material throughout the country's history and an ingrained part of its culture. As a building material it can be readily sourced locally, saving energy and reducing emissions involved with its transportation to site.

- Wood is a renewable resource, and a tree once harvested can be regrown again and again. Despite perceptions forest stores in Canada are not depleted at as fast of a rate as one thinks. Canada has a low rate of deforestation: less than 37,000 hectares per year, and the deforestation rate has been a declining trend since 1990.[18] Sustainably managed forestry practices help ensure that forests are harvested in a responsible way, so as to maintain the health of our forests long into the future while allowing for social and economic development. Three forest certification programs exist in Canada, the most well-known of which is the *Forest Stewardship Council*, and act as a third-party verification that the wood products being used have come from a sustainably managed forest and have been legally harvested. Wood that meets their standards is marked as FSC-certified.[19]

- Life cycle assessment studies have found that at almost all stages of its life, wood construction products are the more sustainable choice over other structural systems.[20]

- Less energy is involved in the harvesting of trees for lumber than in the extraction of raw material for steel and concrete, which both have to be mined which is energy-intensive and heavily degrades the land.[21]

- There is significantly less embodied energy within the manufacturing of wood products than with steel

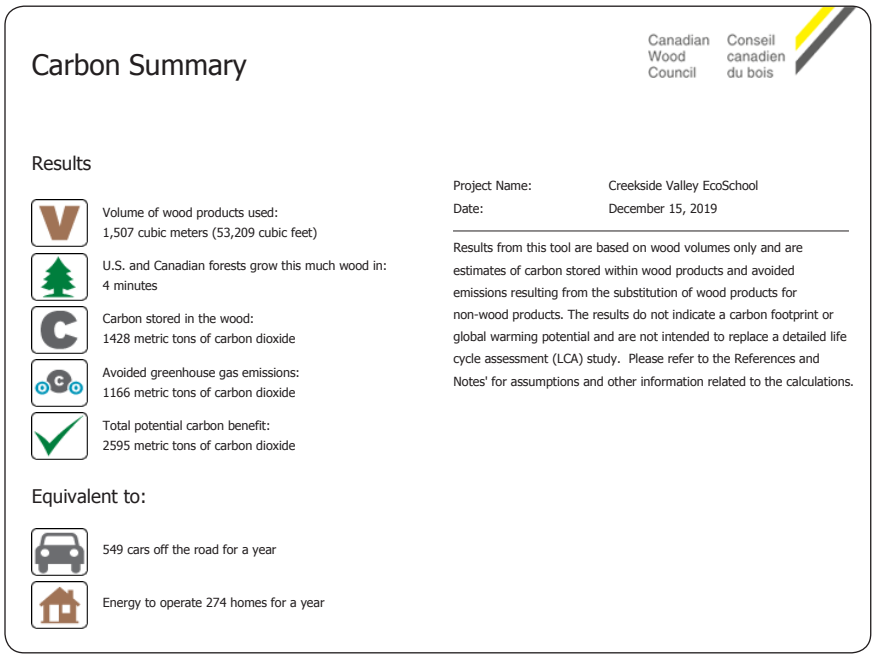


Figure 5.26 - Carbon summary for this project using the Canadian Wood Council's online carbon calculator tool.

or concrete. The manufacturing process for steel and concrete is more complicated, thus much more energy-intensive. The production of steel and concrete relies on fossil fuels to power the process producing increased greenhouse gas emissions, while lumber mills generally use wood biomass fuel.[22]

- Wood is a carbon sink, meaning it stores the carbon which it absorbed from the atmosphere as a tree within the wood itself during its lifetime as a material. One cubic metre of wood stores about one tonne of carbon.[23] This contributes to decreasing wood's overall carbon footprint.

- The building operational energy required for a building with a wood structure has be found to be less than for a building constructed out of steel and concrete. This is due to benefit of the low thermal conductivity of wood compared to the other two materials; the comparable ease with which it is insulated in such a way as to reduce thermal bridging, and the ability for it achieve an highly air-tight envelope, especially when building with mass timber which is manufactured in factories to a high degree of precision.[24]

- At the end of its life, due to its organic structure wood can be recycled and or composted. Possible ways in which wood waste can be recycled is by turning it into new wood products, breaking it down into mulch, or using it as a source of biomass fuel, among many other potential uses. Heavy timber pieces or cladding can be reclaimed for use in a new building. Or it can simply be left to decompose and return to the soil.

Exposing the structure allows it to be celebrated. It's visibility within an interior space has been found by researchers to have a stress-reducing effect on a building's occupants.[25] This is due to the inherent biophilia of wood.

The timber structure creates connections with the building to the site. The material responds to the site, echoing through its repeated frame the rows of trees in the forest just beyond the school's walls, blurring the division between interior and exterior.

Furthermore, the choice of a mass timber structure created an opportunity for innovation. The use of timber for structure and finishes is not particularly commonplace as a material for elementary schools in North America, which generally favour concrete block construction. The proposed design showcases the use of innovative products such as CLT panels, demonstrating to students some of the possibilities of wood design.

Steel Connectors

Steel connectors are used to assemble the framework together. Column-to-beam connections use an embedded knife-plate/ bearing plate connection. Columns are connected to the foundation through a steel plate connection that is bolted to the foundation slab. CLT panels are attached to the frame through self-tapping screws. Steel connectors allow for the disassembly of the structure piece by piece at the end of the building lifecycle, so that the timber frame can be recycled or reused in another building.

Concrete

The timber structure is supported by a slab on grade foundation with perimeter footing. The concrete slab is topped with a thin layer of concrete screed, within which radiant heating tubes are embedded. The finish is left exposed, and polished. Though concrete has a high embodied energy, it was chosen for its thermal mass properties which when exposed to sufficient amount of solar energy, can have a noticeable effect on thermal comfort. Efforts are taken to minimize the concrete's environmental impact by substituting 30% of the cement in the concrete mixture with fly-ash. This is environmentally beneficial because the production of cement consumes high amounts of energy, while fly-ash concrete which is a by-product of the burning of coal is essentially a waste material, thus using less energy while improving the performance of the concrete. [26] [27]

Materials: Building Envelope

Overview

The design of the project's building envelope prioritized the retention of heat and minimizing heat loss as a response to the project's cold climate.[28] The building envelope was designed with high levels of insulation, an airtight envelope designed to reducing thermal bridges, and with a continuous air barrier that controls air infiltration. The control layers are detailed so that they form a continuous layer around the entire building. Refer to the building section of the classroom in **Figure 5.30** for example of the detailing of the building enclosure. Together these strategies make for an efficient building envelope that is the first step in maintaining thermal comfort in the interior space and in reducing the need for mechanical heating and cooling, which in turn reduces the building's energy consumption.

Walls

The wall enclosure is composed out of several different types of assemblies, which are designed in response to their location in the building and/or orientation on the site.

W1 – Exterior CLT Wall

A large portion of the school's exterior walls – particularly areas with large expanses of externally exposed surfaces such as the gymnasium and administration volume - are constructed out of a CLT panel wall assembly clad with a cedar rain screen. The CLT panel acts as the structure of the wall and forms the interior finish. On the outside of the panel are all the control layers: a self-adhered membrane that forms the air barrier, several sheets of rigid mineral wool insulation board with an R-value of 32 *ft2·°F·h/BTU* providing most of the wall's thermal control, and cedar boarding which forms a ventilated rain screen that protects the structure by shedding rainwater. These layers are attached to the CLT panel with long wood screws. The assembly is vapour-permeable, allowing it to dry out in case of wetting, which is important because any trapped moisture can quickly cause rot and damage to the CLT panels, undermining their structural integrity.[29] The total R-value of the assembly is 38.7 *ft2·°F·h/BTU*; this is a highly insulated wall assembly.



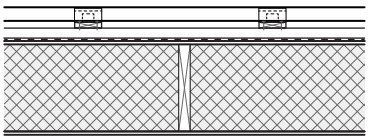
Figure 5.27 - An unframed window opening within the CLT panel reveals the alternating layers of wood of the panel. Example pictured taken at Bill Fisch Forest Stewardship Centre.

The CLT panels are fabricated off-site. Door and window rough opening are cut-out of the panel by CNC machines in the factory. This ensures a high degree of precision in the components, and reduces material waste. The CLT panels would be installed after the foundation is in place. The panels are ready for assembly immediately once they arrive on site are generally installed very quickly. They are lifted into place by crane and attached to the foundation through panel brackets embedded into the foundation. Construction is quick, and minimizes site disturbance with less traffic and noise.[30]

The CLT panel is left exposed on the interior side to showcase the solid wood finish, thereby reducing the amount of material and labour needed in finishing the material. CLT door openings are kept unframed to expose the material's lami-

TYPICAL FLOOR/ROOF/WALL ASSEMBLIES

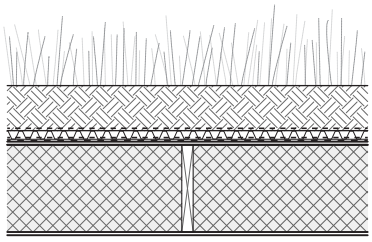
R1 - Copper Cladding on SIP Roof Assembly



- 45 mm high standing seam copper roof panels (24 ga.)
- Roof clips fastened to 19 x 89 mm horizontal wood furring strips at 610 mm o.c.
- 38 x 89 mm wood furring strips installed vertically at 406mm o.c.
- Vapour Permeable Roofing underlayment layer: Asphalt Felt (#15)
- 310 mm thick Structurally Insulated Panels (SIPs) sealed and taped at seams (R-42)

R-Value ≈ 42 ***ft²·°F·h/BTU***
RSI ≈ 7.4 ***m²·K/W***

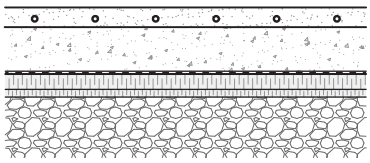
R2 - Extensive Green Roof on SIP



- Vegetation: native grasses and meadow flowers
- 150 mm Engineered soil
- Filter fabric
- 30 mm Drainage board with moisture retention blanket
- Root barrier sheet
- TPO waterproofing membrane
- 310 mm SIPs sealed and taped at seams (R-42)

R-Value ≈ 42 ***ft²·°F·h/BTU***
RSI ≈ 7.4 ***m²·K/W***

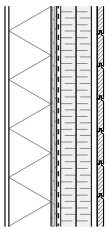
F1 - Typical Radiant Floor Slab



- 65 mm Concrete topping with embedded radiant tubes; polished finish
- 150 mm Concrete slab on grade
- Vapour barrier
- 75 mm Expanded polystyrene (EPS) rigid insulation (R-12)
- 200 mm Loose gravel fill for drainage (capillary break)

R-Value ≈ 12 ***ft²·°F·h/BTU***
RSI ≈ 2.1 ***m²·K/W***

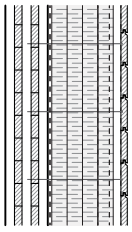
W1 - Upper Clerestory Exterior Wall



- 21 mm Untreated cedar tongue and groove boarding
- Air space with 19 x 38 mm vertical wood strapping at 610 mm o.c.
- 100 mm Expanded polystyrene (EPS) rigid insulation (R-16)
- Water-resistant air/vapour barrier membrane (drainage plane)
- 18 mm Exterior OSB sheathing
- 38 x 140 mm wood stud framing at 400 mm o.c. with 140 mm dense pack cellulose insulation (R-20.2)
- 12.7 mm gypsum board

R-Value ≈ 36.2 ***ft²·°F·h/BTU***
RSI ≈ 6.4 ***m²·K/W***

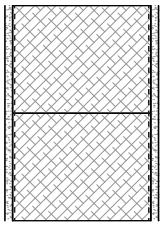
W2 - Typical Exterior CLT Wall



- 21 mm Untreated cedar tongue and groove boarding
- Air space with (2) 38 x 38 mm vertical wood strapping at 610mm o.c. attached with long screws
- 205 mm Rigid mineral wool insulation board (R-32)
- Air barrier: vapour permeable self-adhered membrane
- 140 mm Cross laminated timber (CLT) 5-ply wall panel (R-6.7)

R-Value ≈ 38.7 ***ft²·°F·h/BTU***
RSI ≈ 6.8 ***m²·K/W***

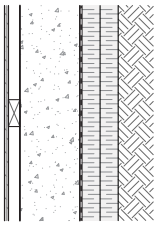
W3 - Exterior Straw Bale Wall



- 25.4 mm Lime plaster finish over metal lath
- 457 x 356mm Straw bales stacked horizontally (R-37)
- 25.4 mm Earthen plaster finish over metal lath

R-Value ≈ 37 ***ft²·°F·h/BTU***
RSI ≈ 6.5 ***m²·K/W***

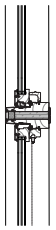
W4 - Retaining Wall



- 120 mm Rigid mineral wool insulating drainage board (R-20)
- Dampproofing
- 200 mm Concrete retaining wall
- 38 x 89 mm Wood stud cavity
- 13 mm Composite natural fibre board (left unfinished)

R-Value ≈ 20 ***ft²·°F·h/BTU***
RSI ≈ 3.5 ***m²·K/W***

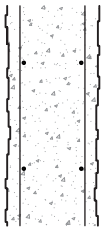
W5 - Glazing



- Triple-glazed insulated glass unit; argon-filled with single low-emissivity (low-e)

U-Factor:
U-0.25 (R-4) for south orientations
U-0.2 (R-5) for north orientations
SHGC: 0.6 for south orientations to maximize solar heat gain; 0.3 for north orientations as solar heat gain is low

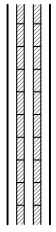
W6 - Thermal Mass/Storage Concrete Wall



- 300 mm Solid concrete wall; board-formed finish

R-Value - ***negligeable***

W7 – CLT Shear Wall



- 140 mm Cross laminated timber (CLT) 5-ply wall panel (R-6.7)

R-Value ≈ 6.7 ***ft²·°F·h/BTU***
RSI ≈ 1.2 ***m²·K/W***

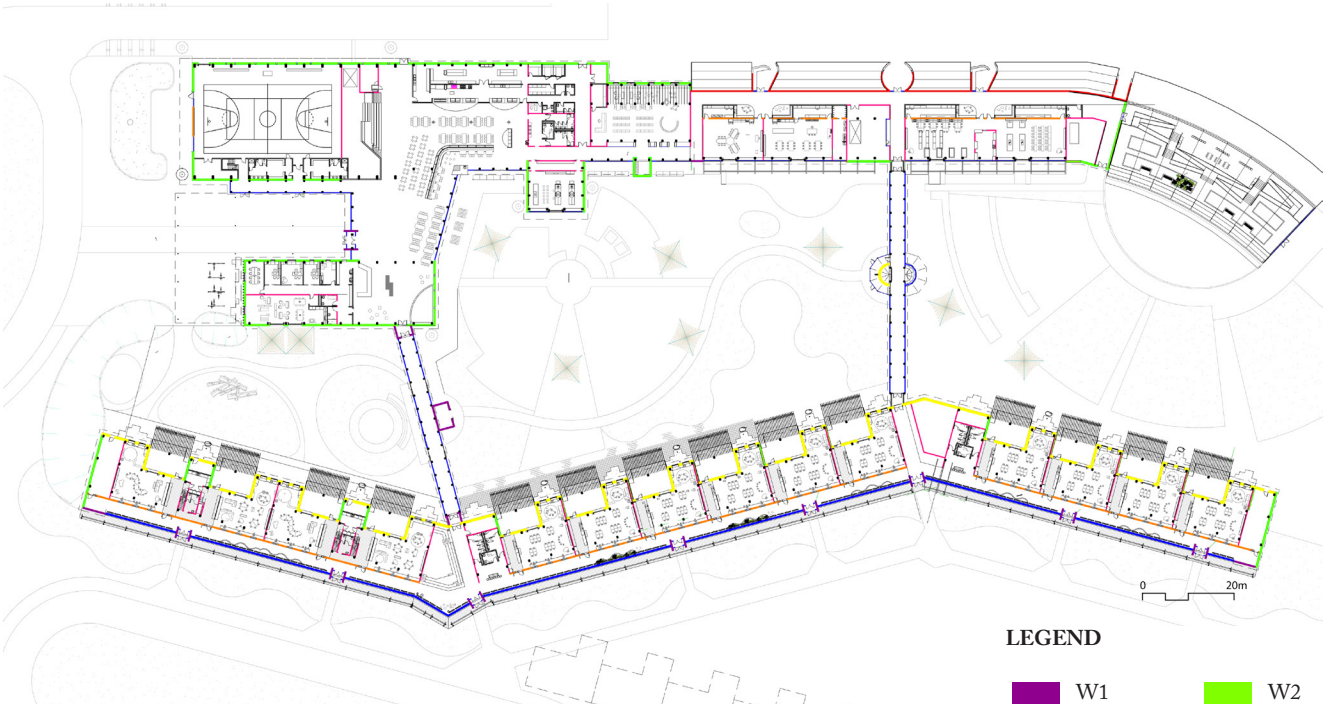


Figure 5.28 - (opposite page) Typical Floor/Roof/Wall Assemblies
Figure 5.29 - (top of page) Diagram of the location of the various wall assembly types throughout the building.

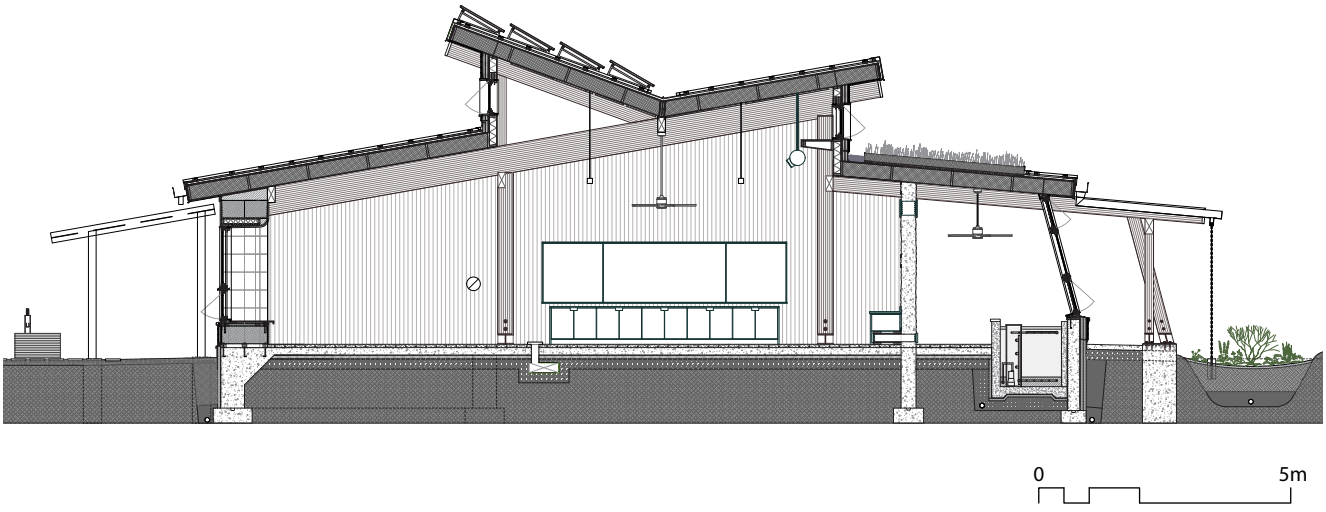


Figure 5.30 - 1.100 Cross section of the classroom module showing the construction of the building envelope.
The envelope was designed to be highly insulated, airtight with a continuous air barrier that minimizes thermal breaks, and properly sealed for moisture protection, forming an high-performance building enclosure that keeps heat in, cold air out, and reduces the heating/cooling load demand of the building.

nated layers, and create a learning opportunity for students.

CLT panels have been found to have a positive effect on quality of the interior space and occupants' wellness. They improve the air quality of space by reducing humidity through the hygroscopic qualities of wood.[31]

W2 – Light Wood Framing Stud Wall

In areas of the façade where CLT panels were not suitable, a light wood framing stud wall was constructed. This is primarily for walls such as the upper clerestory walls where the use of CLT panels would have been an inefficient use of material for such a short wall and one with so many openings.

The wall assembly uses two types of insulation, in two locations within the wall in order to increase the overall R-value of the wall. If all of the insulation were to be placed in between the stud framing, the current standard 140mm thickness of the cavity would have to be built-out in order to accommodate the additional insulation, requiring double the framing material. The solution was to fill the cavity with 140mm of dense-packed cellulose insulation in between the studs, and place 100mm of expanded polystyrene (EPS) rigid insulation on the exterior of the sheathing. The proportion of rigid insulation to fluffy insulation needs to be a certain ratio in order to keep the sheathing warm and prevent condensation. The project site is in Climate Zone 6, and thus required a minimum of 36% of the wall's total R-value to come from rigid foam insulation. [32] Correspondingly, in a wall assembly with a total R-value of 36.2 *ft2·°F·h/BTU*, R-16 comes from rigid insulation.

The wall assembly's vapour barrier membrane is placed on the warm side of the exterior insulation, right over top of the sheathing, forming the drainage plane. The wall assembly can dry to the inside or outside of the drainage plane in case of wetting.

Both insulations selected are an environmentally sustainable choice and offer good insulation performance. Dense-packed cellulose insulation is made out of recycled newspaper that has been shredded into smaller pieces. It is generally blown into wall cavities which packs it together densely, helping minimize air infiltration.[33] EPS insulation has a lower R-value per inch of material than other rigid foam insulation, but it makes up for that with a lower environmental impact than others. EPS insulation is the only foam insulation manufactured without CFCs or HCFCs (toxic chemicals that are red-listed).[34] Other environmental benefits are that the manufacturing process is not energy intensive and at the end of its life it is recyclable.

Western red cedar cladding is the primary exterior finish material in this project, and was a suitable choice for the material of the rain screen because of its durability. Cedar is a wood that is naturally resistant to moisture and decay due to oils in the wood, which make it an excellent material for exterior applications.[35] The material does not require the application of chemical treatments for protection, and so in this project it is left to weather with age. The cladding was also chosen due to aesthetic reasons. The rich reddish-gold tones of the cedar boards will over time turn a softer silvery grey that blends in well with the natural surroundings of the site. Allowing materials to show their age is an element of biophilic design, as nature is not static.[36]

W3 – Exterior Straw Bale Wall

The north façade of the classroom side of the campus is constructed entirely out of straw bales. The enclosure on this orientation was treated differently than on the other sides due to its facing the prevalent winter wind direction, and it not receiving any direct daylighting or solar gain. More than any other orientation, the north face of the building envelope needed to be highly insulated, to protect it from cold air infiltrating the assembly. Straw bale walls were thus chosen for the north-facing envelope as they are able to provide very high levels of insulation, and at a reduced economic and environmental cost than conventional insulation. It also created an opportunity to showcase an unconventional but natural building material.

The straw bale wall assembly in this project consists of three-string straw bales (457mm wide x 356mm high x 813mm long) laid flat and reinforced with a 25.4mm thick plaster skin and metal lath on both sides of the bale. On the portion of the wall that forms the window seat the bales are doubled up to increase the seat depth. In straw bale systems the bales act only as insulation. At a thickness of 457mm, they are able to provide a thermal resistance somewhere around R-35 *ft2·°F·h/BTU* (tests have found varying values, generally though they range between R-30 to R-40).[37]



Figure 5.31 - The various soil types found on the project site. To the left is the clay soil that would be suitable for use as plaster. Soil in this region in known for being clay-rich. Photo taken on the Milton project site.

It is the plaster skin that supports the structural load with its stiffness, forms the air and vapour control layer, protects the bales from moisture and damage from insects and pests.[38] The plaster skin in the project's assembly differs on the exterior and interior. The exterior skin is a lime plaster finish, selected due to its "durability, strength and permeability."[39] Since the plaster contains lime it has a higher embodied energy from its production (it comes from limestone), but it is long-lasting making it suitable for exposure to the elements. In contrast, the interior skin is earthen clay plaster (a mixture of sand and clay) which is a more natural but softer finish. Clay plaster has a very low embodied energy, and this project's site has soil that is suitable enough (clay-rich) that the plaster could be made from the site soil.[40] This would create an immediate connection between the building and the site. Both plaster skins provide the wall assembly with a thin layer of thermal mass that is spread out over a large surface area.

As the timber frame supports the entire roof load of the classrooms, the wall assembly was able to be designed as a non-load bearing straw bale system, also known as a "bale wrap" or bale infill system[41]. The bales are tied to the frame, and a simple plywood baffle at the top of the wall to air-seal it. The connection point between the bales and foundation is designed so that the bales do not directly sit on the foundation, but on a 2x4 wood sill that in anchored to it. The foundation footing is widened underneath the thick straw bale wall, and the slab edge is thickened to support weight of the bales. Using straw bales as infill allows for the structure and roof to be built beforehand; thereby providing protection from rain during the construction of the straw bale wall which is important because straw bales need to be kept dry to prevent mold issues. The inherent imprecision of the system allows the installation and plastering of straw bales to be done by anyone (no need to be an expert), and so would be able to involve volunteers from the community, including future students. The plastering of straw bales is a very hands-on and messy process and can be great fun for those involved.

Besides their effect on improving the energy efficiency of the building envelope, straw bales were also chosen because of the low environmental impact of the material. Straw bales are seen as a waste material of agriculture – the stalks left over from the harvesting of crops – and are generally burned if no other use is found for them. The material is renewable, growing at a fast rate, and is locally available in a rural area such as that of the project site. The system has a very low embodied energy and the straw as a material sequesters carbon.

Furthermore, the wall assembly also improves the air quality of the interior space. The materials are entirely VOC-free, and produce no off-gassing. Similarly to wood, both straw and earthen plasters are hygroscopic material that absorb and release water helping regulate indoor humidity levels.[42] Earthen plaster also has the ability to filter out pollutants from incoming air. Also have good sound insulation qualities as the mass of the wall has been observed to reduce noise coming from the outside. [43]

The aesthetics of straw bale walls were also influential in the decision to use them. The massive appearance of the wall is immediately perceptible around window openings and stands in sharp contrast to other wall finishes. The thickness of the wall assembly is taken advantage of in the design to create a niche on the window sill that becomes a window seat. The biophilic properties of the material such as the naturalness, the lack of straight edges and the imperfections of the surface, have an overall positive effect on the indoor environment. To touch the earthen clay finish feels different from other machine finished surfaces, and can sometimes even "dust..if brushed by moving bodies." [44] The malleability of the material allows for rounded window openings, introducing organic elements into the space. The colour of the wall will depend on that of the site soil, or if a classroom choose to it can uses pigments or natural paints can be used to colour the plaster. Each classroom has a "truth window" to reveal the composition of the walls.



Figure 5.32 - A truth window revealing the straw bales, reinforcement mesh, and string ties beneath the inconspicuous white plastered wall. Example of what truth windows can appear like, taken at the Grand House in Cambridge, ON.

Roof Assembly

SIPs

The main component of the school's roof enclosure are structurally insulated roof panels (SIPs). SIPs are composed of a thick layer of rigid insulation sandwiched between two exterior sheathing boards and laminated together.[45] The SIPs used for the proposed school are all 310mm thick panels and are made up of 11mm oriented strand board (OSB) for the outer shells and EPS insulation for the core. They provide a thermal resistance rating of R-42 *ft2·°F·h/BTU.*[46] EPS insulation was chosen over other foam cores with a higher R-value due to the reduced environmental costs associated with it, despite the need to specify thicker panels to reach the same level of thermal insulation. Furthermore, with EPS insulation as the core and OSB as the outer sheathing, at the end of their life the panels will be able to be recycled in their entirety.

The SIPs come in large panel sizes, readily available as panels measuring up to 2.4m by 7.3m. Panels are splined together at the seams with a block spline (a thinner SIP assembly block), and sealed with foam along the edge.[47] The connection

points are sealed with SIP tape supplied by the manufacturer.

SIPs and timber framing are a perfect match. SIPs work well with post-and-beam timber construction because the panel system can serve as more or less an infill system. The strength of the panels combined with their large size allows them to span across the wide structural bays. The heavy timber structure is erected first and provides the frame on which afterwards the insulated panels are placed to enclose the space, creating a continuous uninterrupted layer of insulation. When properly taped and sealed it creates an airtight envelope that eliminates/reduces thermal bridges and reduces air infiltration. This continuous air barrier in combination with the high R-value makes for an energy-efficient building envelope that reduces the energy needed to heat and cool the interior space. The interior air quality is also improved as air infiltration from the outside is controlled, preventing pollutants from coming in.[48]

Another benefit to using SIPs for the roof envelope is a fast and efficient construction process. They are prefabricated off-site, and once the structure is ready they are lifted into place over top of the framework. SIP screws will be used to join the panels to the structure. The SIP system is assembled quicker than and uses less wood than conventional framing.

The panels are left unfinished on interior in the majority of the spaces in the school. The OSB sheathing is left visible, and the SIP tape is covered at the seams with a thin wood trim. The purpose of the raw design aesthetic is for "transparency" – to allow the students to see and study the materials from which the school is constructed, rather than have them hidden away neatly underneath the surface.

Roof Finishes

There are two roof finish types for the building: standing seam copper roofing, an extensive green roof system.

Copper Roofing

Majority of the roof surface is finished with standing seam copper roofing. The copper metal sheet panels are folded into 45mm high pans, and fastened with clips to furring strips, not directly to the OSB sheathing. The standing seams run parallel to the direction of the roof slope, channeling rainwater and snow off the roof and into the gutter. Standing seams shed water and snow well and have historically been used in cold climates that annually receive snowfall.

The roof is designed as a vented assembly: a ventilation channel runs between the copper roofing and the SIPs, allowing air to be introduced at the fascia. The purpose of this detail is as an extra measure to keeping the SIP panels dry in the case of wetting. While when installed correctly the copper metal roofing reliably protects the roof's structure from the elements, water particles carried in the air usually find their way into an assembly. If the roof is not able to dry out, the moisture can become trapped, condense on the cold outer surface of the SIPs and cause water damage to the exterior OSB sheathing board.[49]

Copper roofing was chosen as the main finishing material due to its high durability, which makes up for the initial high cost and energy it takes to manufacture it. The material is durable because it naturally develops a patina that protects it

from corrosion, allowing the roof to last for upwards of 100 years and with infrequent maintenance.[50] A copper roof will endure for the entire school building's life. Copper is a more sustainable material than it appears at first, because when its embodied energy takes into account its long lifecycle, the value is much lower than that of many other roofing materials. Furthermore, after its life as a roofing material ends it can be recycled, as it is a very salvageable material.[51]

Copper was also chosen as a roofing material for aesthetical reasons. The material is a great example of the biophilic design attribute of "age, change and patina of time."[52] The material naturally weathers, gradually changing its colour and texture from the bright, shiny copper colour of a new penny, to a sequence of increasingly darker more muted shades of brown, to eventually a bluish green colour that is its fully developed patina. The connection to the context of the site was another reason for choosing this material. The copper material with the patina it will soon develop will closely resemble weathered roof of the barns across the road, connecting the building to vernacular agricultural architecture found in the town's more rural parts.

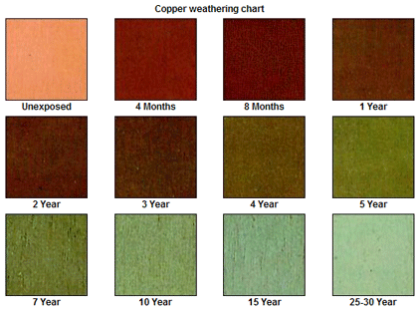


Figure 5.33 - "A Patina of Time." Copper changes colour as it is exposed to the atmosphere, developing a patina over time. The process is gradual and over its course the copper takes on a number of shades before its final green.

Green Roof

The desire to showcase a green roof was limited to a few locations due to the system's dependence on a low-slope surface. A green roof is found on: the roof above the classroom corridors, the rooftop terrace above the main entrance, and the portion of roof over top of the science lab corridors that is built into a berm.

The green roof above the corridors was designed as an extensive green roof, with 150mm depth of growing medium. Designed to be inaccessible to humans so as to keep it lightweight and the support structure to a minimum, the roof is vegetated with plants with shallow roots and little to no irrigation needs, limiting the plant community to sedum, grasses, native prairie flowers, and herbs (like thyme, sage and rosemary). The green roof assembly was designed with attention to protecting the SIPs below from water damage, as any water leakage can quickly lead to the rotting of the OSB layer which would compromise the structural integrity of the panel. A TPO (thermoplastic olefin) waterproofing membrane was selected to create this impermeable layer over the more commonly used but toxic PVC membrane (a toxic, red-listed material, but very durable).[53] A root barrier sheet – a thin polyethylene layer – protects the waterproofing membrane from root penetration. The subsequent layers above this are designed to support the health of the vegetation.

The green roof above the main entrance to the school is similarly an extensive system in regards to being a shallow build-up, but the roof is accessible to people and used as a terrace by the school. To address this the structure below is designed to support the extra weight. The green roof above the science lab corridor acts as more of a berm, and so the building structure in that part of the school is designed as a retaining wall.

When constructed carefully a green roof can offer many benefits to the building. It helps moderate indoor temperatures by providing additional thermal mass that acts as extra insulation in the winter reducing the amount of heat that is lost through the roof. In the summer the plants help keep the roof cool as they absorb less radiation than dark conventional roofing material. The green roof introduces

elements of nature to the building, and helps the school blend more harmoniously into the landscape. Green roofs also provide numerous environmental benefits to the site. They help with stormwater management by reducing rainwater runoff, help mitigate heat island effect, and provide a new habitat for small wildlife like birds and insects.[54]

Transparent Elements

Glazing

Much of the south façade of the building is glazed to increase passive solar gain and daylighting. This is due to the prioritization of heat gain in the project's cold climate. The north façade also has some glazed elements (mostly on the south wing), in order to bring daylight from the other side. Openings are minimized on the east and west facades in order to reduce heat loss and prevent undesirable heat gain during the cooling season; as daylight from these directions due to its angle provides little winter solar gain, as well as causing glare issues (especially from the west direction).[55]

Two types of windows are used throughout the building. Both types are triple-glazed insulated glass units filled with argon gas and with a single low-emissivity (low-e) coating to insulate the weakest point (in regards to thermal performance) in the building envelope. The varying U-values and SHGC respond to the orientation of the glazing:

South Orientation: Windows have a U-factor of 0.25 (R-4) and a SHGC (solar heat gain coefficient) of 0.6 to maximize solar heat gain.

North Orientation: U-factor of 0.2 (R-5), and a SHGC of 0.3 as solar heat gain is low from the north side.

All windows frame are constructed out of timber and clad with aluminum on the exterior side. The external cladding will protect the wood frame from moisture damage, extending the life of the glazing units, which is particularly desirable as windows are generally the most expensive component if the building enclosure.

On areas of the envelope with large expanses of glazing a bird screen is installed over the windows to help prevent bird collisions and thereby protect the abundant wildlife which inhabits the adjacent woodland. The bird screen of choice is a playful white dotted pattern sticker placed across the outside surface of the window.

ETFE

The skin on the greenhouse is constructed out of a three-layer ETFE cushion system. ETFE (ethylene tetra fluoro ethylene) is a thin plastic foil that can be used as a replacement for glazing due to its ability to transmit high levels of daylight (up to 85% light transmittance) and across the entire UV light spectrum.[56] This transparency makes it ideal for use as a greenhouse envelope, where high levels of light are vital for the wellbeing of the plants. ETFE cushions are made by expanding layers of foil with air, which is continuously pumped into each individual cushion from an air handling unit. A three-foil cushion inflated with air has a U-value of

1.96 w/m^2 °K, as the air gives the cushions some insulative qualities.[57]

ETFE foil is a fairly environmentally sustainable material. It has a lower embodied energy than glass and other transparent materials, as the thin lightweight nature of the foil requires little energy to manufacture (though as a plastic material it still requires to be manufactured with fossil fuels), and its weight and ability to be rolled make it easier to transport and install thereby further reducing its embodied energy. Its low weight of 2 - 3.5 kg/m^2 [58] has further benefits in terms of resource efficiency as it allows for reductions in the size of the structure supporting it. ETFE foil has a long life expectancy of approximately 50 years due to the durability of the material against weathering, and at the end of its life is completely recyclable.[59]

ETFE was specifically chosen for this project because of its ability to act as a tensile fabric. It can follow the curved glulam frame closely, in a way that glass cannot, while offering superior light transmission levels that are required in a productive greenhouse. In regards to its aesthetic value, the fascinating appearance of the cushions would no doubt intrigue the students. Its use creates an opportunity to showcase the application of an innovative product, demonstrating to students alternative and more sustainable methods of construction.

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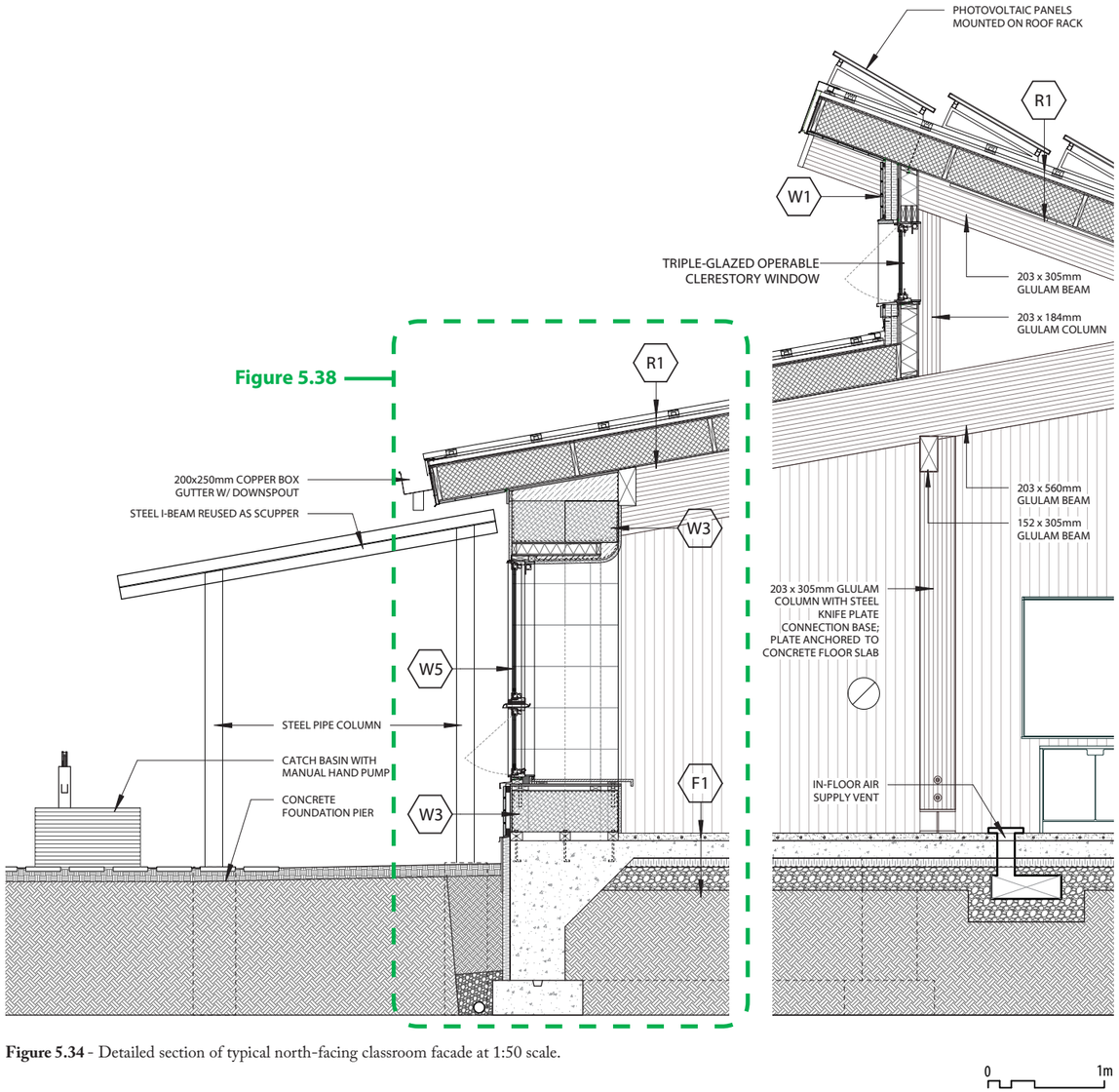


Figure 5.38

Figure 5.34 - Detailed section of typical north-facing classroom facade at 1:50 scale.



Figure 5.35 - Rendered elevation of typical north-facing classroom facade at 1:50 scale.



Figure 5.36 - Rendered elevation of typical south-facing classroom facade at 1:50 scale.

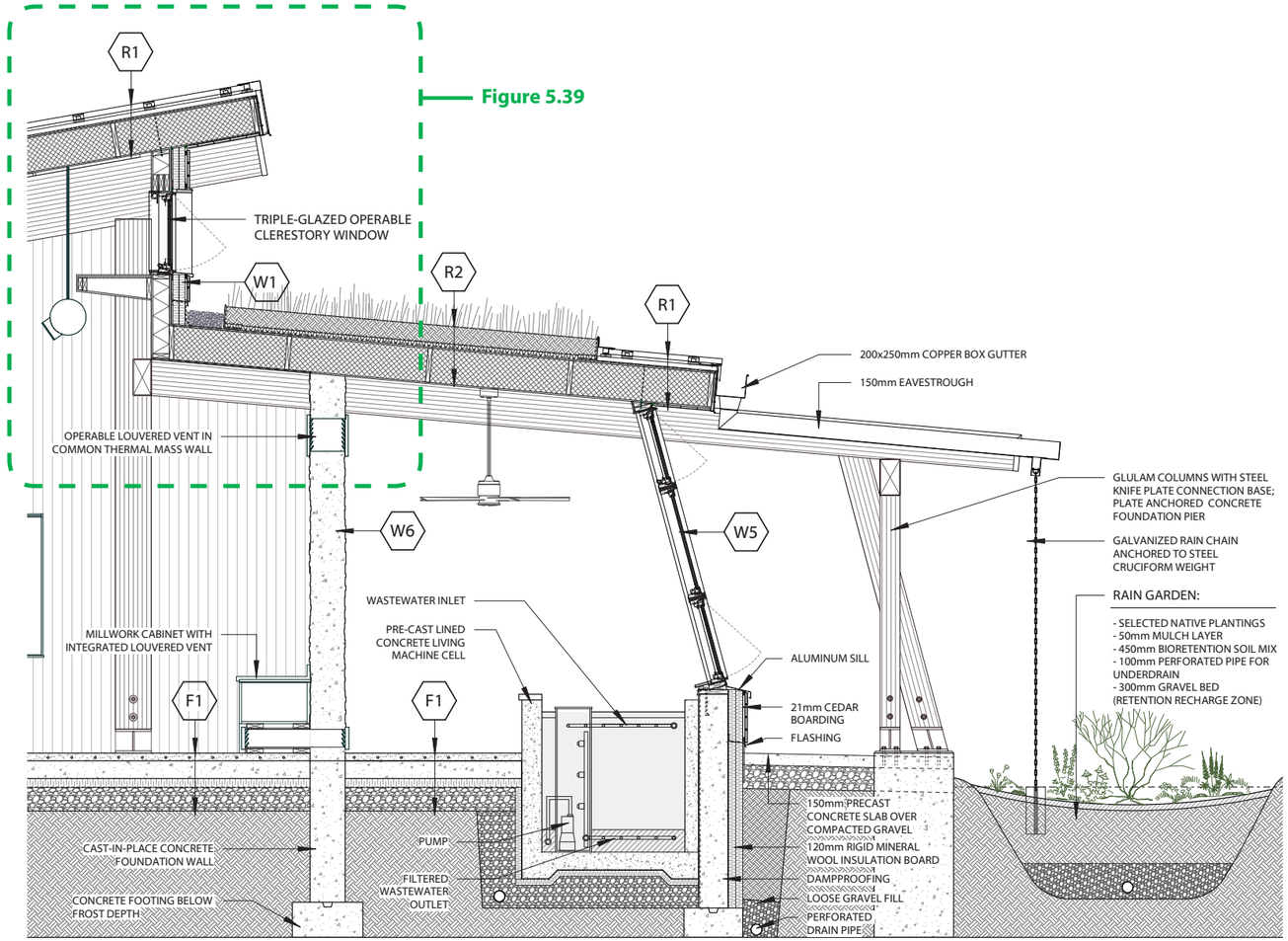


Figure 5.37 - Detailed section of typical south-facing classroom facade at 1:50 scale.

Figure 5.39

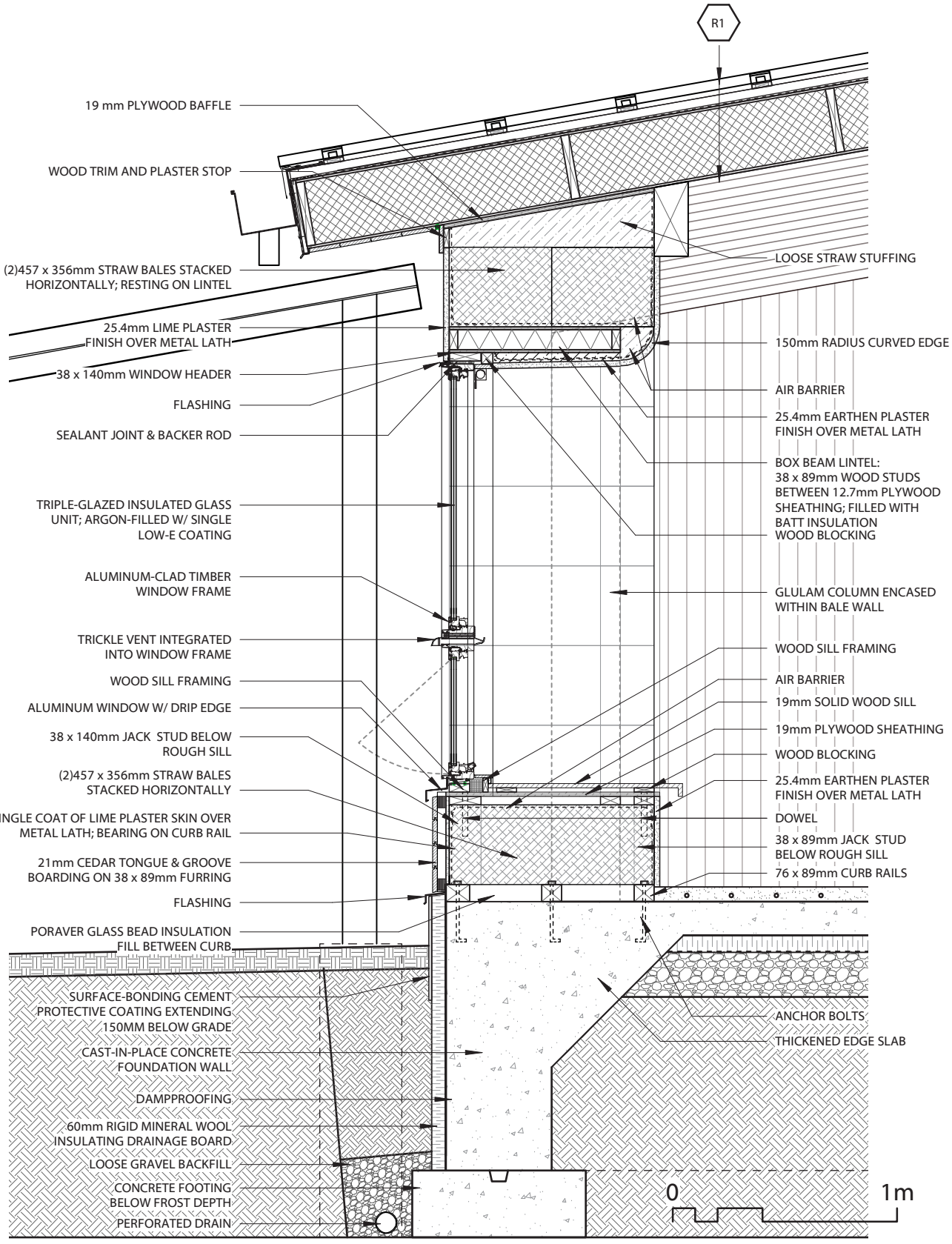


Figure 5.38 - 1:25 Typical Classroom Straw Bale Window Seat Detail

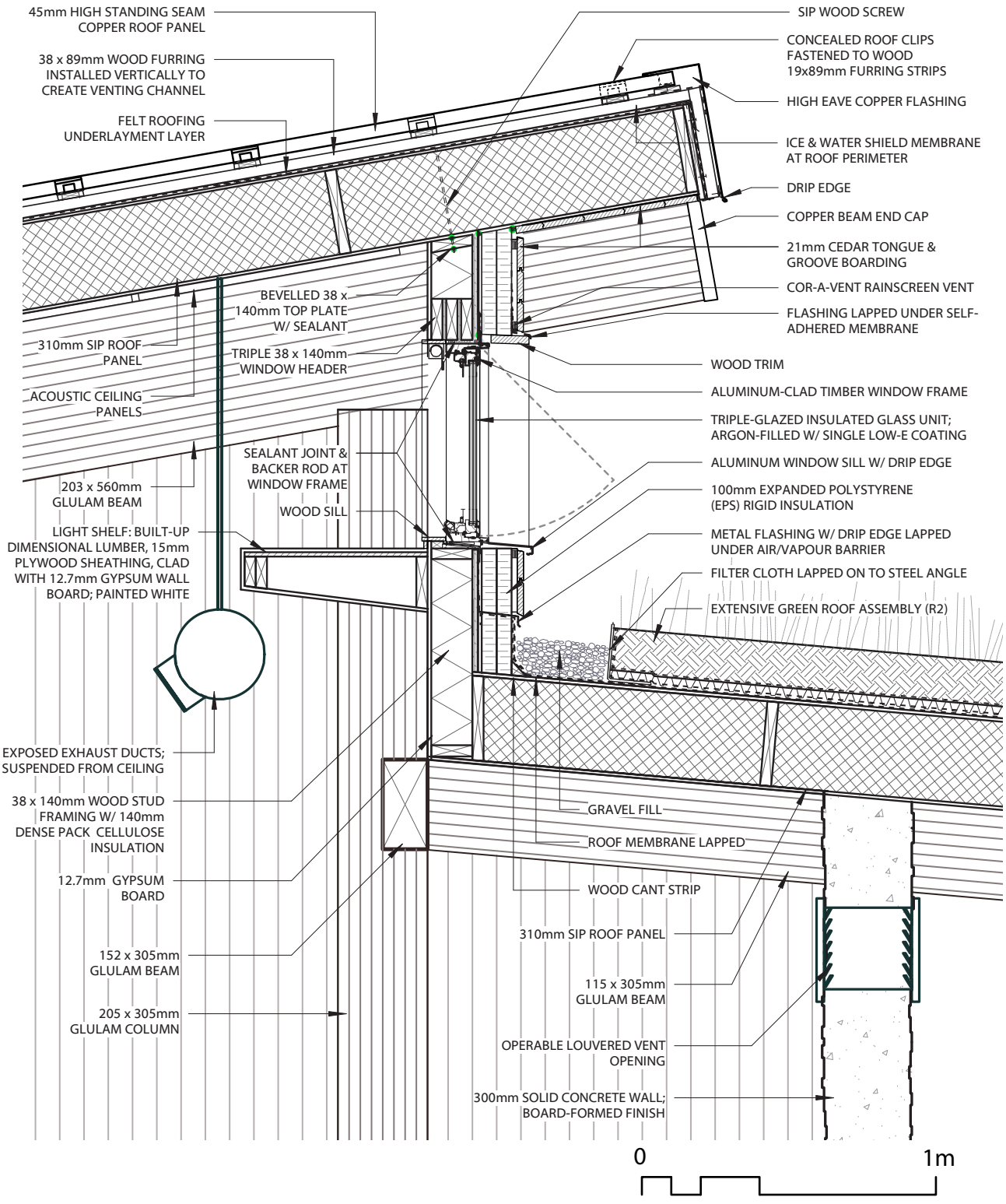


Figure 5.39 - 1:20 Typical Classroom Clerestory Detail.
"INNIE WINDOWS" – All windows are inset to protect them from exposure from elements such as rain and wind which increases their durability, as well as slightly improving their thermal performance, (as recessing them into the wall creates a small sheltered microclimate around the face of the windows keeping them warmer). Innie windows are also more structurally sounder as they rest on and are supported by the structure of wall, not only by the rigid insulation layer.

5.3 - Sustainable Design Strategies

Overview

As a *green school*, the overarching goal of the proposed school design is to foster environmental stewardship behaviour in its students, and accordingly the built environment of the school is designed to model to students a positive and responsible relationship between the building and nature. The sustainable design of the school takes an ecological design approach, integrating the building with the living processes on the site in order to minimize its negative environmental impact. The building connects to the flows of energy on the site – the sun, wind, and water – using them as sources of renewable energy and resources. The building's operations are merged with the natural processes of the site, functioning as part of the ecosystem.

Passive Design Strategies

The design's approach relies on passive strategies first to control the environmental comfort within the school building, and then fills in the gaps with active strategies where needed. Passive strategies help reinforce the students' connection between the indoors and outdoors, using elements of the site for daylighting, natural ventilation and radiant heating from the sun in nearly all the spaces of the school.

The passive design strategies of the project respond to the site's variable climate of cold winters and warm, humid summers, addressing both heating and cooling needs by developing the building's form and material design in relation to the presence of the sun and wind on site. As a result, the school is able to function in "natural mode" for much of the year (fall and spring seasons) as the indoor environment is able to be kept comfortable without needing to rely extensively on mechanical heating and cooling, and artificial lighting. This is turn results in a building with a reduced operational energy demand for heating, cooling and lighting. The following section breaks down the specific passive strategies employed to achieve these bioclimatic goals in the design of the school building and grounds.

Figure 5.40 - (opposite page) Nature at the school. How the elements of nature are at work in the school. The diagram provides an overview of the environmental design strategies incorporated into the design and how they connect to the natural processes and flows on the site.

DESIGNING WITH NATURE

SUNLIGHT:

- Natural light is admitted to daylight the space, activating and illuminating them
- Sun is blocked to shade building and keep it cool during the summer
- Rooftop PV array captures solar energy to power the building through renewable resources
- Thermal mass storage materials capture & store solar radiant heat and release it to heat the building
- Solar collector heats hot water through sun
- Sundial & compass teach about sun's position & building orientation

WATER:

- Rainwater in collected from roofs, stored in visible cisterns and used on site
- Exaggerated gutter and hand pump engage students; make process visible
- Distinctive inverted umbrella canopies collect rainwater for use in courtyards
- Rainwater run-off is retained in rain gardens and bioswales
- Wastewater is filtered on-site, the process of which is highly visible to occupants

WIND:

- Fresh air is introduced through operable windows, improving air quality
- Cross ventilation through space provides free cooling
- Windcatcher introduces fresh air to spaces without access to windows
- Wind energy captured through root-top wind turbine
- Building creates microclimate within courtyard by protecting it from cold winds

EARTH:

- The earth's capacity to store heat, is taken advantage of, providing geothermal energy to heat and cool the building. Energy is transferred through earth tube and vertical ground loop system.
- School is built into the earth, with a portion of the north wing underneath a berm
- Outdoor classrooms are cut out of earth
- Touching the soil when working in garden

PLANT LIFE:

- Natural materials such as straw, wood and clay are used in construction
- Edible garden is incorporated into lessons
- Seasonal changes of colours and leaf cover are observed through landscaping
- Living Machine & constructed wetland both utilize plants to filter and clean water
- Natural playground utilized elements of nature for play
- Plant life is introduced indoors through green wall, planters, and living machine cells
- Native wildflowers and grasses are propagated

ANIMAL LIFE:

- Pollinator garden & green roof attracts wildlife
- Students help care for & interact with chickens
- Microorganisms are utilized in the Living Machine to clean wastewater
- Species room in science wing showcases native aquatic species
- Bird screen on windows protects local birds
- Iconography & symbols around the school familiarize students with local wildlife

Building Orientation and Form

The orientation and building form are important passive design strategies that were developed to maximize opportunities for passive solar heating, natural ventilation and daylighting in the building design. Careful thought was given to how the school would be placed on the site. Orientation and form as elements of basic building design have a significant impact on the energy efficiency of the school as they determine its future energy consumption from the offset and for the rest of the building's lifetime.[1, 2] They are designed in conjunction to each other to harness solar energy and prevailing winds, admitting or blocking them as is seasonally appropriate to the building's advantage and help contribute to the achievement school's targeted net-zero energy performance.

Orientation: East-West Axis

In the context of the cool climate of southern Ontario, priority is given to heating of spaces for much of the year and the orientation of the building on the site is primarily guided by the sun's path, seeking to capture as much free heating during the winter as possible by positioning majority of the rooms to face the sun. The school is oriented on the site with the long axis of the building running in the east-west direction. The programme spaces are arranged along an east-west axis so that majority of the building envelope is oriented towards the north and south direction. This forms a long south-facing façade which maximizes the surface area exposed to the winter sun and increases the potential for passive solar heat gain. In turn, this reduces the amount of supplementary winter heating (mechanical) that is needed within the building.

Effort was made to position all major programmatic spaces in the design proposal so that they face due south, for in order to maximize the potential for winter solar gain fenestration must be positioned within 30 degrees east or west of true south.[3] This is because in the northern hemisphere true south is where the sun is when it is at its highest position in the sky, and thus at its strongest.[4] This occurs at noon, when the sun's high position shortens the distance UV rays (the incoming heat) must travel. The closer to due south that a surface faces the greater the potential for passive solar gain. Conversely, the greater the difference from due south, the less effective the glazing will be at capturing free heating.

The north wing of the school faces due South and the south wing (housing the classrooms) faces near due south. The south wing which was broken down into three segments, a design move made in order to form grade divisions and create more interesting pockets of outdoor space, is oriented so that each classroom wing is rotated 15 degrees of either east or west of true south, allowing it to maintaining near-maximum passive solar heating efficiency.

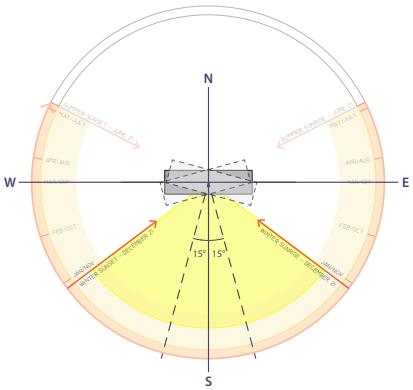


Figure 5.41 - The building must be oriented within 15° east or west of true south to maximize solar gain during the winter.

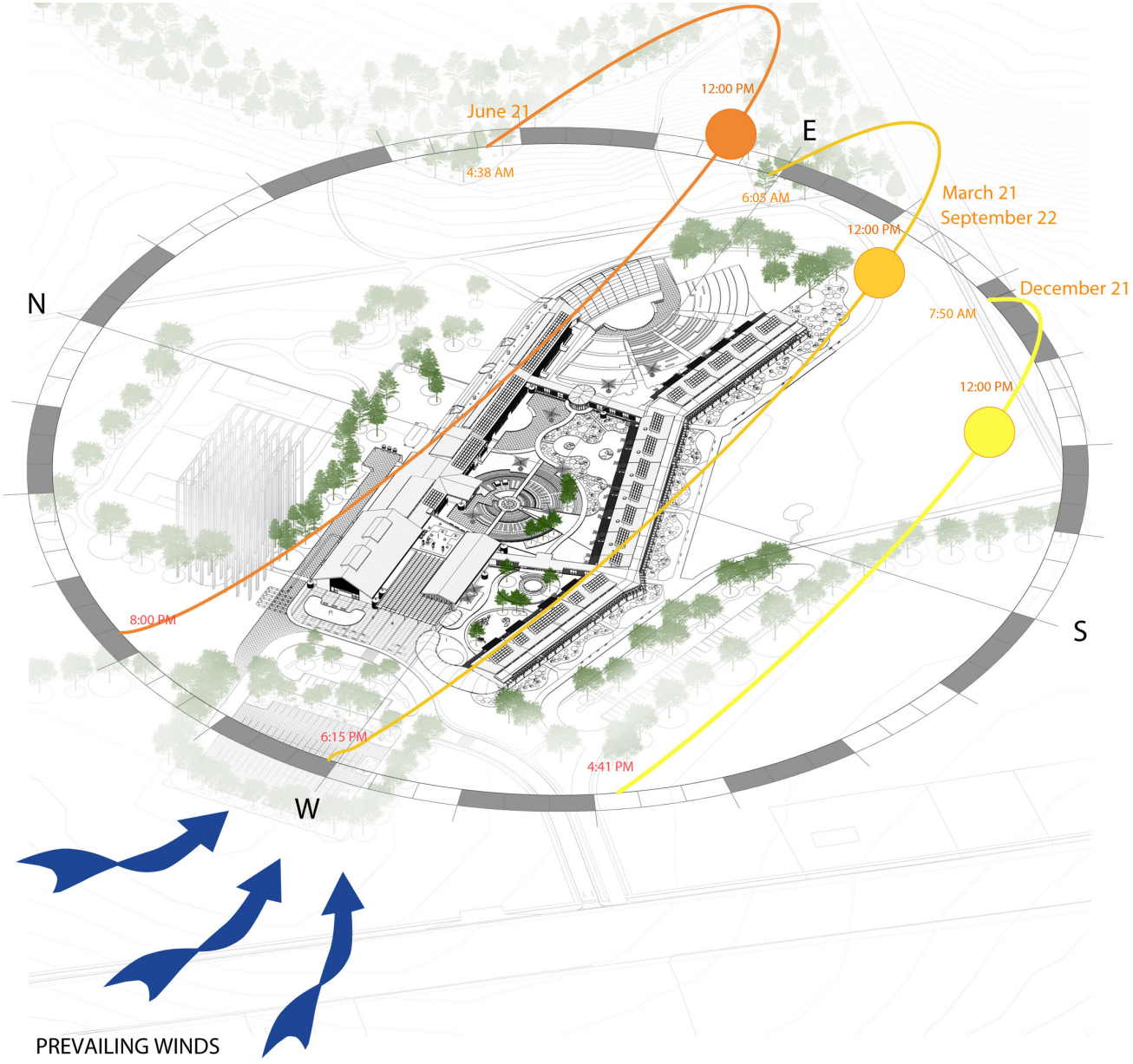


Figure 5.42 - Axonometric Sun Path Diagram

Building Form: Skin-load Dominated Building

"Whereas a mechanical system shapes the climate to fit the building, a passive solar building shapes the building to fit the climate."[5]

The school is designed as a *skin-load dominated building*. This term refers to a building where all occupied spaces are arranged along the perimeter, resulting in a building form with a long and narrow floor plate and a large surface area that is exposed to the exterior. Due to the large perimeter surface area that is exposed to the elements, the climate has significant influence on the thermal comfort within the building.[6,] In the proposed design the skin-load dominated form was developed as a strategy for passive solar heating, natural ventilation and daylighting, as it increases the surface area of the façade that faces the sun and wind. This building form is beneficial to improving the thermal comfort and environmental quality of the school's indoor spaces because each room is situated on the perimeter which gives users direct access to operable windows from at least one exterior wall. This increases the admission of daylight and natural ventilation in each space, and allows occupants control over their environment. Beyond environmental performance goals, the large perimeter surface areas have the additional advantage of increased visibility of and access to the outdoors, improving occupants' connection to nature.

The floor plate of the south (classroom) wing alternates between 11 and 16 meters in width. The width of the floor plate of the north wing ranges between 13.7 to 18.6m in the regularly occupied areas of the plan, with the exception of the gymnasium the width of which extends to 25m and was necessitated by the program requirements.

By minimizing the amount of envelope that is exposed to east and west direction, the arrangement further improves thermal comfort during the summer preventing overheating by minimizing openings on the east and west faces which are more difficult to shade than windows facing south.[7] Glazing on these sides generally results in unwanted heat gain in the summer, glare issues in regards to daylighting as the sun is at a lower angle in these directions, and during the winter very little heat gain, just heat loss.[8]

One unfavourable condition that is created is that a large portion of the north building envelope is exposed to the elements. The negative effect however is mitigated by employing design strategies to shelter the building from the cold north-prevailing winds. The north wing is partially uses earthen mass to shelter the north face of the building. Trees on north-side serve as windbreak. The amount and size of the windows on the north face are limited to minimize heat loss maintaining the minimum aperture opening size to allow for natural ventilation during warmer months.

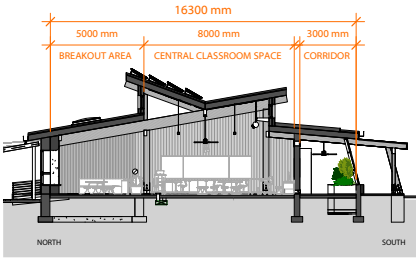


Figure 5.43 - Cross section through classroom with dimensioned width of floor plate.

Building Form: Courtyard

The building program is divided into two wings which are arranged on opposite sides around a series of three courtyards. In addition to providing a shared gathering spaces and creating a protected outdoor space for the school, there are also bioclimatic benefits to the courtyard. The courtyard allows access to daylight to the interior rooms from all sides, as it is designed wide enough so that the south wing does not shade the north wing. The courtyard forms as microclimate between the two wings, one that is slightly warmer during the winter and slightly cooler in the summer. This microclimate is created because the north wing shields the enclosed courtyard improving the comfort of this space and allowing it to be used as an outdoor room for a greater length of the year.[9]

Building Form: Sloped Rooves

The sloped rooves of the education facility, a combination of shed and gable roofs, are climatically appropriate for the region which receives moderate amounts of rainfall and snow fall. Sloped rooves are better than flat rooves in terms of drainage because they are able to shed water and snow which serves to extend the life of the roof materials. They are also better at channeling rainwater into the gutters which allows for greater volumes of rainwater to be captured and stored for later use on site. The sloped rooves of the design allowed for high ceilings which make the rooms feel bright and airy as they bring in more light through the clerestories. This contributes to the wellbeing of the occupants. The sloped rooves creates an overhang that serves to shade windows in the summer, and provides the building with a degree of protection from the elements. Furthermore the slope of the rooves allowed for photovoltaic panels to be installed at an inclined angle that which maximized the amount of solar energy that they can harness. The sloped gable rooves further benefits the building by connecting the architectural design to the local context and site, as the rooves are a form derived from the agricultural buildings and barns found in the region.

Thermal Zoning

The strategy of thermal zoning[10] or energy programming[11] was used to develop the layout and organization of the school building. The design proposal takes reference from the precedent "The Aldo Leopold Legacy Centre," which similarly used thermal zoning to organize the building program into zones based on shared thermal comfort requirements. Spaces are grouped together depending not only on typical programmatic divisions such as functional use, size and adjacencies of spaces, but also according to "similar heating, cooling, ventilation or lighting requirements" and shared occupancy schedules.[12] This strategy has been of benefit to the sustainability of the proposed design because by grouping together programs with common thermal conditions and energy use patterns into a spatial zone, they can utilize the same environmental design strategies. This allowed for the layout of the school to be developed in such a way that it increases the energy efficiency of the building operations by concentrating the employed passive and active strategies to the areas where they will have the greatest impact on improving thermal comfort, and avoiding wasted energy by operating only when a thermal zone is occupied.[13]

One early step in the design development process was identifying the various environmental characteristics and requirements of all the areas in the school and outlining them in a chart for ease of comparison. The chart format (refer to **Table 5.2**) is adapted from the "Design Criteria for Energy Zones"[14] table in the book Sun, Wind & Light, 3rd e.d. The book was written as a tool to assist architects in the design of sustainable buildings, and recommends this exercise to aid in the organization of energy zones. Rooms with similar combinations of environmental comfort requirements and levels of occupancy can be placed adjacent to each other and employ the same passive and active environmental strategies. Through this method, several spatial zones emerged in the proposed school design. The major ones:

- Classrooms: The various types of classrooms all share many of the same thermal requirements, which are at variance from some of the other programmes in the school. They all have high light levels requirements, require a stable comfortable temperature as they are occupied for long periods of time, and due to their high occupant density experience high internal heat gains. This drove to the grouping of all classrooms into one zone, leading to the formation of a classroom wing separate but connected from the rest of the school.

- Science Lab Wing: The science labs though sharing many of the same environmental requirements, varied from the homeroom classrooms in regards to occupancy. They are occupied for shorter periods at a time, but their occupancy hours extend to the evening or weekends due to their potential use for community programs. This difference led to the creation of a separate spatial zone for the science labs from the classroom wing.

- Gym and Cafeteria: Programmatically both of these spaces have a large area and are used as gathering spaces for large groups. They also have many similarities in terms of their environmental characteristics. As

Table 5.2: Chart outlining the various environmental characteristics and requirements of all the areas in the school.

Area	Characteristics & Environmental Requirements of Space					
	Light Levels	Allowable Temperature Range	Internal Heat Gains	Occupancy Period	Occupancy Hours	Occupant Density
Classroom	high ambient/ high task	small	high	long	daytime	high
Kindergarten Classroom	high ambient/ high task	small	high	long	daytime	high
Science Labs	high ambient/ high task	small	moderate	medium	daytime with occasional night	high
Computer Lab	low ambient/low task (computers generate their own light)	small	high	medium	daytime with occasional night	high
Resource Rooms (Prep and Storage)	Low ambient/low task	large	low	short	daytime	low
Gymnasium	Varied: high ambient/low task for sports low ambient/low task for presentations & ceremonies	large	high	periodical	day/night	high
Change Rooms	low ambient/low task	large	high	short	day/night	high
Library	Varied: high ambient/high task for reading area high ambient/low task for book storage/shelves	large for bookstacks small for reading area & checkout	moderate for reading area and checkout low for bookstacks	medium	daytime	moderate
Cafeteria	high ambient/low task for eating high ambient/high task when functioning as learning area	small	moderate	periodical	day/night (predominantly late morning to early afternoon)	high
Cafeteria Kitchen	low ambient/ high task	large	high	periodical	daytime (predominantly morning to early afternoon)	moderate
Student Kitchen	high ambient/high task	small	moderate	medium	day/night	high
Storage/ Receiving	low ambient/low task	large	low	short	day	low
Circulation	high ambient/low task	large	low	short	day/night	varies
Instructional Flex Space	high ambient/low task	large (not always occupied)	low	short (part of circulation space	daytime	varies
Front Entry/ Foyer	high ambient/low task	large	low	short	day/night	varies
Administration Offices	high ambient/high task	small	moderate	long	daytime	low
Staff Room	high ambient/high task	small	moderate	medium	daytime	varies
Washrooms	high ambient/low task	large	low	short	day/night	low
Mechanical Rooms	low ambient/low task	large	low to moderate	short	day/night	low
Outdoor Classroom	high ambient/high task	large	dependant on season/weather	medium	daytime	moderate
Greenhouse	high ambient/low task	small	high	medium	day	low

The chart format is adapted from the "Design Criteria for Energy Zones" table on page 218-219 in the book *Sun, Wind & Light,* 3rd e.d. The book was written as a tool to assist architects in the design of sustainable buildings.

both spaces are only occupied for certain periods of the day, they are able to accept a wider range of temperature fluctuation. At their peak occupancy both experience high occupant density which results in higher internal heat gains. Further heat gains occur in the gymnasium due to the higher metabolic activity of the occupants using the space, and in the cafeteria from its programmatic relationship to the kitchen. While they are only occupied for certain periods of the day, both spaces will experience extended occupancy into evenings and weekends for after-hours school and community programs.

It is in this manner of analysis that the layout of the school was developed. The chart was used as an aid again when developing active environmental strategies such as when organizing the building programme into mechanical ventilation zones and radiant heating zones.

Passive Solar Heating Zones

The cross section of the south classroom wing was organized into passive solar heating zones,[15] dividing the rooms into distinct heating zones each with varying temperature requirements. The differences between the allowable room temperatures and required conditions along with varying periods of occupancy between the main classroom, the outdoor classroom and the corridor, guided their organization.

A passive solar system is one which "collects, stores, and redistributes solar energy without the use of fans, pumps, or complex controllers"[16] instead using the arrangement of architectural elements of the space such as the walls, floors and fenestration and natural methods of heat transfer to do so.[17]

The passive solar system employed in this area of the school is an *isolated gain*[18] or *sunspace*[19,20] system, and the corridor which acts as the sunspace in addition to its circulatory function is the key component in this system. The sunspace is placed on the exterior south-facing wall of the building, which is entirely glazed and results in daytime periods where the space receives large amounts of solar heat gains making the space too hot, and conversely too cold at night because of heat loss through the glazing. The corridor was able to function as a sunspace because of its generally short occupancy period which permits a larger allowable temperature range, giving it more flexibility in terms of thermal comfort. However when used properly, the sunspace can improve the thermal comfort of the adjoining spaces, reducing their required heating and cooling load (depending on the season).

Priority of thermal comfort was given to the classroom as it is regularly occupied and for long periods of time, with the understanding that the other rooms need not be always be used and can be occupied when conditions are favourable. Based on this, the classroom was placed in the most stable location where it is neither directly exposed to the strong solar radiation from the south, nor fully exposed to the cold north winds being partially sheltered from them by the outdoor classroom. The sunspace is only heated with passive solar strategies, while the classrooms use a hydronic radiant floor heating/cooling system for supplementary space conditioning.

The science lab wing was similarly organized into passive heating zones. The passive solar system employed in this area of the school is a *direct gain* system. [21,22] The lab classroom is the direct gain room with southern exposure allowing the room to collect solar heat through a large expanse of south-facing glazing. The space receives the best access to the sun because it has the most stringent environmental requirements as in this cross-section it is the space that is occupied for the longest period and requires the most stable conditions. Moving in the north direction are lab storage and preparatory spaces followed by the corridor which function essentially as service spaces. The common wall between the lab and storage is thick concrete providing a thermal mass to store radiant heat. A south-facing outdoor terrace that is partially sheltered by a trellis and overhang helps shelter the main room from temperature extremes. On the far north is an outdoor classroom that due to its embedded position in the earthen mass receives daylight from above from all directions. Variations on the direct gain system are used throughout the rest of the school.

The Sunspace or "Thermal Flux Zone"

The following section will explain the sunspace in more detail and its function as a passive solar heating strategy for the classrooms. The sunspace is one of the most interesting spaces in the school and gives a distinct character to the whole south wing. Its form and function have been influential in defining the appearance of the south-facing façade of the classroom wing.

The entire length of the corridor in the south classroom wing was designed as a 3m wide sunspace, positioned in the cross section as a space that helps modulate thermal comfort in the adjacent classrooms. The sunspace is referred to by the school by the term "thermal flux zone" which was borrowed from *The Leopold Legacy Centre,* which in the precedent was the name given to the corridor which similarly functioned as a sunspace. The name is apt in defining the nature of this space, as an unconditioned sunspace such as in the proposed design typically experiences wide fluctuations in temperature between day and night, and by season, changes which are completely powered by the natural properties of heat transfer.[23] As a result it also fluctuates in regards to when it is comfortable to occupy. The name reminds students that not every space in a building must be perfectly comfortable all of the time – it is accepted in this school that some spaces will not be ideal depending on the season and that they need not be mechanically conditioned to be so. Instead of adapting every space to our needs, we adapt to it. That said the comfort of the space aligns fairly well with the classroom wing's daytime occupancy schedule, and school year calendar. The sunspace is a valuable addition providing many environmental benefits to the building. Benefits of a sunspace:

- It reduces the heating load of the classroom by being a source of supplementary heat. It provides pre-heated air that is circulated to classroom by a convective loop. It provides further indirect heat gain by radiation from the common thermal mass wall.
- It acts as a buffer space or "draught lobby"[24] between the inside and outside taking the place of the exterior wall that is most exposed to

temperature extremes, air infiltration, and experiences the most heat loss, thereby sheltering the classroom from this exposure.

- It provides additional useable space that can be used as an extension of the classroom space, as the corridors' 3m width is large enough to accommodate seating and a small table. It is further used as a greenhouse space and as an intermediary space that feels somewhere between indoors and outdoors.

Designed as a passive solar system, the sunspace contains the three key components[25] of such a system that work in conjunction with each other to improve the thermal comfort of the classroom space. Components:

- The Collector: The sun is harnessed through the sloped south-facing glazing on the exterior facade that is angled at 15° to allow the sun deeper interior access
- The Storage: Radiant heat is stored in the thermal mass – materials that have a high heat storage capacity – within the sunspace. The common thermal mass wall that separates the classroom and sunspace is a 300mm thick solid concrete wall and acts as the main storage element. Solid concrete is a material that has a high heat storage capacity, with an approximate value of 2000 $kJ/m^3 \cdot °C$[26], allowing it to effectively absorb and store heat from the sun. Other concrete elements in the sunspace that provide additional thermal mass are the polished concrete floor, and the living machine cell/container.
- The Distributor: Openings in the common mass wall – a pair of vents at the top and bottom of the mass wall, casement windows, and the classroom door – can be opened to allow the transfer of heated air by convection.

How it functions: day vs. night, winter vs. summer

On a sunny winter day, the sun is admitted through the south-facing glazing and radiates into the sunspace hitting the surfaces of the concrete floor and common mass wall. The surface of these concrete elements absorbs the solar energy, collecting it and storing it in the thermal mass of the material during the day. The air in the sunspace is passively heated throughout the day, causing the hot air to rise to the ceiling. The difference in temperature between the hot sunspace and the cooler adjacent classroom drives the formation of a convective energy loop. Hot air from the sunspace moves into the classroom via the top vent in the common mass wall introducing pre-heated air to the space and replacing the cooler air from the classroom, which travels into the sunspace by the bottom vent. At night, the vents are closed to reduce heat loss and to allow the classroom to retain the day's heat by confining the convective loop there. The sunspace which was hot during the day quickly begins to lose heat once the sun goes down through the windows. The thermal mass wall releases the heat it has stored up during the day, radiating it into the classroom space. The result is that the classroom spaces will be comfortably warm when students return in the morning.

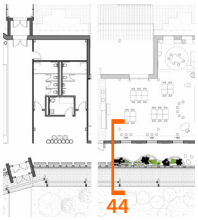
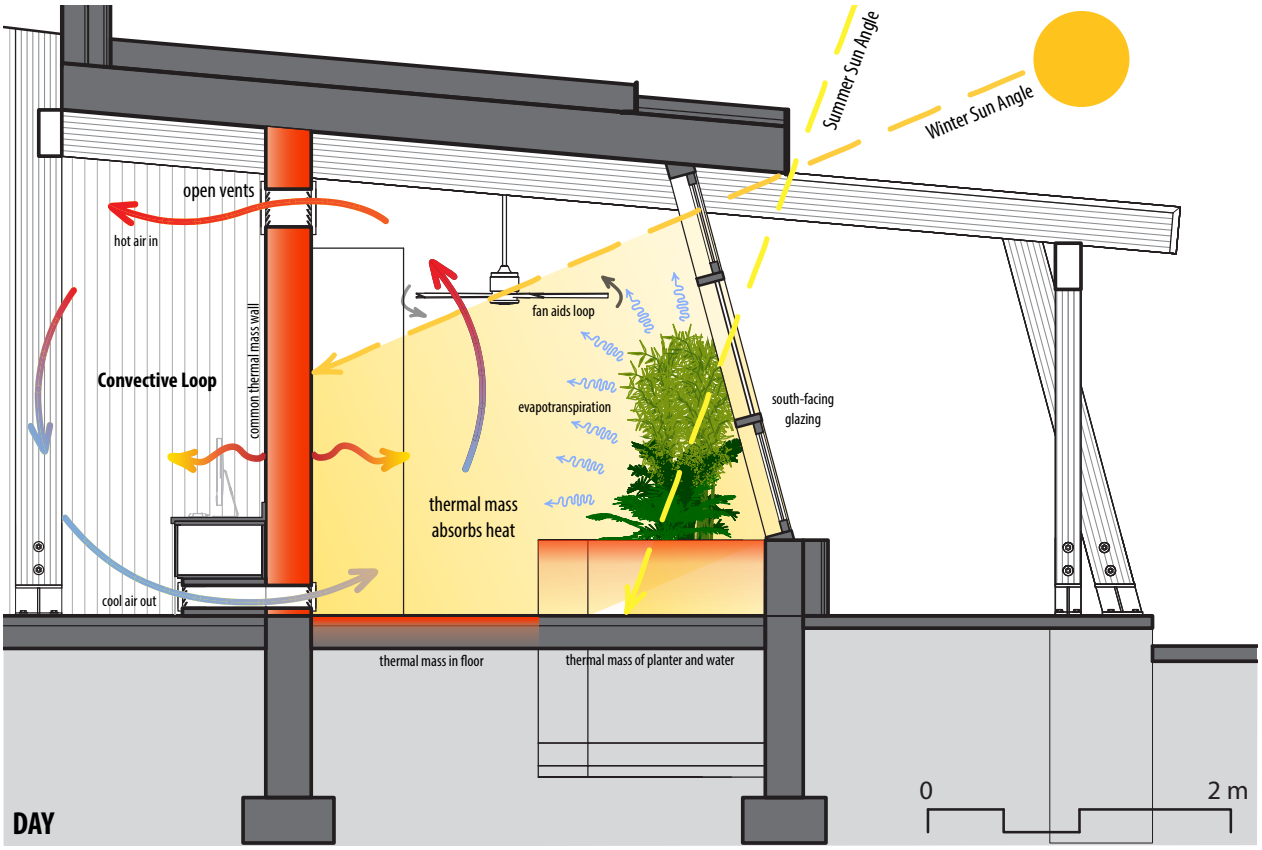
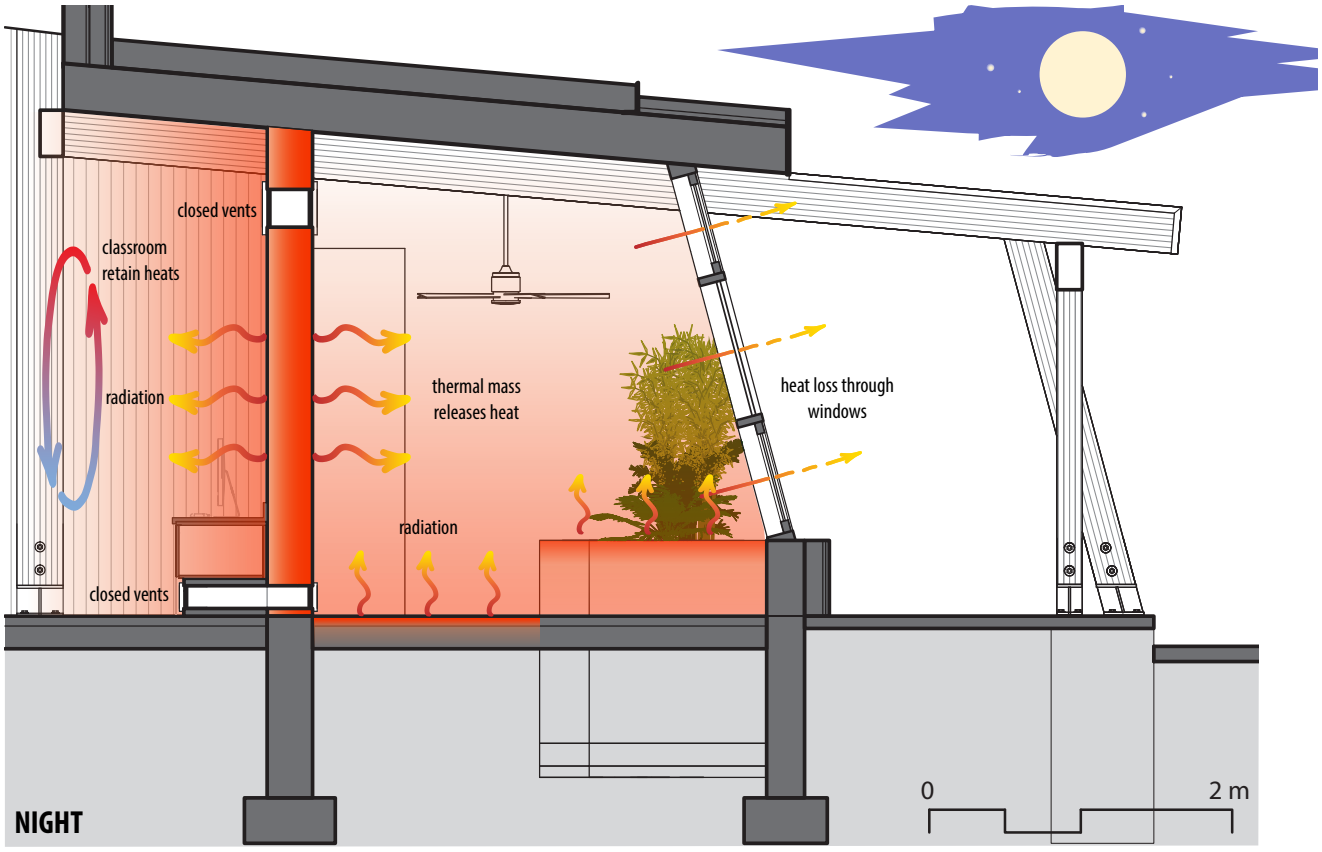


Figure 5.44 – 1:50 Thermal Flux Zone cross-section diagram showing day vs. night operation.


Summer Sun Angle
Winter Sun Angle
open vents
hot air in
common thermal mass wall
Convective Loop
fan aids loop
evapotranspiration
south-facing glazing
thermal mass absorbs heat
cool air out
thermal mass in floor
thermal mass of planter and water
0
2 m
DAY


closed vents
classroom retain heats
radiation
thermal mass releases heat
heat loss through windows
radiation
closed vents
0
2 m
NIGHT

During the summer, the sunspace is isolated from the classroom. The vents and openings in the common mass wall are closed to prevent unwanted heat gain. Overheating in the sunspace is controlled by the roof overhang which shades the space (though some light is admitted to sustain the plants in living machine cells) and by releasing the build-up of hot air in the sunspace through operable windows located at the top and bottom of the south façade. The thermal mass in the floor and common wall is also beneficial in the summer as it absorbs excess heat, helping moderate the temperature in the classroom.

In the sections of the corridor next to the washrooms, the solid concrete partition is replaced with a water wall. The solar water tubes similarly act as a common thermal mass wall, absorbing radiant heat during the day and radiating it back into the washroom area at night, which in turn helps keep it comfortably warm overnight. The purpose of this is to showcase to students another heat storage material. Water is an even more effective thermal mass material than concrete with an approximate heat storage capacity, of 4000 $kJ/m^3 \cdot °C$.[27] Furthermore, the water wall allows daylight to reach the communal sink area of the washrooms while partitioning it from the corridor.

The sunspace demonstrates to students how a passive solar heating system can be used to help meet the energy demands of a building without solely relying on mechanical systems, but by using the architectural elements of the space. Additionally, it models the methods of heat transfer – radiation, convection and conduction – more clearly than any other space in the school. All three are at work in this space and can be experienced by the occupants. Radiation can be felt when standing near the windows or working at the bench next to the adjoining concrete wall as heat radiated from the thermal mass will hit them. Conduction is understood by simply placing a hand on the 300mm thick concrete mass wall on a sunny winter's day as it will be pleasantly warm to touch. On a summer day, the floor in the sunspace might get so hot during the day that one can't sit on it. Students come to understand the concept of convection when they interact with the passive solar system by opening and closing the vents in the common mass wall, thereby controlling the admittance of heat into the classroom space.

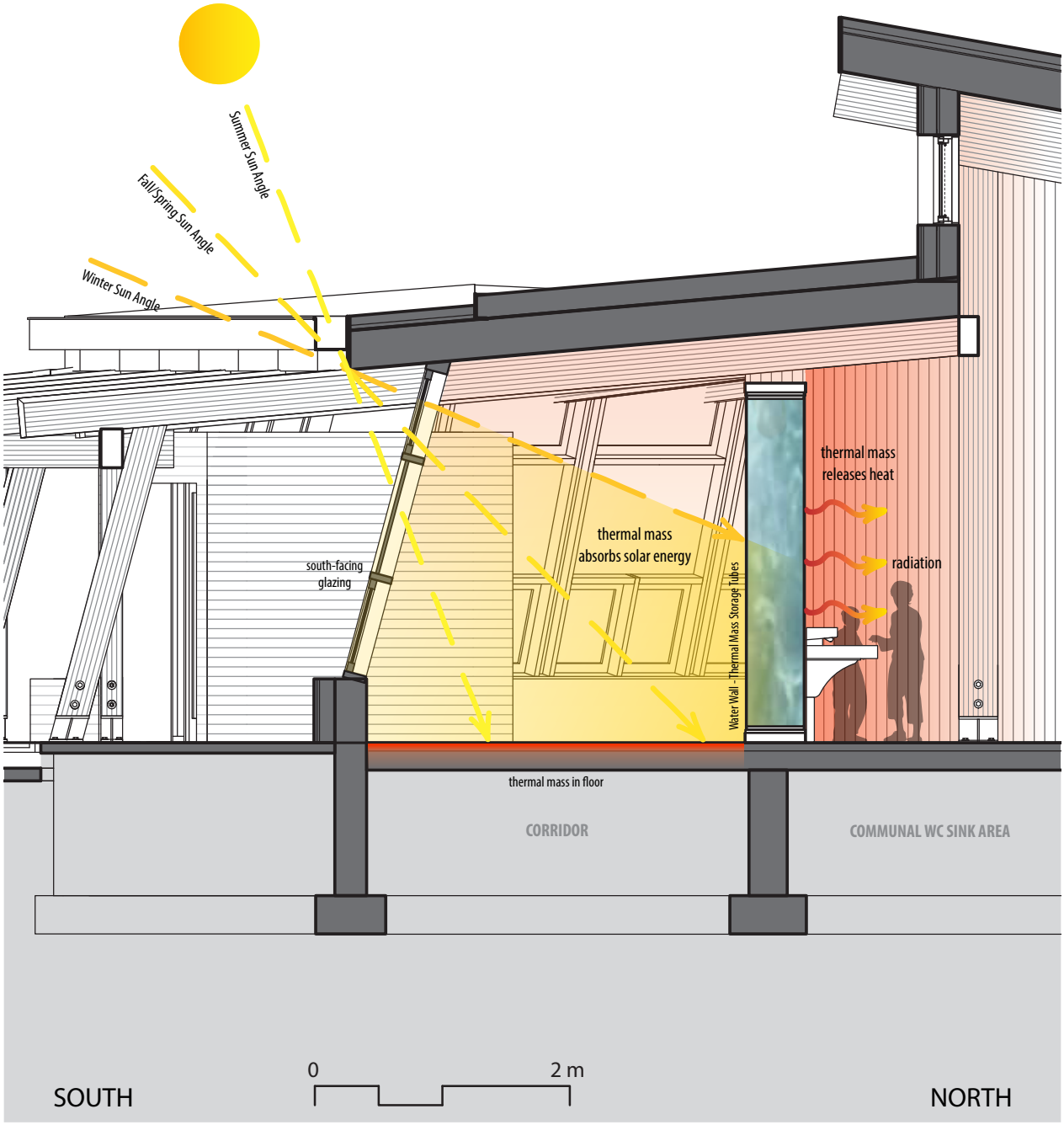
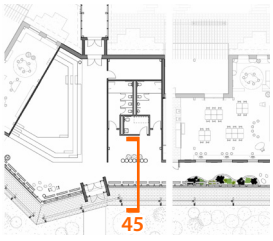


Figure 5.45 - 1:50 Water Wall Section Diagram



KEY PLAN

Daylighting

Natural daylighting is a key contributor to environmental quality. The daylighting strategy for the school uses a combination of windows, skylights and clerestories to bring natural light into the building, and thereby reduce the need to use electrical lighting during daylight hours. The daylighting strategy is designed to meet the requirements of LEED, by achieving daylight access in 90% of regularly occupied areas of the plan, with a minimum illuminance level of 300 lux (approximately 27 foot-candles) and not greater than 3000 lux (278 foot-candles) in each space.[28] To demonstrate that sufficient daylighting levels were achieved throughout several spaces in the design, computer daylighting simulation studies were performed. The opposite and following pages show the luminance renderings in false colour for key programmatic spaces within the school. This tool helped in determining window size and placement for achieving balanced daylight conditions. Spaces were designed to be completely daylit by natural lighting when sky conditions allow for it, as natural daylight enhances students' and teachers' wellbeing, productivity, and performance[29, 30], as well as contributing to decreasing the energy consumption of the building.

The daylighting design follows best practice standards for a cold climate in the northern hemisphere. Daylighting guides for buildings in Canadian climates recommended placing majority of windows on the south façade as it is the orientation with the greatest access to daylight and potential solar gain, while also being the easiest to shade during summer months. Fenestration on the north is recommended for its softer diffused properties as a source of indirect light, but openings should be strategically placed to minimize heat loss. It is suggested that exposure to daylighting from the east and west direction is minimized as the low sun angles from those directions can cause issues with glare, result in little winter heat gain and are prone to overheating in the summertime as sunlight is more difficult to control on these orientations.[31]

Figure 5.46 - (opposite page, top) Typical Classroom Daytime Illumination Levels (measured in foot candles; using Perez All-Weather Sky Model)

Window placement was based on orientation, seeking to achieve sufficient daylight levels and views to the exterior while eliminating glare, and without significantly increasing the heating/cooling load as glass has lower insulative properties than opaque walls and is generally the point of heat loss within a building envelope. As previously explained, the building orientation along an east-west axis in combination with the long but narrow form of the building, maximized daylight access to all occupied areas. In the proposed design, windows were mostly concentrated on the south and north elevations of the building. Large expanses of windows, curtain wall style, form most of the south-facing façade on both wings of the building allowing direct light to enter into the spaces located on the perimeter. This is designed in combination with the passive solar heating strategy explained in the previous section. A continuous band of clerestory windows on the south façade of the classroom wing draws daylight deep into the interior of the classrooms. Clerestory windows on the north side of the classrooms introduce indirect light from the opposite direction, helping balance daylight levels by admitting light from two directions. The open floor plan and high ceilings (arising

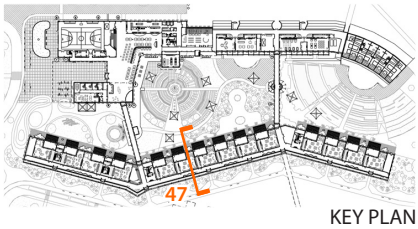
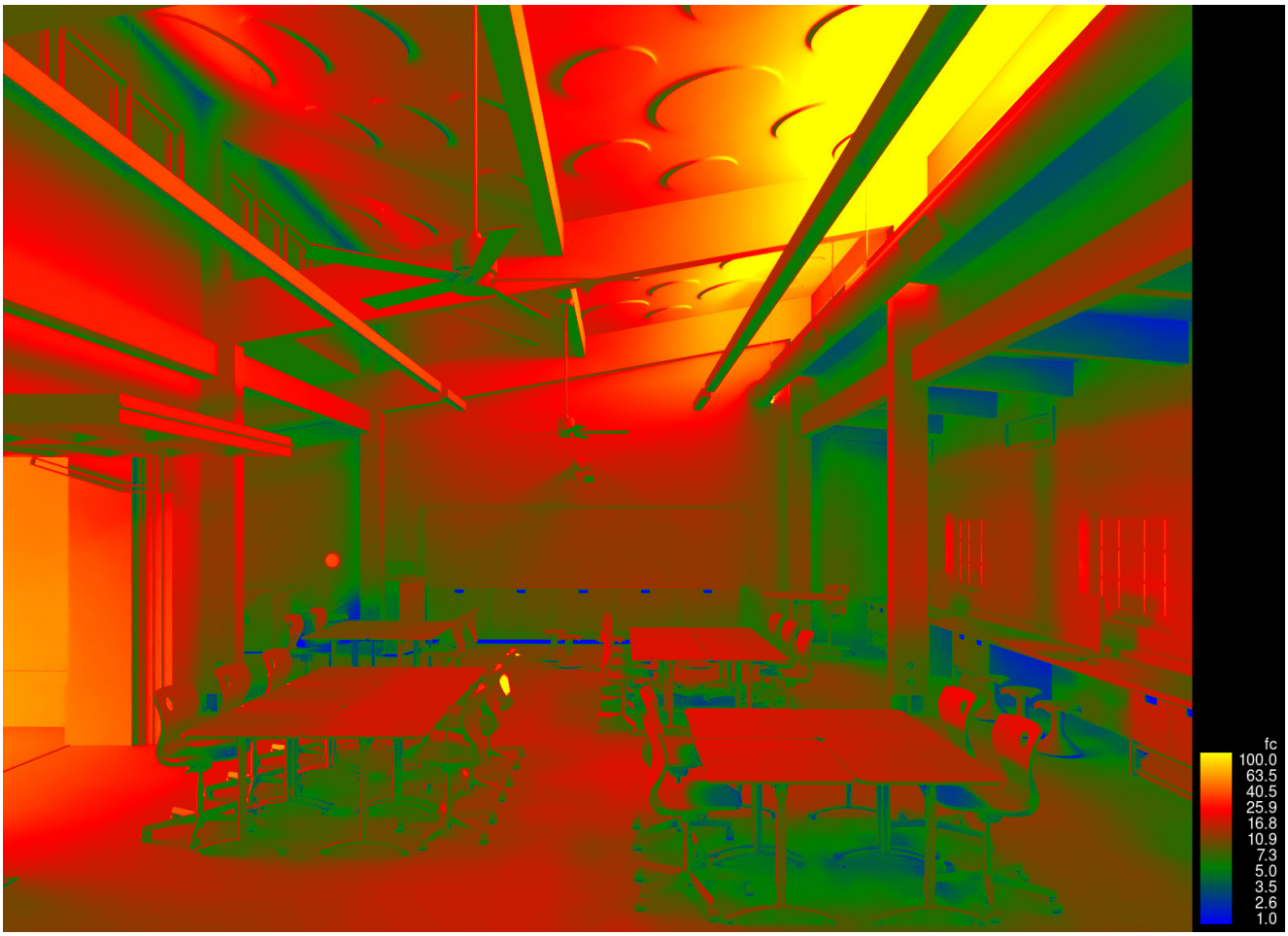
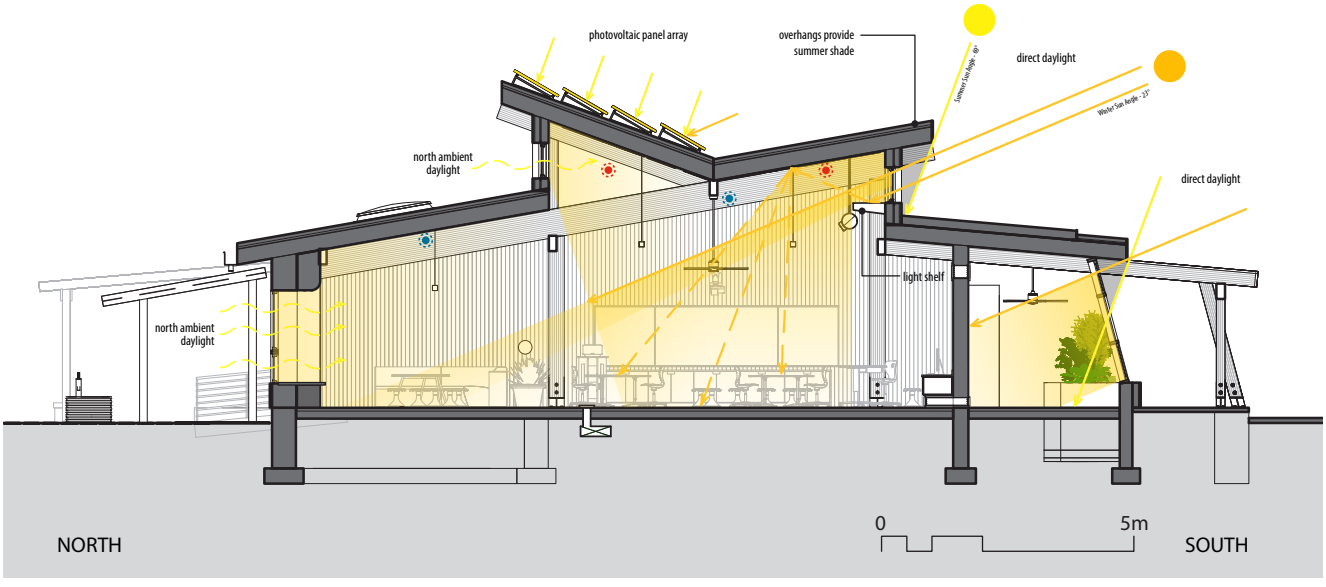


Figure 5.47 – (opposite page, bottom) 1:150 Daylighting Section of Classroom





Daylight Level Sensor
Occupancy Sensor



Figure 5.48 - Typical Science Classroom Daytime Illumination Levels (measured in foot candles; using Perez All-Weather Sky Model)

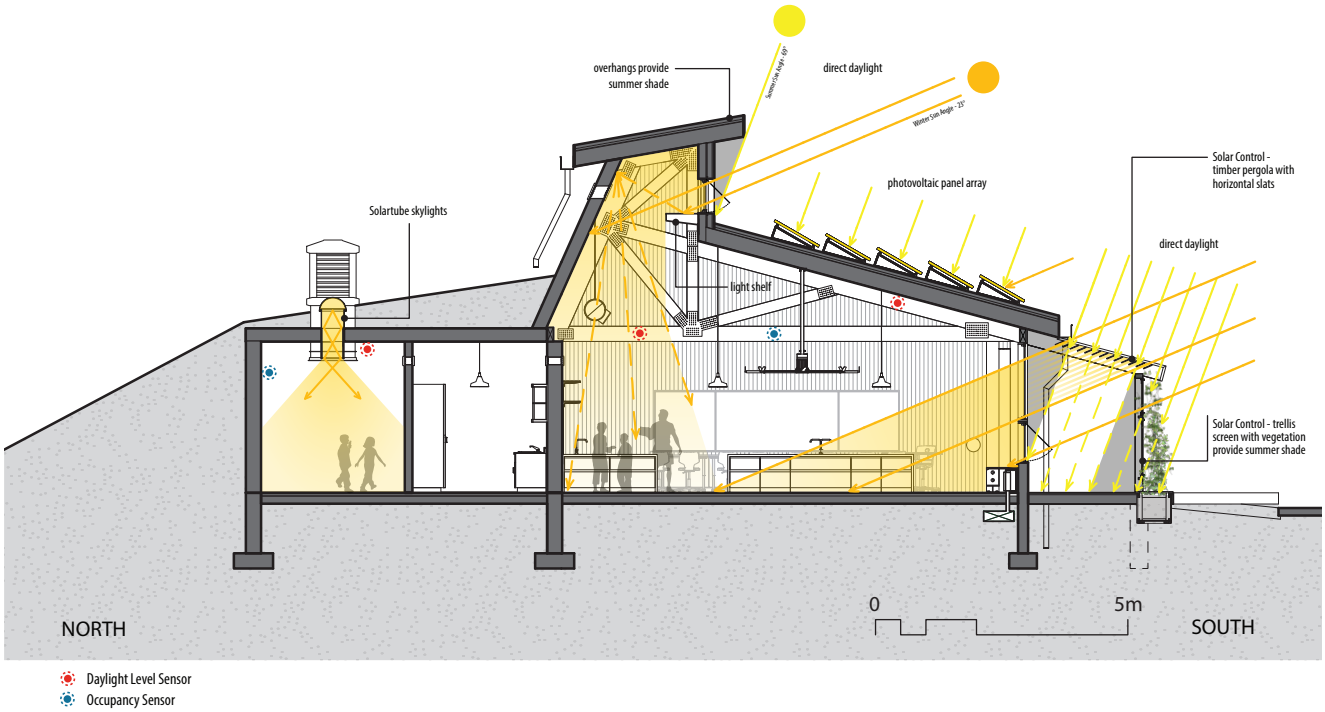


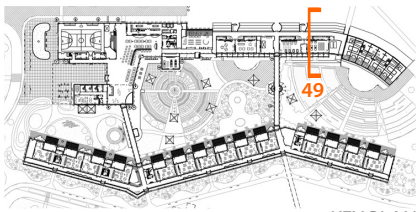
Figure 5.49 - 1.150 Daylighting Section of Science Lab Classroom

from the clerestories) further aid in improving the brightness of the space. The north wing similarly utilizes bands of clerestory windows on both the north and south elevations to bring daylight in from opposite sides deeper into the floor plate. On the north façade, each classroom has two windows sized to admit sufficient levels of light into the breakout space and a glass garage door which lets in plenty of soft diffused light free of glare into the flexible classroom space. The garage door is large in size, so potential heat loss from it is reduced by providing for it thermal insulated drapes that can be drawn in the evening as well as when using audio-visual equipment. The north wing has limited north-facing glazing to mainly small clerestory window near the roof line, glass exterior doors, and a scattering of smaller windows in the gymnasium and library. The general strategy for east and west windows was to reduce the amount or altogether avoid placing windows on those elevations unless other programmatic reasons called for it. The school's narrow floor plate does not provide much wall surface area for east and west windows, so overall they are limited to a few locations: the west façade of the gymnasium and front entry as these spaces are the public face of the school; the east elevation of the cafeteria for which windows were deemed necessary as daylight from the east corresponds to the time of use of the space; and the glass enclosed breezeways that link the two wings of the school. These windows were all accompanied with solar control strategies to reduce glare issues.

Skylights are used to bring daylight into the front lobby and north wing corridor, which are both spaces that are located deeper in the floor plate and do not have full access to the perimeter. The specific skylights used are Solatubes – a tubular domed skylight that uses a lens, daylight tracking reflector and reflective material to maximize the amount of daylight captured.[32] The Solatubes are accessible to students from the roof terrace (next to gymnasium) allowing them to interact with them by looking down into the dome.

Daylight Control and Shading

Large amounts of direct daylight can become a problem resulting in thermal and visual discomfort if not controlled or blocked. Excess solar gain while desired during the winter becomes an issue during the summer as it can result in the overheating of spaces, and increases the mechanical cooling load. Architectural elements are used to shade the transparent elements of the façade from the exterior, and vary based on their orientation. A deep roof overhang provides shade to the south-facing windows and clerestories, and is designed to block direct light during the summer while admitting it during the winter. Another shading strategies for the south façade includes a wooden trellis screen that uses vegetation to seasonally shade the windows of the science lab classrooms. During the summer the vines climb up the trellis and the leaves of the plants block sunlight from the interior, while in the autumn they are culled to allow daylight into the interior. A third south shading strategy is the vacuum tube solar collector integrated architecturally into the south façade as a vertical screen that provides shading to the upper windows of the cafeteria and a portion of the north wing corridor. Functionally the screen, lessens the solar gain during noon hours when otherwise this space has the potential to get very hot. Aesthetically, the shadows create an alternating play of light and shadow, which paired with the glulam columns in the space, bring to



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mind the feeling of being in the forest. The main shading strategy for the east and west elevation are vertical fins that serve to block harsh the daylight from those directions, thereby reducing overheating and glare. The vertical fins take the form of a wooden screen on the west gymnasium façade. On the west administration façade they are likewise timber, extending out deeply to properly shade the windows and with a verticality that lends them the appearance of rows of trees. The vertical fins that provides solar control on the east and west faces of the enclosed breezeways are designed to be a more shallow depth but tightly spaced. The fins are constructed out of a durable recycled plastic composite material whose bright colours add liveliness to the courtyard spaces.

Outdoor spaces are also designed with solar control strategies in-place. Glass-encased bifacial photovoltaic modules mounted on a steel frame structure are integrated into the building as exterior glass canopy that stands over the front entry courtyard. The PV modules allow some light transmission through the individual cells, while providing shade and shelter to the outdoor space below. Outdoor classroom spaces are shaded by a wooden pergola constructed out of dimensional lumber. To provide relief from the sun, dispersed throughout the courtyard are inverted umbrella canopies. The canopy of these freestanding structures is constructed out of a tensile membrane fabric stretched over a steel frame which shelters a hexagonal wooden bench at its base.

All of the solar control devices are highly visible elements of the building and site, allowing students to observe them and how they alter the light conditions throughout the day. For example, the vertical fins are colourful to draw attention to themselves, the trellis plantings continuously change throughout the year as they grow and recede, the inverted umbrella canopies stand tall in the courtyards, and so forth.

On the interior, several solar control devices are provided to improve the illuminance level in the spaces. Light shelves are provided on the interior side of all south-facing clerestory windows. They are installed right below the window where they can bounce direct daylight that hits them upward to the ceiling, reflecting it deeper into the interior of each space. This serves to reduce glare by diffusing the light and redirecting it more evenly across the room. The light shelves are constructed out of dimensional lumber covered with gypsum board and painted with a glossy white finish to increase reflectance. Though this makes them a permanent fixture, they are less expensive and less energy-intensive to construct than manufacturer produced light shelves. Operable blinds are also provided as a shading device that gives occupants control over the admittance of daylight. The product specified is Vela Eco Screen sunshades made out of a sheer transparent fabric that blocks daylight and reduces glare, while maintaining visibility to the outside.[33] The sunshades installed high above the clerestories are motorized (the motor is powered by a rechargeable battery), and can be lowered and raised by a hand held remote. The blinds installed above all lower-level windows are accessible to be operated by hand.

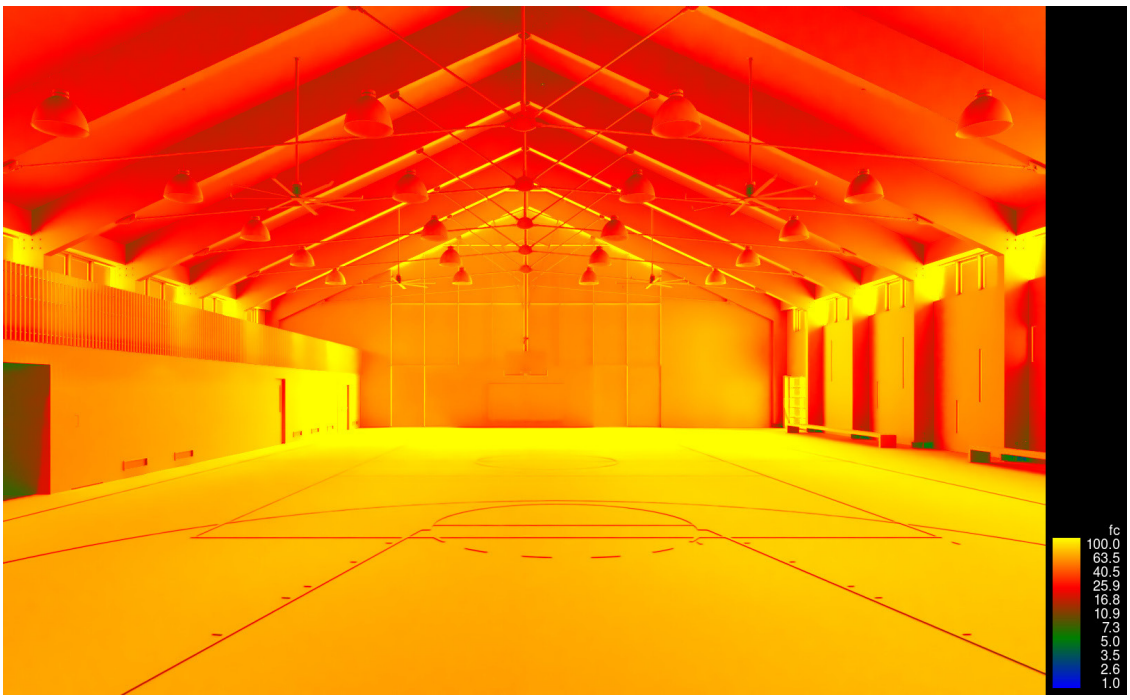


Figure 5.50 - Typical Gymnasium Daytime Illumination Levels at Noon (measured in foot candles; using Perez All-Weather Sky Model).

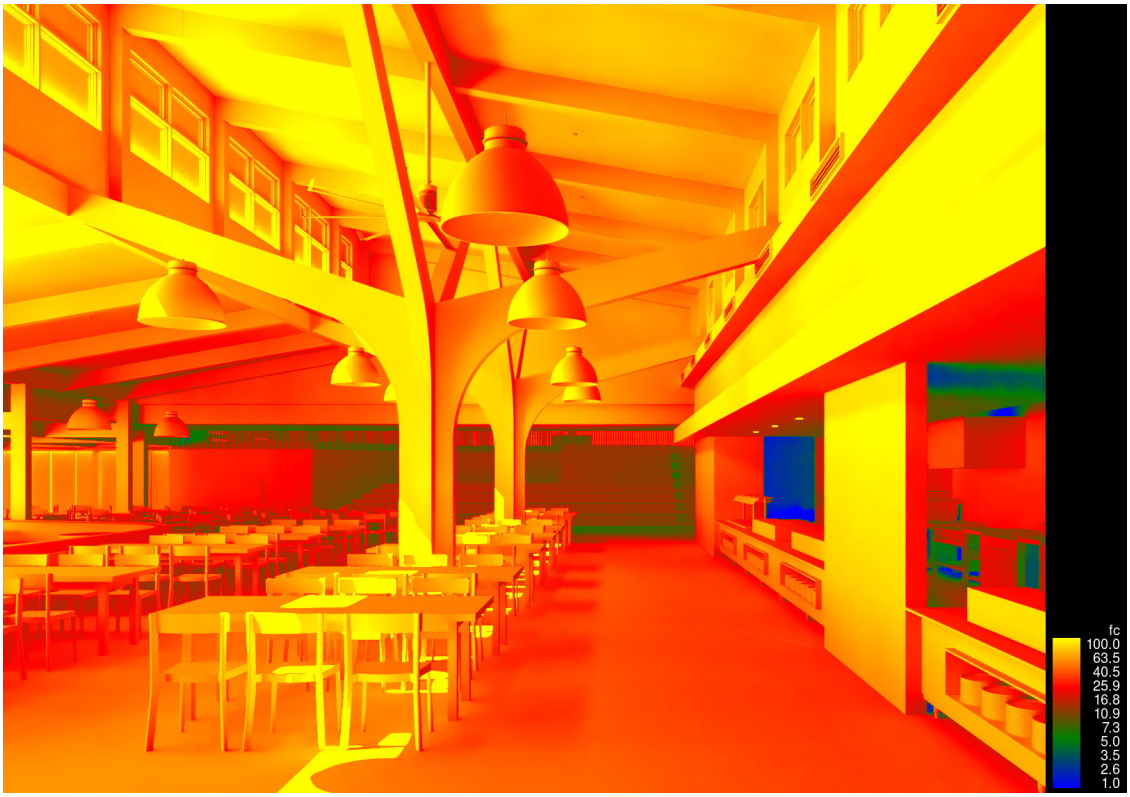


Figure 5.51 - Typical Cafeteria Daytime Illumination Levels at Noon (measured in foot candles; using Perez All-Weather Sky Model).

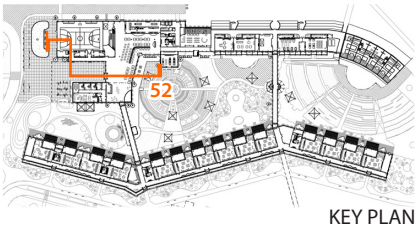


Figure 5.52 – (opposite page, top)
1:200 Daylighting Section through Gymnasium and Front Entry Courtyard

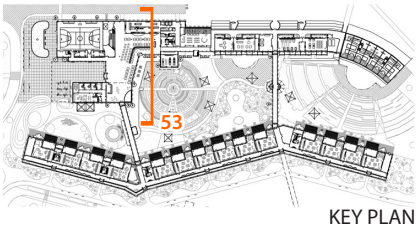
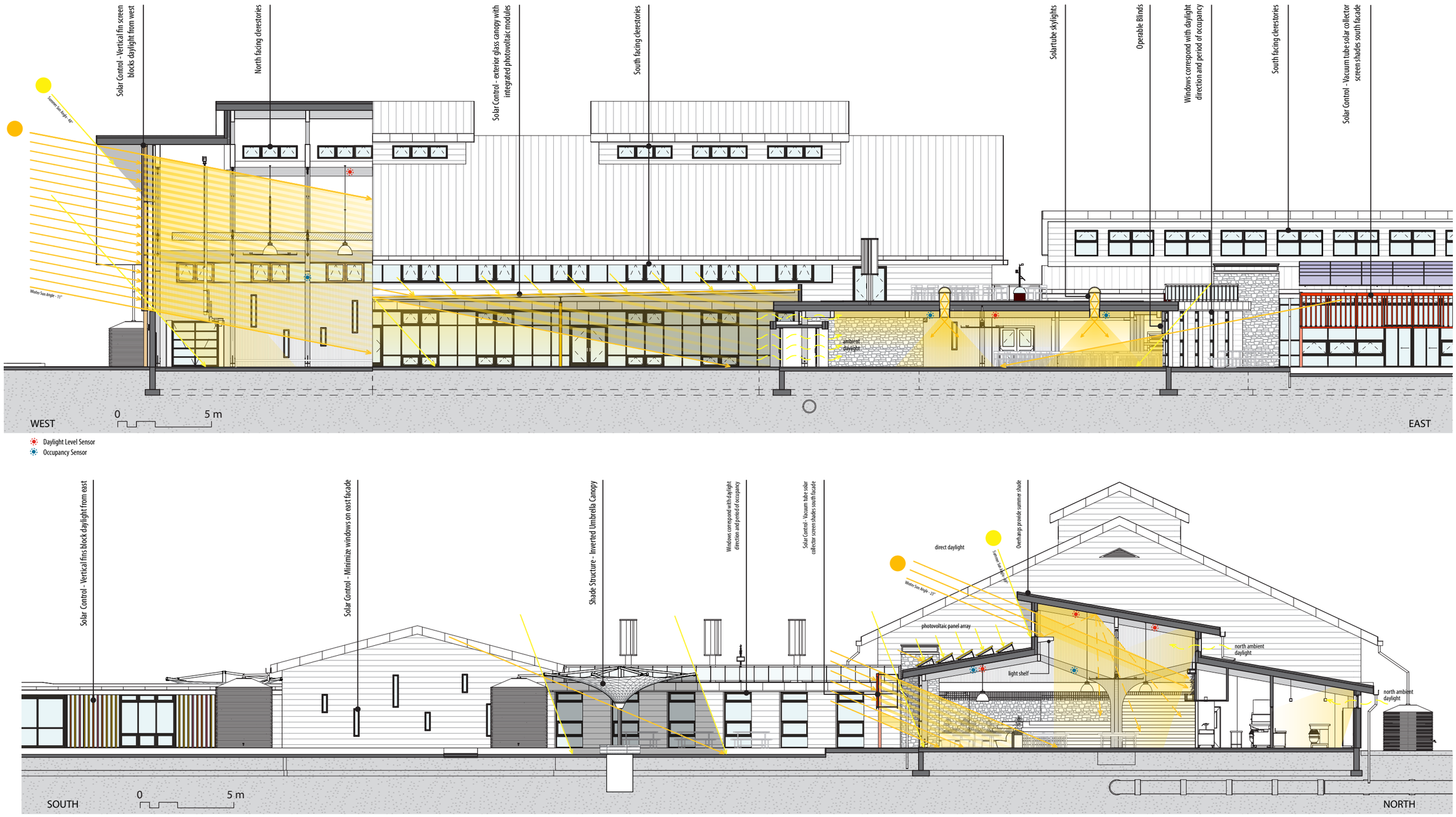


Figure 5.53 – (opposite page, bottom)
1:200 Daylighting Section through Cafeteria


Solar Control - Vertical fin screen blocks daylight from west
North facing clerestories
Solar Control - exterior glass canopy with integrated photovoltaic modules
South facing clerestories
Solartube skylights
Operable Blinds
Windows correspond with daylight direction and period of occupancy
South facing clerestories
Solar Control - Vacuum tube solar collector screen shades south facade
Summer Sun Angle - 42°
Winter Sun Angle - 11°
ambient daylight
WEST
0
5 m
EAST
Daylight Level Sensor
Occupancy Sensor
Solar Control - Vertical fins block daylight from east
Solar Control - Minimize windows on east facade
Shade Structure - Inverted Umbrella Canopy
Windows correspond with daylight direction and period of occupancy
Solar Control - Vacuum tube solar collector screen shades south facade
Overhangs provide summer shade
direct daylight
Summer Sun Angle - 42°
Winter Sun Angle - 23°
photovoltaic panel array
light shelf
north ambient daylight
north ambient daylight
SOUTH
0
5 m
NORTH
Daylight Level Sensor
Occupancy Sensor

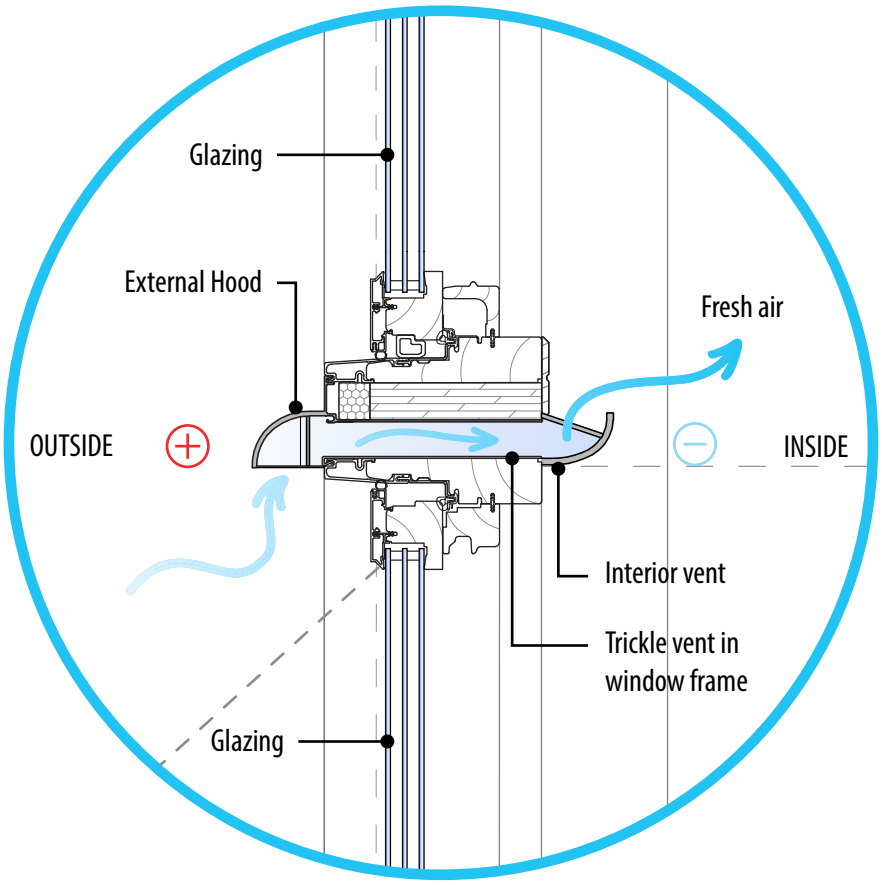
Natural Ventilation

The primary strategy for maintaining high indoor air quality within the school, is by increasing outdoor air intake flow through the introduction of fresh air by way of operable windows and background ventilators. The building uses a mixed-mode approach to ventilation, relying on natural ventilation for the period of the year when outdoor conditions are optimal, when the building can function in what is referred to as "natural mode." The building is able to operate in "natural mode" during the fall, spring, and parts of the summer when the weather is not too hot and/or humid. The natural ventilation system improves IAQ within the school by "supply(ing) fresh air and remov(ing) excess heat, odour, CO_2 and other contaminants,"[34] which creates an indoor environment for students that is healthy, comfortable and supports learning. As a passive system it does this without having to rely on mechanical equipment for much of the year; only relying on the energy of the wind and the building's ability to harness that wind through its orientation and envelope, which results in energy savings for the building.

The cross sections of the different areas of the school were developed to enhance cross ventilation. Operable windows are located along the perimeter of occupied floor plan, with openings on opposite sides to allow the movement of air from prevailing winds across the rooms. The movement of air through cross ventilation is based on the principles of thermodynamics: cool, fresh air enters the room at a low inlet and as it travels across the room it heats ups through internal gains rising to the ceiling due to the pressure difference created, where it exits the building through an outlet opening.

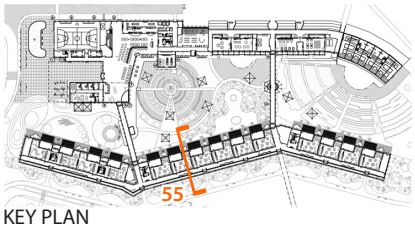
The classroom section will now be examined, as the general design principles are the same in the other areas of the school. The classroom section features operable windows on both the north and south elevations allowing the exchange of air as it enters and passes through the room, the effect of which this is enhanced by the 16m depth of the floor plate giving the air flow a shorter path to travel and one free of obstruction due to the open plan. In the classroom, low level operable windows for the intake of air are located on the windward (north) side and the clerestory windows on the leeward (south) side are located at the highest point in the classroom where they serve as outlet windows to exhaust air at roof level. The classroom section can accommodate changes in wind direction; in this scenario low inlet windows on the south façade of the corridor can admit air which passes through the openings in the shared thermal mass wall into the classroom space where it is exhausted through the north facing clerestories.

To allow for continuous air exchange, the ground level windows throughout the school are fitted with trickle vents. Trickle vents "provide a general background level of ventilation to provide fresh air to occupants and to dilute generally spread pollutants,"[35] helping maintain minimum IAQ levels. This means that if the windows are closed, there is still an introduction of fresh air into the building. Pressure-difference controlled vents were selected over manually operated vents because of their ability to self-regulate, which reduces the risk of them being shut closed and then forgotten to be opened again. The vents work according to the difference in pressure between the indoor and outdoor environment – when the pressure difference increases it cause the vent flap to partially close thereby decreasing the size of the opening, and reducing the amount of air that flows from outside to the inside. This helps protect the indoor occupants from the admittance of too much fresh air when conditions are not ideal and from cold drafts.[36] As they only admit in small amounts of outdoor air – a little more than a refreshing trickle – there remains a need in winter time when the operable windows are closed, for mechanical ventilation to provide a more active ventilation.



Background natural ventilation through pressure-difference controlled trickle vent

Figure 5.54 - 1:5 Detail of trickle vent incorporated into the window sills.



KEY PLAN

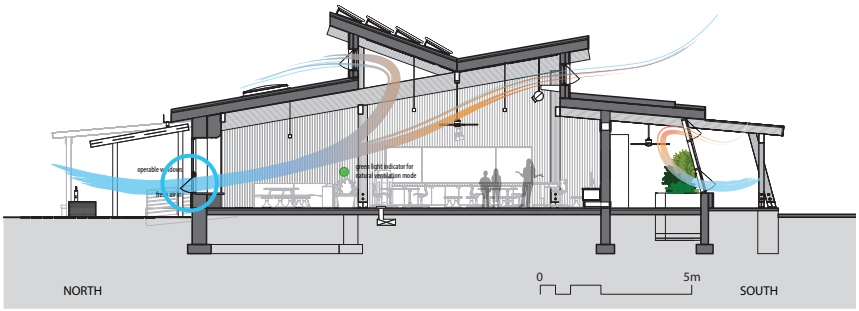


Figure 5.55 - 1:500 Cross section of classroom showing the path of natural ventilation and location of detail.

Involving Building Users

"Passive Buildings Require Active Users"[37]

The way that the future students will interact with the building was a key consideration, and influenced the decision to design a school that primarily uses a passive system to make the environment comfortable and habitable. Passive design strategies were implemented not only to showcase them, but as a way of engaging users in the building's operation, so that the building could be used as an educational tool. This is because in order for passive systems to work as intended they require the building users to be involved in their operation. Unlike with a standard HVAC system that provides continuous thermal comfort with the touch of a button, passive strategies require the occupants to be hands-on and adjust elements of the building in order to maintain appropriate levels of comfort.[38] This in turn calls for building users to be trained in how to operate the building.[39, 40]

The classroom is designed with an environmental system that actively involves the students in its operation, giving them a role in maintaining thermal comfort of their space. By being involved students will come to understand how their building works through learning by doing, gain a sense of control and responsibility over their environment, and become more in-tune with their surroundings growing aware of changes taking place around them. The following are some of the ways that students are involved in the operations of the classroom.

Ventilation:

- All windows are operable to allow for natural ventilation. Lower windows that are accessible to students are manually opened/closed, while windows higher up like the clerestories are motorized but manually operated in regards that either the teacher or students must use the remote open/close them when notified.

- In order to help guide and train users when to open or close windows, the building is continuously monitored through numerous sensors that measure indoor and outdoor conditions for CO_2 levels, temperature, humidity, wind speed, etc. These sensors relay this information to the Building Management System (BMS), which in turn processes the information to determine whether external conditions are ideal for natural ventilation. If they are optimal the BMS will turn off the mechanical system in that ventilation zone, and proceeds to notify the occupants in the classrooms whether they can open their windows. The BMS system utilizes scheduling to turn equipment on/off based on the building occupancy and season, as a way of saving energy, so that the system is not always running.

- The notification system for natural ventilation is designed to be simple and highly visible. A large circular light located near the whiteboard turns green when conditions are ideal to open the windows. The light turns red when windows need to be closed, and continues to shine red to indicate that mechanical ventilation mode is on. The colour changes are accompanied by flashes coupled with a notification sound to alert the users that the conditions have changed.

- Each space is provided with operable ceiling fans to help with air circulation.

They can be turned on to improve comfort levels in the rooms by increasing air movement, and during cold months redistribute rising heat.

Daylighting:

- The rooms of the school are fitted with occupancy sensors and daylight level sensors to help control the levels of daylight illumination in the space. The light level sensors were considered to be necessary because human occupants' ability to judge whether there is a sufficient level of illumination is not always accurate, which either results in energy waste or insufficient lighting levels that can cause users discomfort and strain.[41] Occupancy sensors work in conjunction with the light level sensors to ensure that if the room is not occupied for a certain length of time, that all artificial lights are off so as not to waste energy. An occupancy sensor was considered important in particular for the shared spaces of the school, over which occupants do not generally have the same sense of ownership as they do with their classrooms.

- An on/off switching daylight sensor system was chosen for the classrooms, science labs and administration offices, while a continuous dimming system was provided for the shared spaces in the school such as the gymnasium, cafeteria, front entry lobby and library. Both light level sensors result in energy savings for the school. An on/off switching ballast integrated into the lighting still provides educational benefits, because instead of teaching children to turn off the lights, it teaches them when to turn them on.[42] The action of artificial lights switching on will signal to the class that the sky has darkened. This calls attention to changes in the sky throughout the day.

- If too much daylight is being provided in a space or if the task at hand (such as an audio-visual presentation) requires low levels of light, students have the option to draw the sunshades down that are installed above all windows.

Heating & Cooling:

- Students can temper the conditions of the classroom by operating the openings in the common thermal storage wall between the classroom and corridor. By opening the vents and windows they let in preheated air from the sunspace, but if it becomes too warm the vents can be closed to isolate the sunspace.

- Students will learn to judge over time what is comfortable as they learn to be more aware how they feel. In any case, temperature readings are accessible from the thermostat that is located in the "Energy Wall Unit" in each classroom, allowing students to qualitatively judge the thermal comfort level of the space.

- The thermostat in the room also allows the occupants to control the amount of heat the in-floor radiant coil system provides, but that is considered to be a supplemental active strategy.

Adjusting Students' Expectations and Mindset

In a building that relies on a passive environmental system for a large portion of the school year, it becomes necessary that building occupants adjust their perception of what they consider to be "comfortable." In regards to thermal comfort, a slightly larger range of temperatures will have to be tolerated as passive buildings

cannot necessarily always maintain a temperature within the ideal range and still operate with minimal energy use.[43] Students and staff will need to accept that there may be days when the school is a little bit warmer or cooler than they are accustomed to.

At the proposed school, students are encouraged to keep a sweater in their cubbies (the classrooms were designed to provide each student with storage space), as personal levels of thermal comfort vary by person, and are dependent on characteristics such as age, body mass, level of activity. It will generally have to be accepted that not everyone will be pleased always and at the same time. Another solution to thermal discomfort that can be employed is to modify the desk/seating arrangement in the classroom so that students are situated according to their thermal preference. Those kids who tend to feel warmer can sit next to the open windows, and vice versa. Likewise, the layout of multiple zones within the classroom (part of the L-shape strategy) allows for migration to a different learning zones when a student finds their current area uncomfortable. The sunspace can also be utilized as additional classroom space when conditions in it are pleasant.

It must also be accepted that the in the learning process building users will make mistakes. But students will learn from careless mistakes, as these have the potential to be valuable teaching moments. For example, if someone leaves the windows open overnight the next day the room will be too cold. When the energy dashboard is reviewed by the class it will show an increase in energy use.

Maintenance and Care:

A passive building has components that require the building users to care for them. One such strategy is the direct gain passive solar heating system in the sunspace corridor and throughout other parts of the school. The direct gain system is maintained through the washing of the windows (the collectors) to ensure that high levels of solar transmission are preserved. Similarly, in order for the daylighting strategy to work windows must be regularly cleaned. Other components like the thermal mass wall must have a clear access path to the sun in order to effectively condition the space, so it must not be blocked or covered up by any other materials. Likewise the air flow path of the natural ventilation strategy must remain clear of obstructions. Students will be assigned responsibility over the maintenance of their building and will participate in the cleaning of the classroom. While the school will continue to employ custodial services for the spaces that are shared by the whole school and community, giving students primary responsibility over their classroom space will help them develop a sense of ownership over their space. Involving students with the operation and care of the learning environment, will help change their attitude towards the building. This in turn will motivate them to be even more involved in its operation and care.[44] Furthermore, putting students in charge of building operations helps teach them about sustainability, as it makes building operations more transparent thereby allowing the facility to function more effectively as a teaching tool.[45]

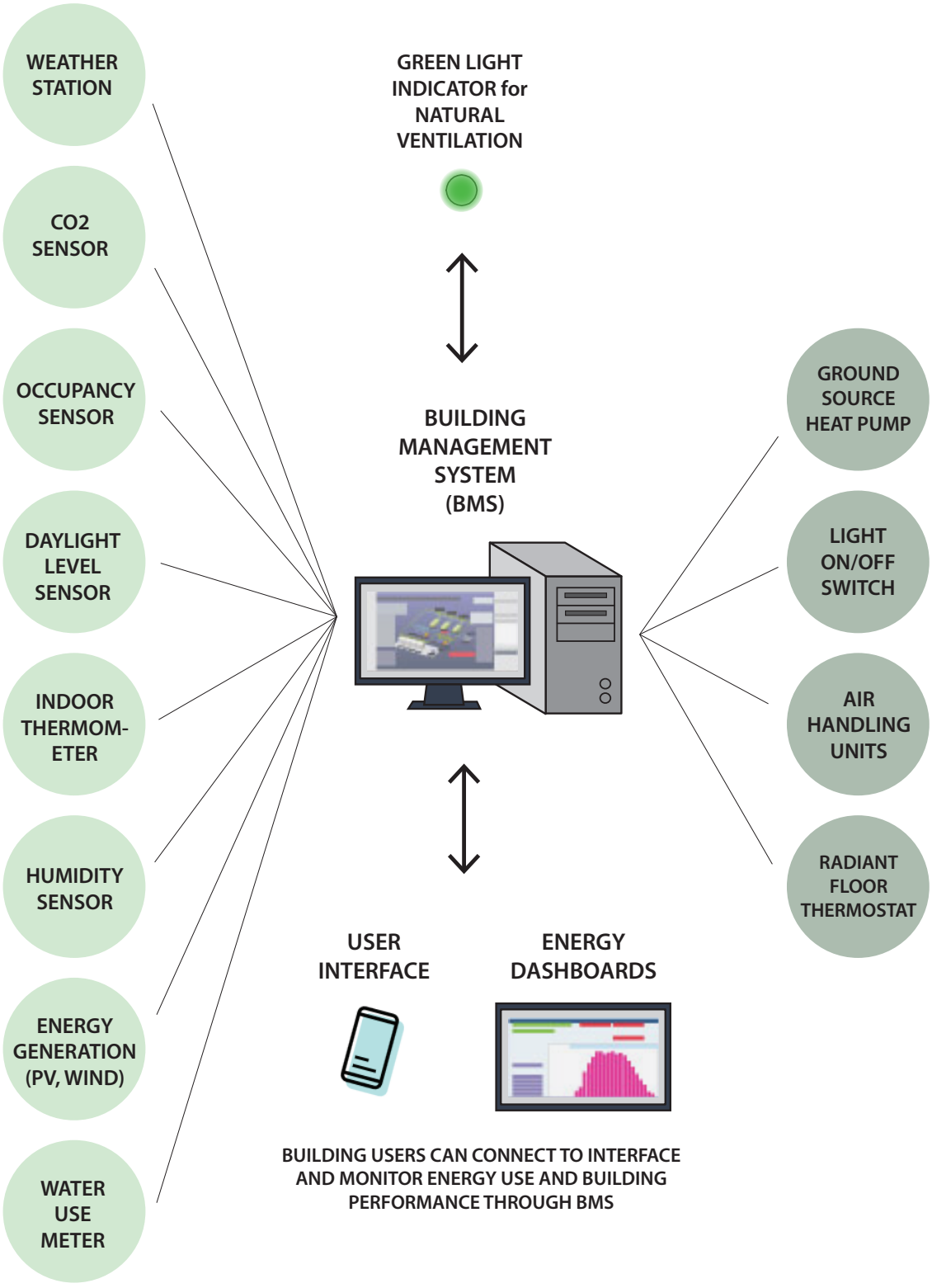


Figure 5.56 - Building Management System Diagram

Active Environmental System Strategies

Supplementing the passive strategies previously described are several active strategies that are employed to provide thermal comfort and improve habitability of the indoor environment all year-round. Energy-efficient mechanical equipment was specified for the proposed project to minimize the energy demand of the building, and several types of systems are used to demonstrate to students various ways that a building can be heated, cooled, and ventilated.

The proposed school is designed to operate as a net-zero energy building – meaning it generates all of its annual energy requirements through on-site renewable sources.[46] The sources of energy that this project specifically harnesses are the sun, wind, and earth's thermal mass, allowing the building to eliminate the use of fossil fuels and thus reduce the building's carbon emissions.

Heating & Cooling:

Geothermal energy is used to provide heating and cooling to the school. The geothermal system functions as heat exchange system with the earth, either extracting from or depositing energy to the ground, depending on the season. This process is possible because at a certain depth below the surface the earth remains at a constant temperature year-round, one that during the winter is much warmer than above-ground allowing the system to use the earth as a heat source, and vice-versa.[47] The proposed school's geothermal system consists of the following components:

1) A closed vertical loop well field located underneath the athletic field that acts as the heat exchanger. The vertical loop consists of pipes installed in 58 individual boreholes that extend 110m below the ground surface. These pipes circulate a fluid that is a mixture of glycol and water which serves to transfer energy between the heat pump and ground.

2) The ground source heat pump used in the school is a water-to-water source pump. It extracts the heat from the collector fluid, concentrates it to a higher temperature to make hot water that is then circulated through the building. For cooling, the heat pump transfers indoor heat to the ground loop, and circulates chilled water.

3) The heated (or cooled) water is distributed throughout the building through a hydronic radiant-floor heating system. The radiant floor system is installed in majority of the regularly occupied areas of the school, though the south wing corridor is an exception as it's designed to accommodate large temperature swings. The building is divided into heating zones, each served by a separate manifold that connects to the heat pump. Each zone is controlled by a thermostat. During the winter the water in the pipes radiate heat up into the room from below the floor surface. The thermal mass of the concrete floor absorbs the heat, staying warm for hours, even when the system isn't actively turned on. During the fall and spring seasons the radiant floor system continues to distribute warm water though at a lower temperature than in the winter. During the summer, the floor alternately delivers chilled water, cooling the floor slab which allows it to act as a heat sink for the room.

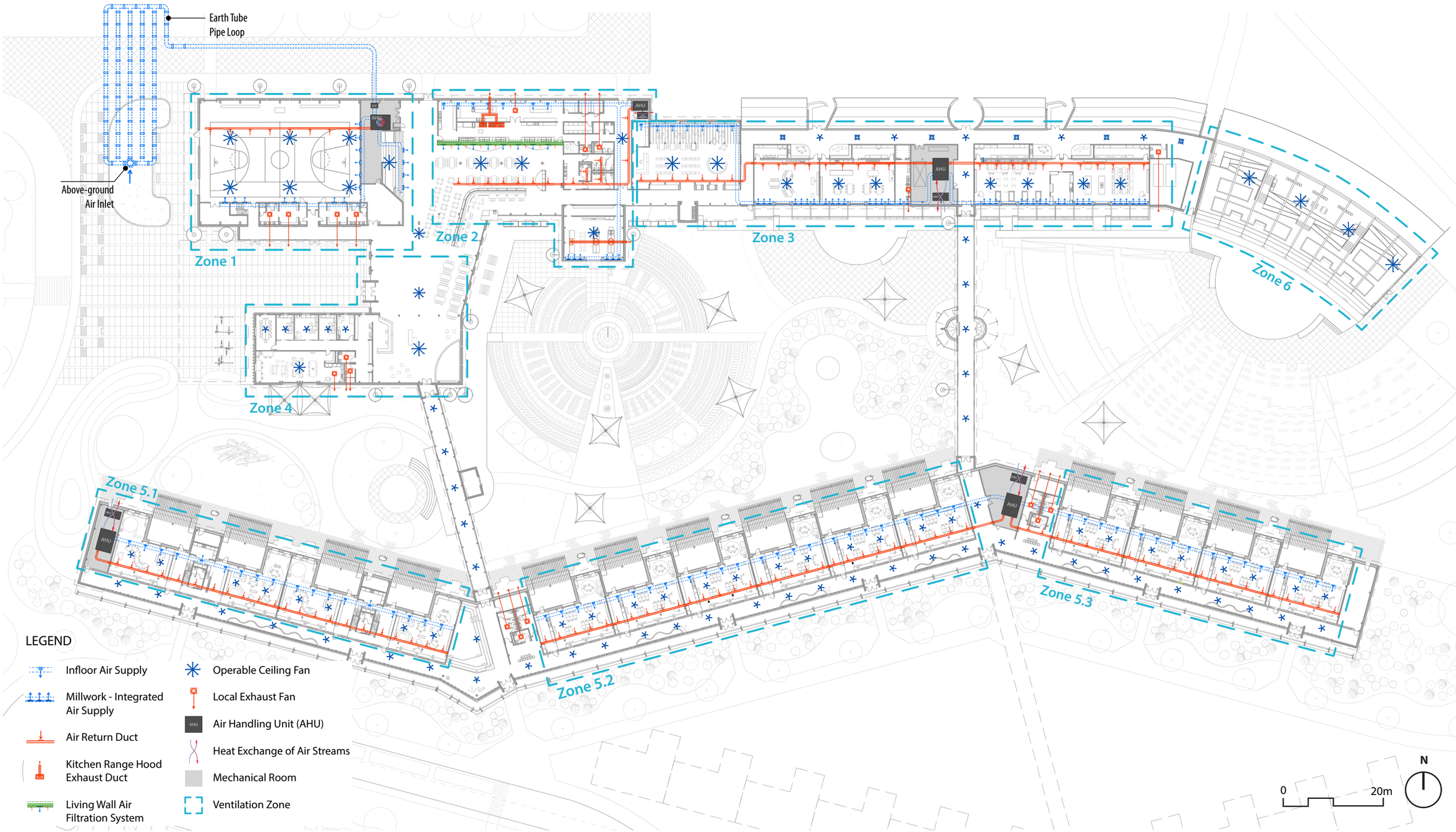


Figure 5.57 - 1:750 Mechanical Ventilation System Floor Plan

The BMS system utilizes scheduling to turn equipment on/off based on the building occupancy and season, as a way of saving energy, so that the system is not always running.

The geothermal heating and cooling system is an efficient heating and cooling system because instead of producing energy, it exchanges it. The geothermal system uses "25% to 50% less electricity"[48] than a traditional system, performs more quietly thereby improving acoustics within the school, and though it is more expensive to install it tends to have higher durability, which when combined with the energy savings making is generally a more economical choice when considered over the whole life-time.[49,50]

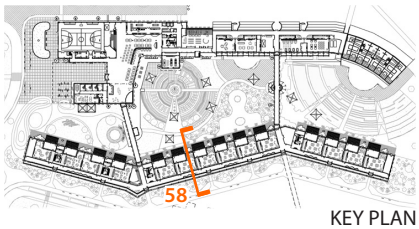
One additional active source of heating is the wood-burning masonry fireplace in the cafeteria. It is only used in winter and when under constant supervision, but it provides a secondary source of heating to the large assembly space, in addition to acting as an architectural focal point around which people gather.

Mechanical Ventilation:

A mixed mode approach to ventilation was necessary due to the climate's extreme variances in temperature between cold and high humidity which posed challenges to solely relying on natural ventilation for air exchange. So while the building primarily operates in "natural mode" during the spring and fall seasons when outdoor temperatures are more moderate, during the winter and on very hot and humid summer days the operable windows are shut and instead a mechanical ventilation system is used to deliver fresh air to the school.

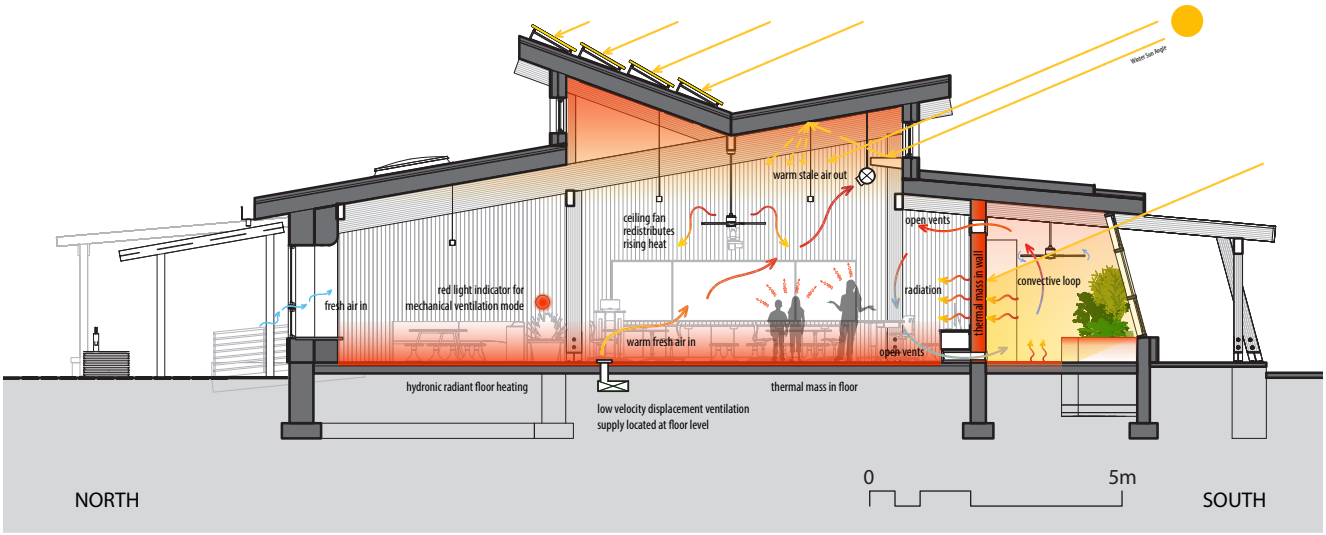
The mechanical system used to deliver fresh conditioned air is an energy recovery ventilation (ERV) system. This system was chosen because of its energy efficiency as it works as an air-to-air heat exchanger, transferring energy between the exhaust and supply air streams rather than letting it go to waste with the outgoing air. In the school's ventilation system, an enthalpy wheel within the air handling units is the method of heat and moisture transfer. During the winter the wheel takes the heat and moisture from the outgoing stale air and transfers it to the incoming fresh air that is drawn from outside. During the summer the process is reversed, and the exhaust air removes the heat and humidity from the incoming outdoor air, before it is distributed any further.[51] The moisture transfer becomes important particularly in the summer as high humid conditions of the site's climate can be negatively impact thermal comfort; the ERV system helps with this by limiting how much moisture is transferred to the indoors with the incoming outdoor air.[52] The use of an energy recovery ventilation system allows the school to downsize the required HVAC equipment.[53] A reduced mechanical system is both economical and resource-efficient because less material is required as ductwork is smaller. A smaller mechanical system is generally quieter than a large-sized one, thereby reducing background noise pollution and improving the acoustics within the school.

The proposed school's mechanical system consists of five energy recovery air handling units, spread out across the school in multiple mechanical rooms. Each air handling unit serves a separate ventilation zone, which increases the energy efficiency of the system as only the zones that are occupied are mechanically condi-

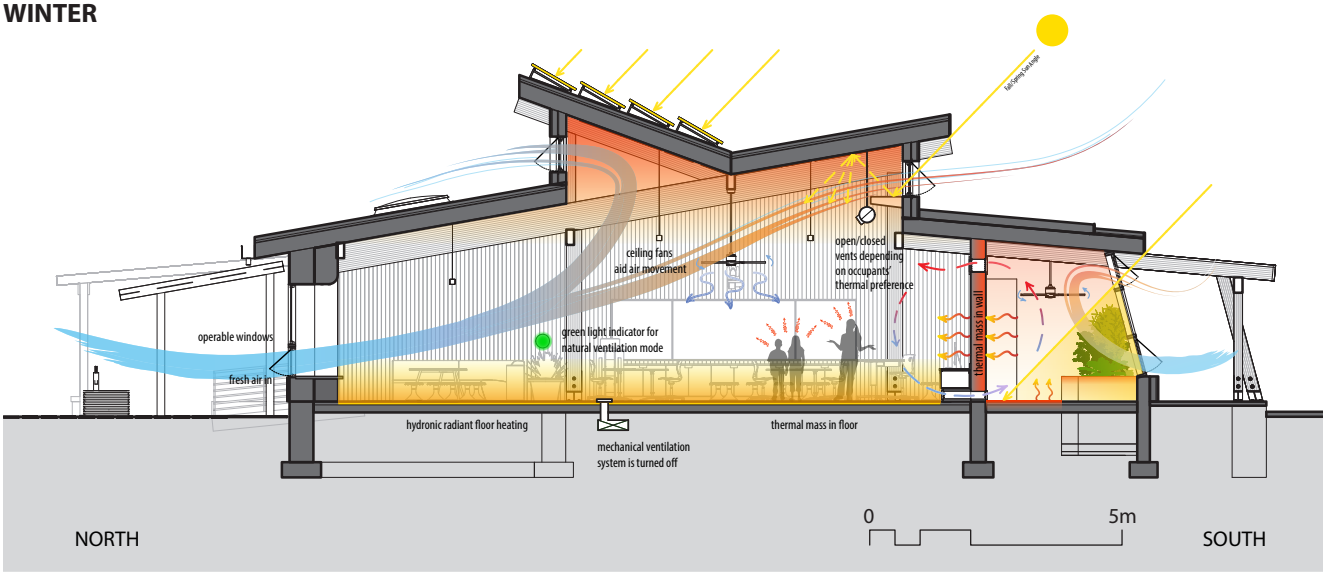


KEY PLAN

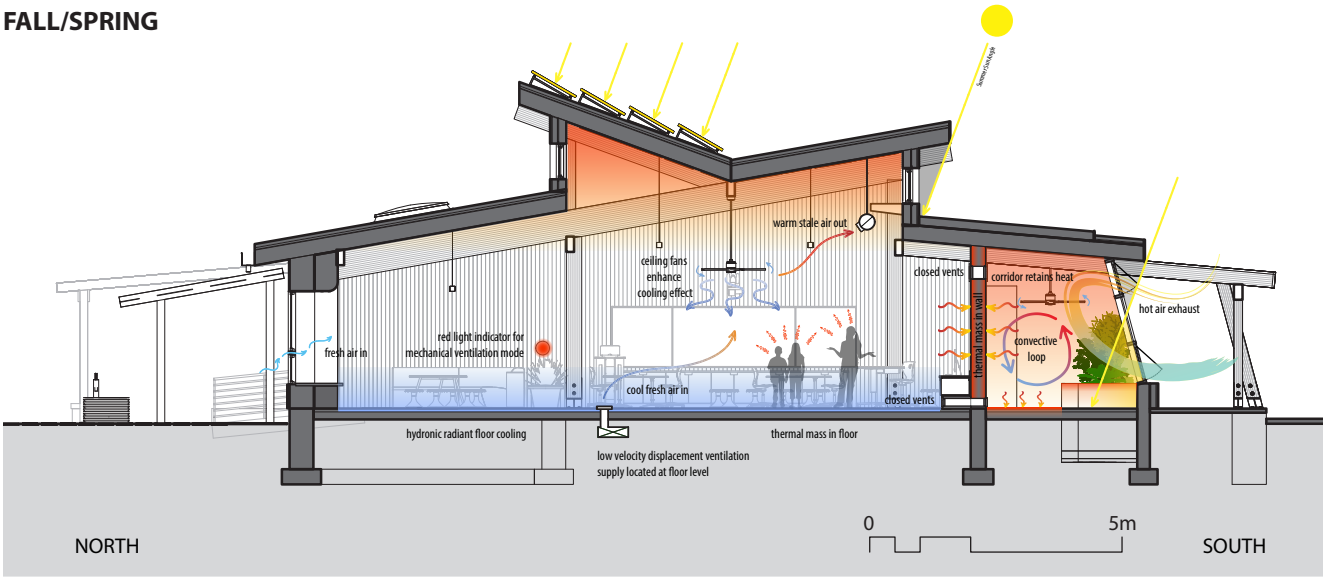
Figure 5.58 – (opposite page) 1:150 Seasonal bioclimatic sections through typical Classroom



WINTER



FALL/SPRING



SUMMER

tioned, rather than the whole building at once. The conditioned fresh air is distributed throughout the school through a method of delivery known as displacement ventilation. In this arrangement the fresh air is supplied into the rooms at a low level, displacing the stale room air which rises up to the ceiling where it is exhausted at a high level. By delivering the incoming air at a lower level the system concentrates on conditioning the occupied zone of the room is rather than the entire space, as is the case with traditional mixed ventilation systems. Furthermore the supply air is delivered at a lower velocity which helps prevent air mixing and drafts. Overall, displacement ventilation helps improve the thermal comfort and air quality of the part of the room that is occupied - where it most matters - making it a more energy efficient method of ventilation.[54]

In the proposed school, the supply ductwork runs below the floor slab and air is introduced through either a floor diffuser such as in the classroom in the south wing, or is through air diffusers integrated into the millwork below the counters such as in the science labs. The air exhaust ducts are placed near the ceiling, right below the upper clerestory windows.

A few other active systems are used to improve the indoor air quality in some of the areas of the school. To prevent cross-contamination of air, separate exhaust fans are used for bathrooms and kitchens so as not to mix the air from these rooms with the air supplied to the rest of the building. The small fans in these exhaust systems are powered by the electricity generated by the photovoltaic system.

A small fan-powered air intake tower is used to deliver fresh air into the corridor buried under the berm, which is achieved through stack effect ventilation. The product specified is the SOLA-BOOST X-AIR® a version of the WIND-CATCHER system manufactured by the company Monodraught. The fan which is powered by an integrated solar panel on the unit, draws air inside through louvres on one side of the tower while extracting the stale indoor air out the other.[55]

Incorporated into the green wall above the cafeteria servery is an air filtration system that harnesses plants' ability to breakdown toxins, and uses them to improve the indoor air quality of the space. The system used is the Nedlaw Living Wall Biofilter™ system which uses a fan to draw contaminated air through the plants, and recirculating the air once it is cleaned through a freestanding duct back into the cafeteria.[56] This system works well for the cafeteria as it is able to help reduce odours from the open kitchen, keeping the space smelling fresh. The system is an energy-efficient way of filtering air, while introducing biophilic elements into the indoor space.[57]

Earth Tube System:

The air handling unit that serves the gymnasium is connected to a horizontal earth tube system. Utilized in two of the precedent projects, the earth tube system is a loop of pipes running horizontally below the ground, with an above-ground inlet pipe connected to them that draws outdoor air into the tubes. Working based on the same principles of heat exchange as the geothermal vertical ground loop, the ground temperature pre-conditions the air that passes through the pipes, either heating or cooling it depending on the season, before it is then delivered to the interior space through the air handling unit.[58] The movement of the air through the pipes is driven by a fan, and a UV light filter removes potential mold

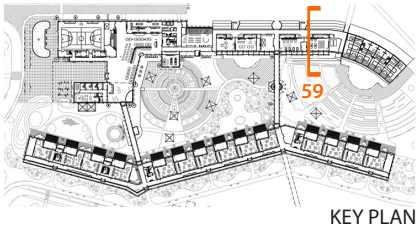
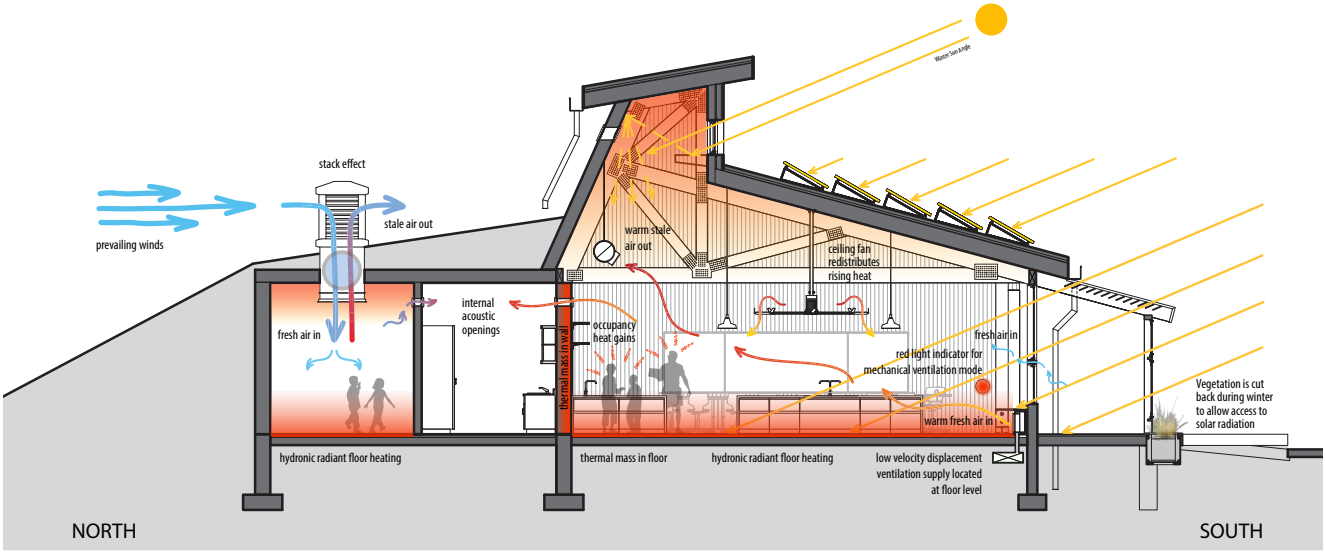
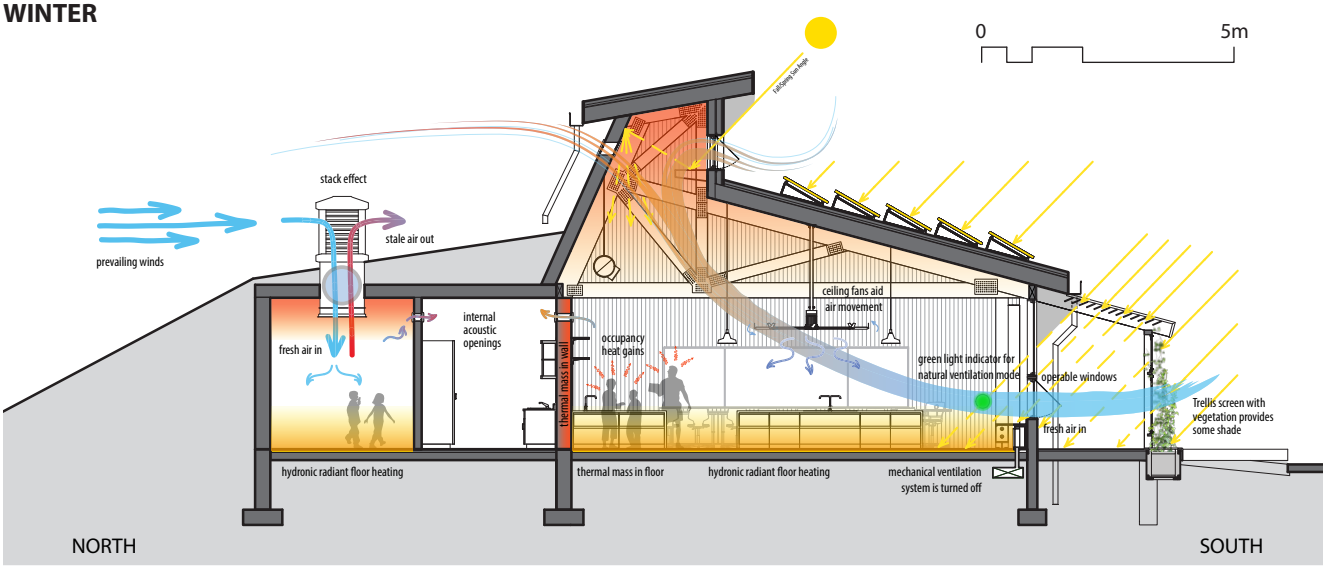


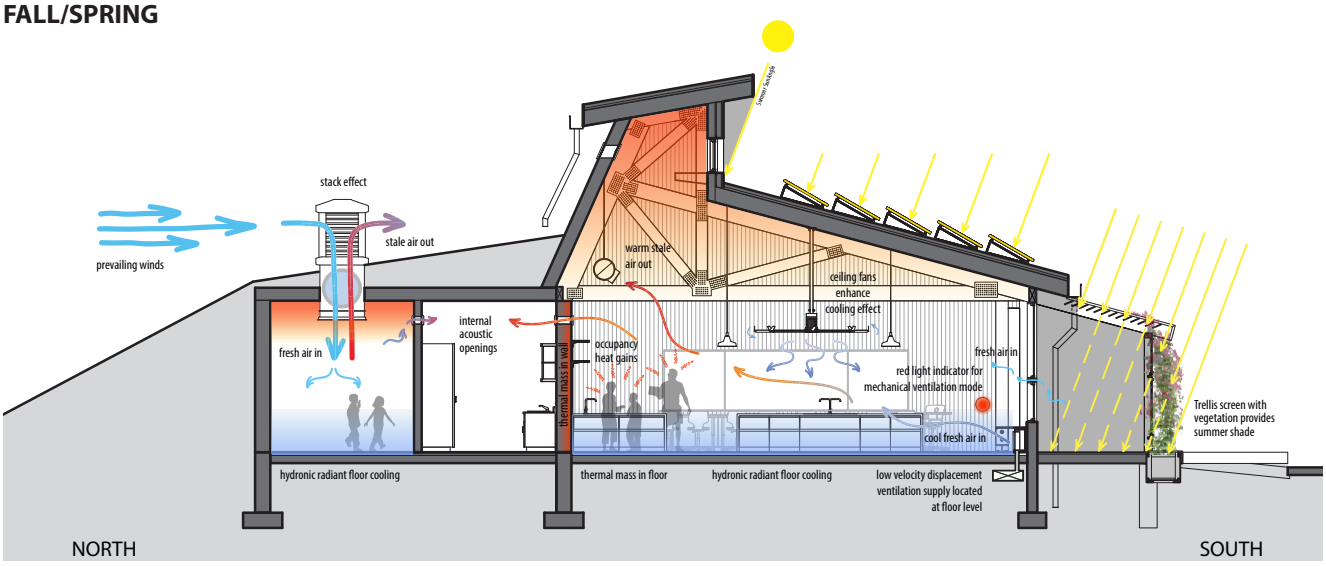
Figure 5.59 – (opposite page) 1:150 Seasonal bioclimatic section through typical Science Lab Classroom



WINTER



FALL/SPRING



SUMMER

in the outside air. The air handling unit contains an energy recovery enthalpy wheel to recover heat and moisture from the gymnasium exhaust air and transfer it to the fresh air coming from the earth tubes further conditioning it. By heating and cooling outside air using a passive strategy (though heat is delivered through an active system), the earth tube system eliminates the need for additional energy input from a mechanical system.[59]

The earth tube system is buried underneath the paved area in front of the gymnasium. The loop consists of five tubes constructed out of precast concrete pipes that are 31.5m long and buried 2m below the ground. Earth tubes were utilized in the gymnasium because the temperature of the conditioned air delivered by earth tubes can at times be slightly cooler than is ideal,[60] but that is not an issue in this space due to the high level of physical activity of the occupants (who are producing their own body heat) and the large assembly of people that gather in the room which results in higher internal heat gains. Though it requires quite a bit of material for a system that only serves one zone in the school, in this case the educational potential was prioritized over economics. The purpose of installing the earth tube system was to demonstrate multiple energy efficient technologies that utilize renewable sources of energy. The low inlet tower is a visible feature at the front of the school, and can be studied by classes.

Renewable Energy Production

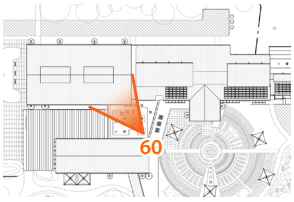
Photovoltaic (PV) Panels: A 255kW grid-tied solar panel system is installed on the rooftop of the school to produce electricity for the building. The system consists of two types of solar panels: standard monofacial photovoltaic panels located on the rooftops of the south wing and north wing, and two-sided bifacial photovoltaic modules incorporated into a glass canopy at the front entrance to the school.

The monofacial PV array are positioned on the areas of the roof that is oriented to the south. The panels are positioned at an angle of 30° - the ideal angle for the climate to maximize the energy production potential of the panels.[61] The south wing holds a 82.5kW system and the north wing a 98kW system. The panels are fixed to the rooftop on a metal rack that helps them achieve the optimal angle in addition to holding them in place. The rooftop panels are partially visible from ground level so the building's occupants are aware of their presence, though they primarily serve a functional purpose producing majority of the energy for the building.

The second type of solar panel – glass-encased bifacial photovoltaic modules – is architecturally incorporated into the entrance canopy so as to showcase that PV panels can be beautiful and can make an architectural statement, in addition to producing energy. As the panels are encased in glass they transmit daylight through the individual cells, and so the shadows they cast on the entrance courtyard help call the PV panels to the attention of everyone passing underneath. With their location at the front face of the building, the panels are a symbol of the school's commitment to sustainability education and practice.

Solar Hot Water: A vacuum tube solar collector is installed with the purpose of capturing the sun's radiant energy to heat water for domestic water uses – such as in the kitchens, janitor's closet, sinks and showers. The solar collectors are mounted vertically on a rack which forms a window shading treatment (a screen) for the south façade of the cafeteria and corridor adjacent to the library. It is placed in front of the areas where hot water is most used which are all clustered around the cafeteria space. The hot water is stored in a cylinder tank within the kitchen service space.

Wind Turbine: Three 1kW residential vertical-axis wind turbines are located on the rooftop terrace above front entry. The energy produced by these is insignificant compared to that of the solar array due to the modest scale of the turbines; their main purpose is to serve as a demonstration of alternative renewable energy sources. The energy produced by the rooftop turbines is used to pump water from the living machine cells to the finishing pond, and then back to the storage tank. The strength of the trickle stream in the finishing pond corresponds to the wind energy available that day. On windy days the stream will have an audible continuous flow; on still days it will be soft and interrupted. This idea was inspired by the fountain at the Adam Joseph Lewis Environmental Centre at Oberlin College, which uses the trickle as a "cue to the building occupants that the weather may be changing."[62] Their fountain was tied to the building's solar panels. Larger-scale wind turbines were not proposed for the school because of their loud volume and the risks they pose to wildlife.



KEY PLAN



Figure 5.60 - Perspective view of the green roof terrace accessible from the gymnasium mezzanine. The green roof allows students to observe the vertical-axis wind turbines and look down into the space below through the tubular skylights. The green roof contains a small weather station that feeds data to the building management system (BMS) about the current outdoor conditions. Students can also overlook the site from a higher perspective, looking down into the activity that is taking place in the courtyards.

Sustainable Site Strategies

Use of Water Onsite

Water conservation is important to the project due to the site's close proximity to the Sixteen Mile Creek. Its situation within the watershed inspires the project to make responsible water use and management both on site and within the building, a key component of the school's sustainable design. This strategy qualifies the project for points under the LEED v4 rating system for regional priorities which place emphasis on existing credits that are considered important to a specific region; for the southern Ontario region "Indoor Water Use Reduction" and "Rainwater Management" are among these credits.[63]

Water Use Reduction:

Water efficiency is achieved through several strategies that are put in place to reduce the school's potable water consumption. These include rainwater collection and storage, onsite wastewater treatment and reuse, the installation of water efficient fixtures, and the use of native vegetation for landscaping.

Supply Source: Potable water which is used for drinking and cooking is supplied by an onsite well which draws water from an underground aquifer. The water required for all other purposes is supplied by the onsite rainwater storage tanks.

Rainwater Collection:

A large system was designed to collect and store rainwater harnessed on site. The rooftop of the school forms the catchment area of the collection system – a role for which it is well-designed. The sloping surfaces of the gable and shed rooves combined with the smooth finish of the standing-seam copper roof help maximize the amount of rainwater that can potentially be collected.[64] With a water catchment area of roughly 8260m^2 (the area of the roof), and an average annual rainfall of 741.5mm, the rainwater harvesting potential of the building is high. The rainwater is channeled across the roof surface and directed into the gutters, from where the water flows into one of the storage tanks. The storage system is made up of a combination of underground cisterns and above-ground metal water tanks. The cisterns are sized to accommodate the peak monthly rainfall average. The two underground cisterns have a storage capacity of 250,000 litres for the bigger one, and 60,000 litres for the smaller one. The above-ground water tanks are distributed around the site and come in an 11,000 litre or 25,000 litre size. The collected rainwater is used for toilets, sinks, showers and irrigation of crops both outdoors and in the greenhouse.

The inverted umbrella canopies also have a rainwater harvesting capability, capturing it and funneling it into a small 3000 litre cistern directly below. The rainwater collected by the umbrella canopies is used for irrigation of the produce garden. Each canopy has integrated into it a hose connection, and as they are dispersed throughout the courtyards, they make watering the garden easier, reducing the travel distance to a water source. The hose is stored underneath the wooden seat-

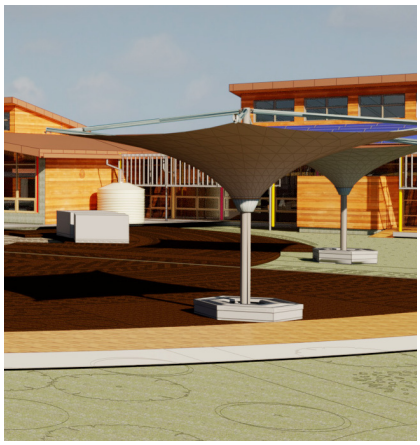


Figure 5.61 – Rendered view of typical inverted umbrella canopy within the primary grades courtyard.



Figure 5.62 - 1:1250 Rainwater Collection and Stormwater Flow Diagram

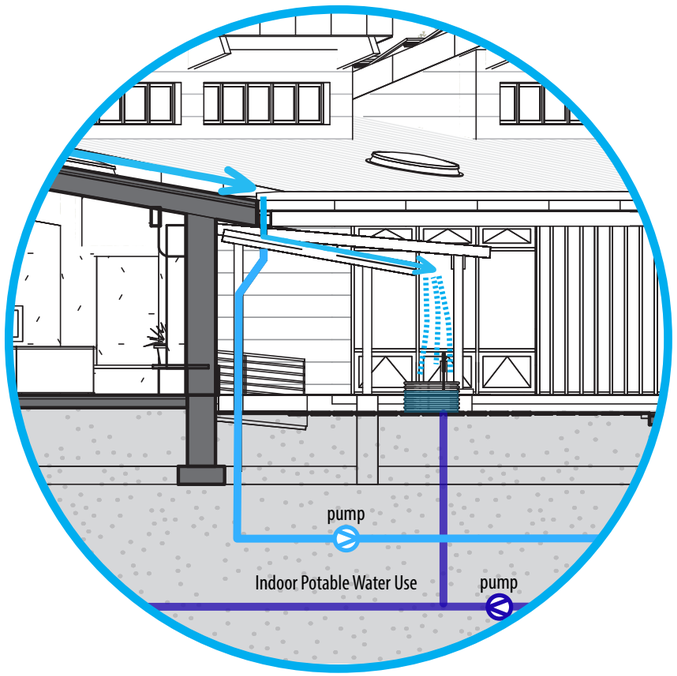


Figure 5.63 - 1:100 Section of Interactive Classroom Water Feature

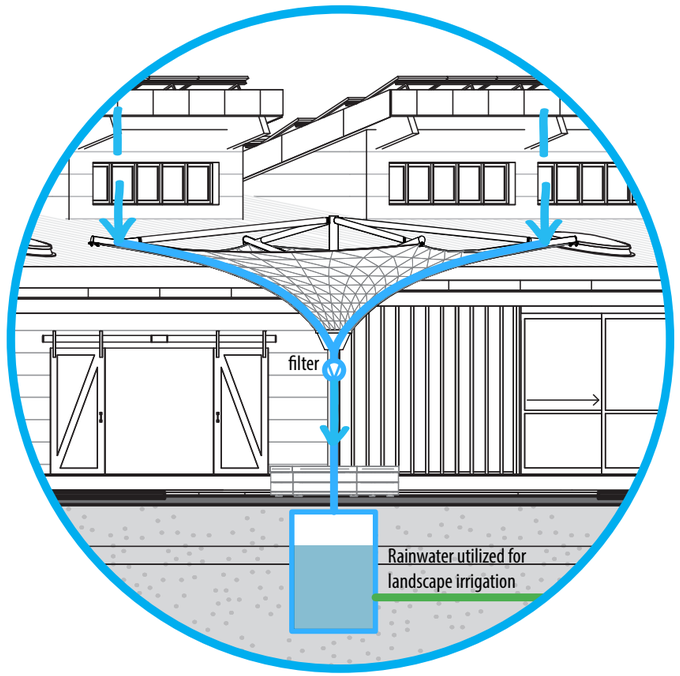


Figure 5.64 - 1:100 Section of Inverted Umbrella Canopy Highlighting the Rainwater Collection System

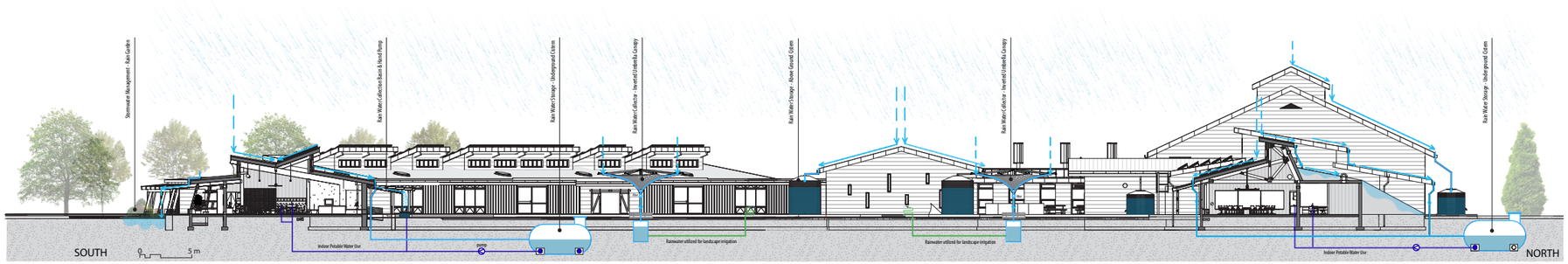
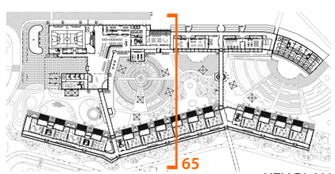


Figure 5.65 - 1:500 Section of Rainwater Harvesting System



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ing, and easily pulled out/stowed away.

The rainwater harvesting system is designed to allow for student interaction. The box gutters across the whole roof area are more largely sized than typically – 250 x 250mm so that they are a feature that stands out on the façade, increasing the likeliness of students noticing their presence. Incorporated into the outdoor classrooms is an interactive water feature consisting of a manual hand pump and small collection basin which is connected to the main underground water cistern. Water from the gutters on the classroom roof is channeled down into a large scupper made out of an I-beam, elevated on steel columns. The scupper carries the water overhead where it directs it down into the metal basin. One purpose of this feature is to make visible the rainwater flow through the open scupper, which forms a waterfall as it drains into the basin. As the feature is positioned right across from the classroom window seats, students are able to directly observe the water streaming down from the roof into the basin during rainstorms. A manual hand pump is connected to the small basin, which is connected to the main underground cistern. The hand pump allows students to draw water from the main cistern and use it for washing dirty hands, to water plants in the classroom garden, or for class experiments, among many other uses. Requiring the use of human power to work, the manually operated hand water pumps help students appreciate the water that comes out effortlessly from the indoor faucets.

Wastewater Treatment & Reuse - The Living Machine:

The proposed school treats all of its wastewater onsite through a biological wastewater treatment system known as the Living Machine®. All water used throughout the building – from the toilets, sinks, and showers – is processed through the Living Machine and cleaned onsite to tertiary standards, allowing it to be reused for flushing toilets and landscape irrigation. This not only reduces the amount of potable water the school uses, but eliminates the need to connect to the city's municipal sewage treatment system. The filtration process is achieved without the use of chemicals, and is less energy intensive as the only electricity needed is to power the pumps that distribute the water, which is supplied by the solar panels. The treatment process is made possible by harnessing the natural filtration abilities of plants and the microorganisms and bacteria inhabiting them, which as previously explained in the precedent study, digest the waste solids in the affluent thereby breaking them down.[65]

The Living Machine system is designed to be visible, engaging, and beautiful, in addition to being functional. The various cells and tanks in which the digestion takes place are spread out around the school, both indoors and outdoors, to make the wastewater water treatment a visible operation which students encounter with on a daily basis. Students are engaged with the process, contributing to it by way of helping create affluent. The aerobic reactors which contain a lush variety of plants, introduce elements of nature into the circulation spaces of the school, enhancing the biophilia of the building, and making the corridors be a place where students want to spend time and linger. The outdoor wetland cells also form a landscaping feature for the courtyard, one that is aesthetically pleasing but also functional.

The Living Machine at the proposed school is also valuable because of the opportunities it provides for environmental education. It demonstrates to students alternative methods of wastewater treatment and biological processes at work; it offers transparency of the systems that support the everyday operations of the school making a process that is often hidden away, very visible. Teachers are able to incorporate the system into lessons on biology, resource management, ecosystems, and sustainable practices, among others. It helps teach students about the importance of water as a resource, and challenges them to reconsider "what's waste vs. what's resource."[66] The outdoor wetland cells are positioned directly across from the science labs so that they can easily be integrated into lessons.

Wastewater Treatment Steps:

1) Washrooms – The washrooms are where the affluent for the treatment process is created. Every building occupant contributes to the process by way of helping make affluent. The process starts when wastewater exits the washroom, flowing to and gets distributed into the primary septic tank.

2) Settling Tank – Wastewater enters the settling tank where gravity helps settle the organic solids, as they are left inside the tank for a few days to allow them to begin breaking down, so the affluent can proceed through the wastewater treatment process as a liquid, and be filtered through with more ease. The lack of oxygen in this tank enables the bacteria to start to digest the organic and inorganic compound in the wastewater.

3) Horizontal Subsurface Flow Wetland Cells – From the settling tank the water is pumped into the wetland cells located outside in the upper grades courtyard. Consisting of three concrete cells that are about 1.2m deep, the wastewater flow through horizontally below the surface, entering through an inlet on one side and slowly flowing through to the outlet on the opposite side of the cell,[67] from where it exits to the next cell repeating the process. Subsurface flow occurs below a thin layer of gravel and mulch which reduces odours and potential contact with the wastewater which could be a health hazard to students,[68] as well as insulates the roots from freezing during the winter. Two separate levels of pipes are installed in this segment of the process – a higher level for the summer, and lower depth for winter - this is another winter precaution taken (inspired by the system at the CAWT precedent). The initial step of wastewater filtration was located outdoors as a way of controlling odour within the building itself, much like it was in the Omega Centre precedent. In these cells the waste is progressively broken down by microorganisms, and absorbed by plants as nutrients. The cells are arranged down a slope, each one lower than the previous one.

4) Open Aerobic Reactors – From the wetland cells, the affluent in pumped indoors through a series of open aerobic reactors located in the corridors of the classroom wings. The curvilinear concrete cells are 1.5m deep and filled with tropical plants that are supported on metal racks, with their roots suspended in the water. The roots are host to bacteria which continue the nitrification and denitrification process, while the plants uptake nutrients form the affluent. The south-facing façade admits high levels of daylight, simulating the greenhouse like conditions which these tropical plants thrive in. This is a highlight feature of the Living Machine, turning the corridors into more than just a circulation space, but a laboratory. The plants introduce biophilic elements into the indoors, and are beautify the space. The cells do not smell, as by this point the water has been treated to some degree outside. The water is pumped in succession between a total of six cells, travelling in the east to west direction through the corridors.

5) UV Filter – From the final aerobic reactor located in front of the kindergarten classrooms, the water is pumped through a UV filter to remove any remaining bacteria in the water.

6) Polishing Pond – The water is then pumped into a polishing pond for the final filtration step. At this point the water is clean enough for use, which is demonstrated in this pond, as people can observe the clarity of the water. The water is pumped into the pond through a small waterfall feature constructed out of local stone, and the pump is powered by the wind turbines situated on the roof terrace above.

7) Reuse Storage Tank – From the polishing pond, the water is pumped to the storage tank which holds the water until it is reused again by the building to either flush toilets or for landscape irrigation.

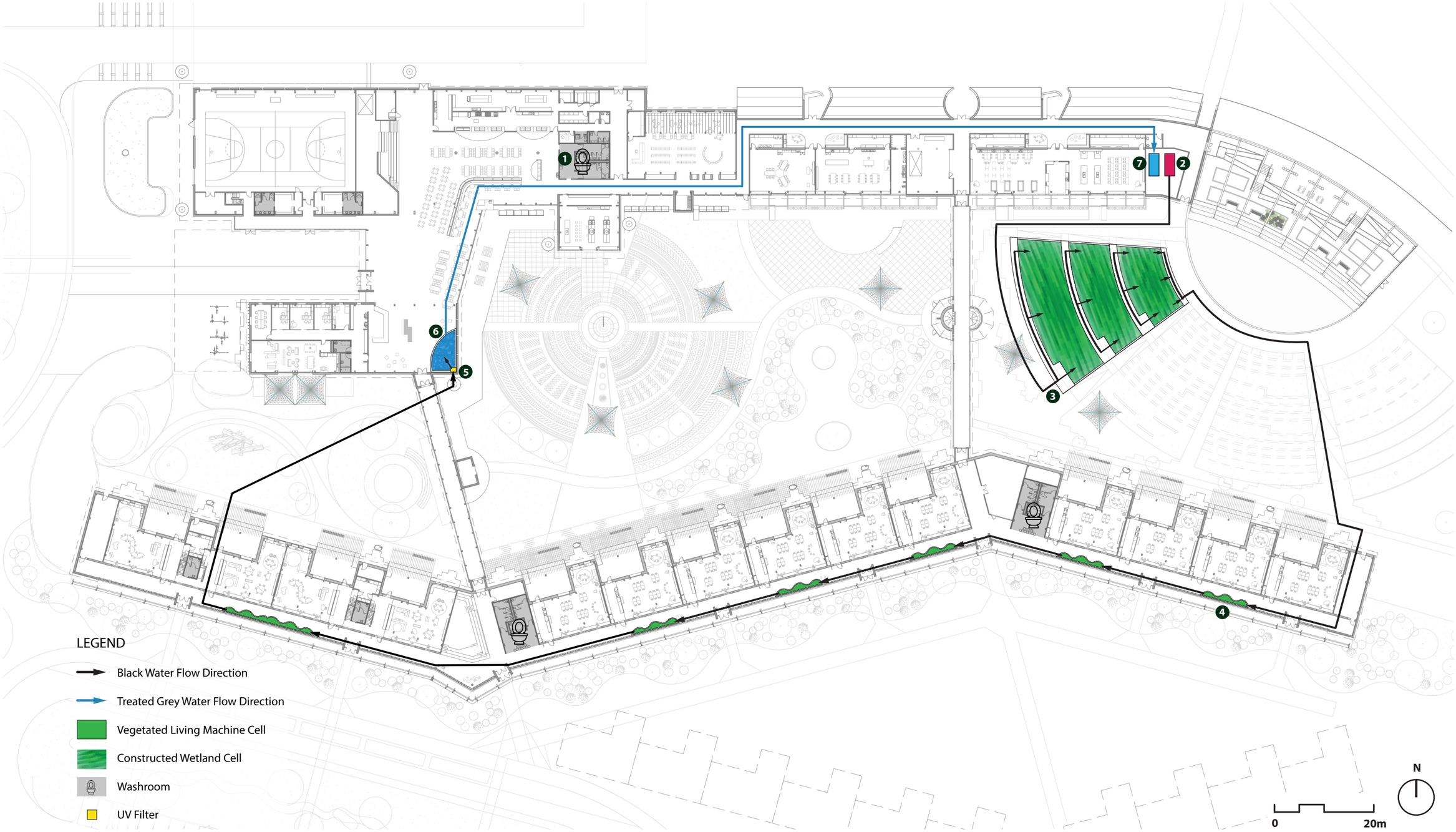


Figure 5.66 - 1:750 Wastewater Treatment Flow Diagram

Water Efficient Fixtures:

To further reduce indoor water use, water efficient plumbing fixtures will be installed throughout the school. These include low-flow dual flush toilets, waterless urinals, and aerators on sink faucets. Sensors are not installed on faucets despite their many benefits, because the school wants students to be personally responsible for turning water on and off, and be aware of how long they leave it running. Water efficient appliances (dishwashers, etc.) are provided in the cafeteria kitchen.

Landscaping – Plant Species Selection

The landscaping strategy utilizes a large palette of native species of vegetation as a means of significantly reducing or even eliminating landscape irrigation requirements. Native plants are able to survive and thrive with little maintenance as they are adapted to the climate of their region. This makes them more hardy against cold weather, and they have an increased ability to survive during drier seasons withstanding periods of low rainfall without any additional irrigation. The native plant species are an extension of the ecosystems found on the site, and thus create a habitat for local species.

The general palette for the site landscaping is illustrated in the figure on the opposite page. Plant species for the landscape of the proposed design were selected with the seasons in mind. It was necessary for the landscape to be visually interesting throughout the whole year, not just during the summer season which is when the majority of plants are in bloom but is the period when school is not in session. All four season are equally represented through the selection of plants. The wildflowers, meadows grasses and trees were chosen based on consideration of texture, colour and form to create year-round visual interest. The palette of species was also selected with the aim of having three distinct canopy heights (low, medium, and tall).

Wildflowers:

The colour palette of the wildflowers is based on seasons. The species that are in bloom during the same seasonal period were all selected so that their flowers form a unified colour scheme. The spring wildflowers colour the landscape in light pastel colours in shades ranging from white to light purple and soft pink. The summer colour scheme is warm, bright and colourful; the summer flowers bloom in bold shades of orange, red, pink and a deeper purple. The fall flowers are more earthy in tone, ranging in colour from white to warm yellows to brownish-pink and mauve. The shifts in colour throughout the year become a way of signalling to students that the next season is approaching, and help them understand seasonal changes that occur in nature. Students come to understand what is blooming and when, as the landscape takes on a distinct identity each season. The wildflowers are planted in the raingardens, bioswales, pollinator garden and planters, as well as in other open areas on the site. The bright coloured flowers help attract pollinators (bees, butterflies and humming birds) to the site.

Figure 5.67 - (opposite page) Visual diagram of the native plant species that would be used for the site landscape. Plants were selected based on seasonal colour palettes, and the species picked for each season come in a three distinct canopy heights: low(L), medium (M), tall (T).

PLANT PALETTE: WILDFLOWERS

SPRING



Foxglove Beardtongue
Penstemon digitalis
* 75-90 cm (M)



Wild Lupine
Lupinus perennis
* 30-60 cm (L)



Dwarf Lake Iris
Iris lacustris
* 3 to 5cm (L)
* Native, but rare



Hairy Beardtongue
Penstemon hirsutus
* 30-90 cm (M)



Prairie Smoke
Geum triflorum
* 20-40 cm (L)

SUMMER



Butterfly Weed
Asclepias tuberosa
* Up to 90cm tall (M)



Bee Balm
Monarda didyma
* 60-120 cm (M)



Purple Coneflower
Echinacea pallida
* Up to 90cm tall (M)



Culver's Root
Veronicastrum virginicum
* 120-210 cm (H)



New England Aster
Aster novae-angliae
* Up to 120cm (H)

FALL



Heath Aster
Aster ericoides
* 60 cm (M)



Canada Goldenrod
Solidago Canadensis
* Up to 200 cm (H)



Black-Eyed Susan
Rudbeckia hirta
* 30-80 cm (L)



Spotted Joe Pye Weed
Eutrochium maculatum
* 60-150 cm (M)



'Autumn Joy' Stonecrop
Sedum spectabile
* 50-60 cm (M)
* Non-native, but hardy

PLANT PALETTE: GRASSES

SPRING WINTER

YEARLONG



Little Bluestem
Schizachyrium scoparium
* 60-90 cm (L)



Big Bluestem
Andropogon gerardii
* 150-180 cm (H)



Canada Wild Rye
Elymus canadensis
* 90-180 cm (M)



Indian Grass
Sorghastrum nutans
* 90-150 cm (M)



Side Oats Grama
Bouteloua curtipendula
* 60-75 cm (L)

Grasses:

The native Ontario grasses that were selected continuously undergo changes in colour, texture and size throughout the year, resulting in an ever-changing landscape. When the wildflowers finish blooming in the late-fall, the grasses become the centerpiece of the landscape. Even when there is snow on the ground, the grasses are able to provide winter interest to the landscape as they are able to hold up under the weight of snow, and gain a striking appearance when frost and snow catches onto the soft plumes of the grasses. The grasses which sway and rustle in the wind, also add the elements of motion and sound to the school's landscape, engaging students' senses beyond just the visual. The grasses are planted in several locations both within the enclosed courtyards, in the open areas surrounding the building, and within the depressions of the bioswales and raingardens. They help merge the school with the existing meadows on the site.

Trees & Shrubbery:

The trees planted on the site are primarily deciduous species that are an extension of the species found in the adjacent woodland and along the 16 Mile Creek. Deciduous trees are planted to create a cool microclimate on the site in the summer, as well as for providing a habitat for wildlife on the school's site. Deciduous trees are planted along the south façade of the classroom wing to provide summer shade, but are placed at some distance from building so as not to interfere with the passive solar gain system during the winter, as even bare branches can have a limiting effect on this.[69] The smaller deciduous species: birch and plum are placed within the courtyard, as well as around the exterior of the building. There is a row of coniferous tree planted alongside the north exterior façade, in the open area between the building and athletic field, which serves as a windbreak to protect the otherwise exposed façade of the gymnasium and kitchen from cold winter winds from the North direction.

Continuing the theme of a seasonally changing landscape, the deciduous trees too change colour and texture throughout the year. Even during the winter, though the deciduous trees lose their leaves, the barks on the trees is able to provide the outdoor space with visual interest. The paper birch with the texture of its peeling bark is one such species. The distinctive red bark of the dogwood also provides winter interest to the outdoor landscape, as does similarly the warm-brown bark of the ninebark, which flakes during the winter. The coniferous trees introduce a deep green colour to the landscape scheme.

- Sugar Maple *(Acer saccharum)*
- White Oak *(Quercus alba)*
- Paper Birch *(Betula papyrifera)*
- Canada Plum *(Prunus nigra)*
- Eastern Hemlock *(Tsuga canadensis)*
- Eastern White Cedar *(Thuja occidentalis)*
- Shrub: Ninebark *(Physocarpus opulifolius)*
- Shrub: Red Osier Dogwood *(Cornus stolonifera)*
- Shrub: Common Juniper *(Juniperus communis)*

Constructed Wetland:
Bulrush *(Scirpus validus),* Common Cattail *(Typha latifolia),* Soft Rush *(Juncus effuses)*, and Blue Flag Iris *(Iris versicolor)*

Plant species for the constructed wetlands were selected based on their suitability to the conditions of the outdoor space and their ability to perform the filtration function. The plants chosen were ones that are native species commonly growing in the region's wetland habitats, as they would be capable of withstanding the harsh winter temperatures of the climate. These species are known for their ability to filter toxins and have proven to be effective at subsurface filtration of pollutants and suspended solids.[70] The use of reeds (*Phragmites australis*) in the design is avoided despite their common usage in constructed wetlands as they are an invasive species in Ontario. It is best to avoid creating a potential threat to ecosystem of the site as they could spread to the creek through natural propagation.[71]

Open Aerobic Tanks (Corridor Planters):
Some of the species contained within the open aerobic tanks are as follows: Canna Lily *(Canna x. generalis),* Calla Lily *(Zantedeschia aethiopica),* Dwarf Banana Plant *(Musa Acuminata),* Elephant Ear *(Alocasia odora),* Taro *(Colocasia esculenta),* Umbrella Plant *(Cyperus alternifolius),* Egyptian Paper Reed *(Cyperus papyrus),* Pennywort *(Hydrocotyle umbellate),* and Yellow Iris *(Iris pseudacorus).*

The plant species selected for this area of the school are not native to the region, but were selected based on their ability to thrive in indoor/greenhouse-like conditions. Thus the plant palette of the open aerobic cells in the corridors mainly consists of tropical plants. The tanks contain a wide variety of plants species, as diversity is beneficial to the water treatment process that takes place in the Living Machine as it allows for a greater variety of toxins to be filtered out of the water.[72] These species provide visual interest through the bright flowers of many of the plants and because of the different canopy heights of the plants. Many of these species were utilized with success in the Living Machines at the IslandWood campus and Omega Institute.

Stormwater Management

Several strategies are used to help reduce and manage stormwater runoff using a combination of landscape features, the rainwater collection system and permeable materials to help minimize the building's impact on the site. The existing site water drainage paths were maintained to allow rainwater to naturally drain towards the creek. The site design reduced the surface area of impermeable hardscapes with a smaller-sized parking lot that provides only 42 parking spaces. Parking overflow (for large school events) is handled through the provision of a larger lot that utilizes a permeable paving surface that allows for groundwater infiltration through the grass between the pavers. The landscape design in the interior courtyards consist entirely of permeable surfaces, using a permeable type of stone aggregate known as stabilized decomposed granite[73] and an elevated wooden deck to allow for wheelchair accessibility. As previously described, all rainwater runoff from the rooves is collected and stored in on-site cisterns, which reduces potential flooding issues around the school.

The rainwater runoff from the impermeable surfaces is managed through the use of bioswales, raingardens, bioretention planters and stormwater retention ponds. Bioswales and raingardens are landscaping features that work with nature to capture and retain rainwater during rainfall, slowing down its flow and filtering it through the plants and layers of soil as it gradually infiltrates the soil until it is released back to the site. They help reduce the volume of runoff on the site at the time of a storm and help clean it from pollutants. [74] Both bioswales and raingardens are a depression or basin in the ground that holds a wide variety of native plants species – mostly wildflowers and grasses - and vary mostly in terms of size and depth.[75] In the proposed project, the raingardens are located along the perimeter of the south classroom wing, collecting surface run-off from the paved colonnade and using a rain chain to convey rainwater from the roof into the garden. The bioswales collect and store rainwater runoff from the impervious surfaces of the parking lots and roadways, and once it infiltrates to the bottom of the basin, the rainwater that was not absorbed by the soil and plants is conveyed into one of two onsite retention ponds. There are two bioswales provided on the site, one at the south wing parking lot, and another at the west front entry lot. The vegetation used in both the bioswales and raingardens are the native wildflower and grass species which are able to adapt well to both flooded and dry conditions. These landscape features in addition being functional also provide a habitat to support onsite wildlife. The bioretention planters which are located at the edge of the front entry courtyard to collect rainwater runoff from the paved surface and glass canopy, work based on the same principles as the raingardens, temporarily storing rainwater and letting it slowly infiltrate into the ground. Students learn from these stormwater management features about hydrology, how water cycles through the site, the importance of healthy watersheds, as well as demonstrating to them sustainable techniques of water management and onsite water treatment.

Other Site Strategies

Other sustainable site strategies include:

Reduced Heat-Island Effect: The potential for heat-island effect on the site is reduced through 1) a reflective metal roof finish (copper) and vegetated green roof areas, 2) a smaller asphalt parking surface area 3) by dispersing trees throughout the site, concentrating them around the roadways and parking lot perimeter and on the parking islands.

Open Space and Site Maintenance: Outdoor green space is maximized through the provision of green space within the courtyards, as well as by leaving open areas of land around the building. The surrounding site areas are left to be naturalized as meadows, eventually merging with the existing meadow ecosystem on the site. The landscape in the inner courtyards is regularly maintained as required, though only a few areas like the vegetable garden and the grassy slope of the amphitheater require irrigation. The landscape on the outside of the building is low maintenance, and the only part that is regularly mowed is the grass on the athletic field. The athletic field is watered sparingly, and it is

accepted by students that during dry season it will be a shade of brown rather than bright green.

Transportation:

- Bicycle parking spaces are provided onsite with one large bike rack area at the front entry courtyard (next to the kindergarten play area) and individual parking stands along the sidewalk running along the exterior south-facing façade of the classroom wing. The bicycle parking is placed near the entranceways to encourage students and staff to bike to school. The bike stands at the front entry are protected from the elements by the PV glass canopy, and both spots are areas that are high traffic and under supervision. The bicycle racks along the classroom entrances features creative designs (featuring bicycles, native wildlife, elements of nature) that act as art pieces as well as parking stands, taking the opportunity to reinforce the school's sustainability theme.

- Plans are made for accommodations for a future public transit connection by extending the sidewalk area and with the provision of a small bus shelter along Regional Road 25. It is expected that the school site would be connected to the Milton Transit System and serviced by Route 9 (Ontario South) as that bus route already travels north and south along Regional Road 25, with the nearest existing stop at Farmstead Road and Britannia Road. The public transit route directly connects to Milton GO Station, which would allow for employees to commute from further away by using public transit rather than having to rely on cars to get to work.

- A walking trail is provided across the site to connect the school to the future residential neighbourhood to be built north-west of the school.

Waste Disposal and Compost: The school utilizes the Molok® waste system for garbage and recycling. The Molok® system consists of a deep waste bin the majority of which is installed underground, allowing it to be emptied less often, about once or twice a year, thus decreasing the use of fossil fuel and noise disruption that comes with weekly garbage pickup.[76] Separate bins are provided for waste and recycling and are located outside the cafeteria kitchen. Students are taught to sort their food scraps into a separate collection bin in the cafeteria, which is then emptied into the outdoor compost bins located in the primary grades courtyard, in a spot just outside the Learning Kitchen. The compost is then used to fertilize the vegetable garden and plants in the greenhouse.

5.4 - Design Narrative

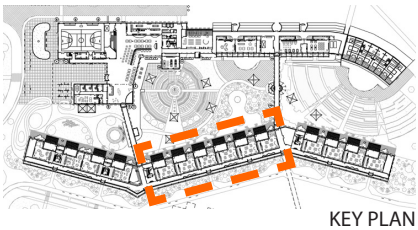
The Classroom Module

The basic building block of the south wing is the classroom module and it serves as the primary space of instruction within the school. Each classroom has a floor area of 145m^2 and is designed to support 20 students and 1 instructor, purposefully allotting more square footage per student than is conventional as a way of improving comfort and wellbeing within the classroom space, as well as to increase the number of possible ways that the space can be used. The classroom follow the traditional homeroom concept, where one set of students utilizes the same room for the entire school year as a way of encouraging students to develop a sense of ownership and responsibility towards the space. Each classroom is like a little community or place of refuge in the larger context of the school. The key driving concepts of the classroom design are: flexibility of use, increased wellness, connection to the outdoors, provision of a mudroom, and provision of a private outdoor classroom for each module.

The L-Shape Classroom and Zones of Use

The floor plan of the classroom is configured in an "L-Shape" layout as a strategy for providing increased flexibility of use within the space. The L-shape allows the classroom to be conceived not as one big space, but a collection of smaller zones of use that are able to accommodate a greater variety of modes of learning and teaching styles.[1] The larger leg of the 'L' holds the mudroom and wet zone which can be utilized by students as a project space. The smaller leg forms a more private breakout space, where groups can meet alone with the teacher, or at which students can sit down on the sofa when they need a break from more focused tasks. In between these two zones is the central flexible classroom space which accommodates group work, teacher instruction and class assembly. The L-shape allows for a degree of separation between these zones while allowing for ease of movement between them. The void space between the two legs is utilized as a private outdoor classroom, similarly to how it was used in the Crow Island School precedent. Other zones that were created in the classroom space are an individual work station with computer access, a window seat wall to allow for students to seclude themselves or take the time for reflection, an active marker board wall, and a wooden screen provides space to display student work.

Flexibility within the classroom space is further enhanced through the provision of mobile furniture. The desks and chairs are on wheels, allowing the class to reorganize themselves into a variety of arrangements depending on the task at hand. Furniture can even be rolled out onto the outdoor classroom deck. The furniture is also height-adjustable to ensure that every student is comfortable.



KEY PLAN

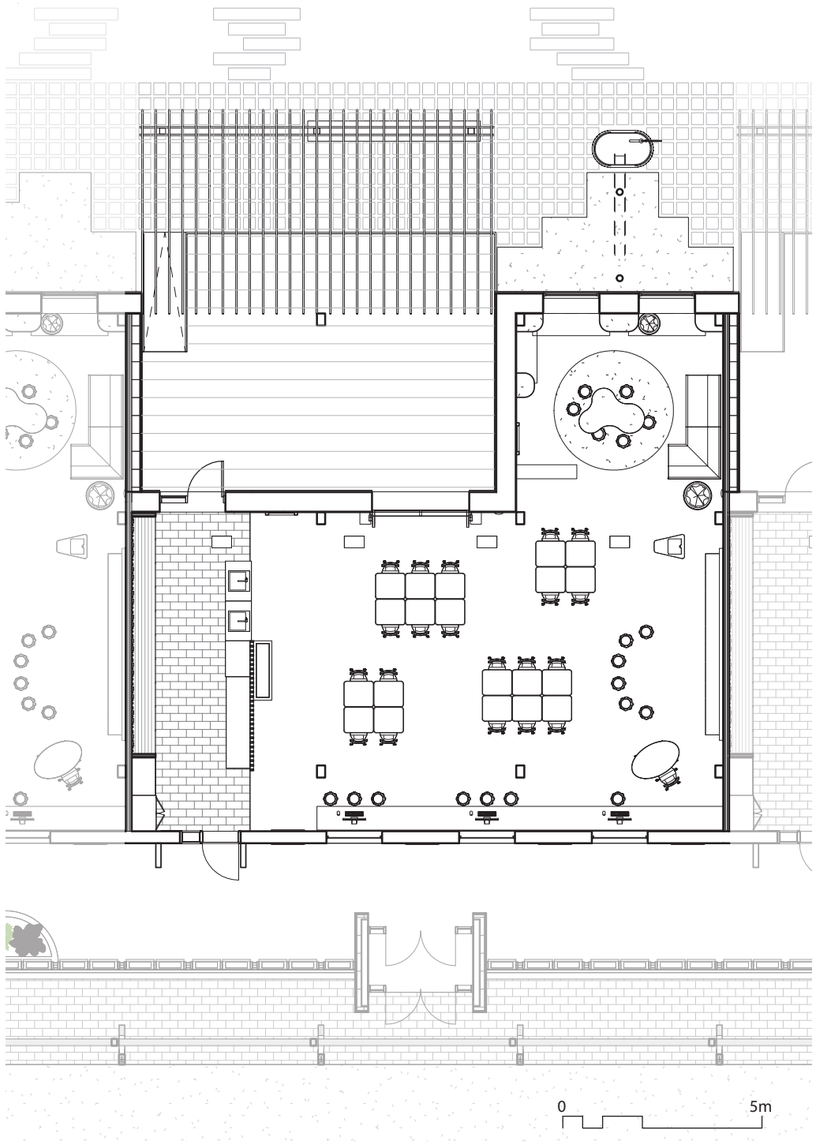


Figure 5.68 - 1:150 Ground Floor Plan of Typical Classroom Module

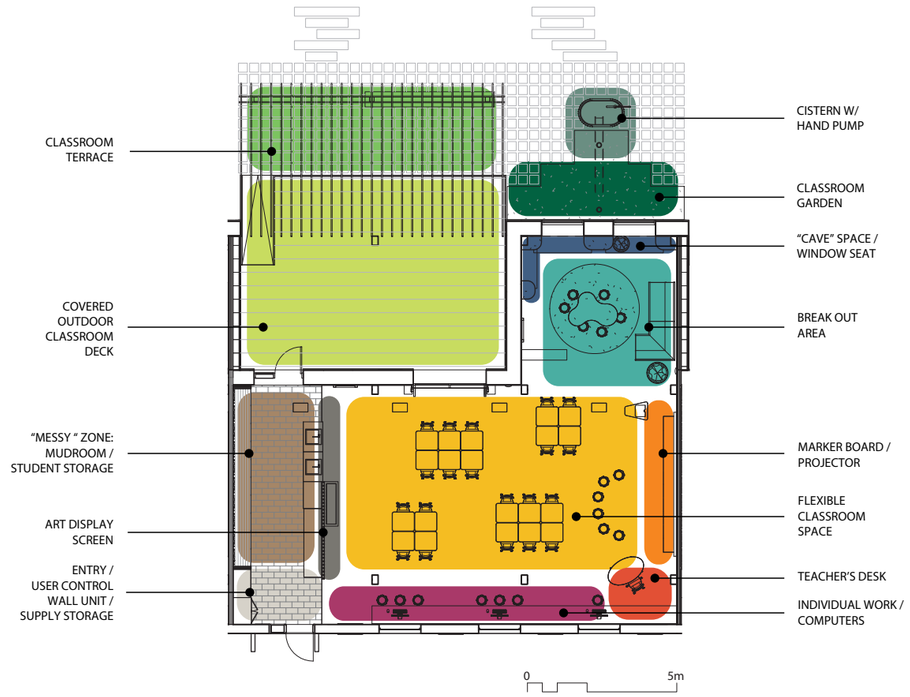


Figure 5.69 - 1:200 Programmatic Zone Diagram of Typical Classroom Module

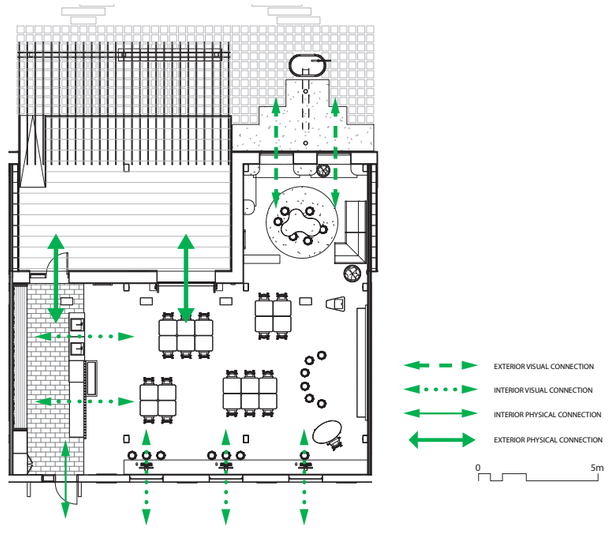
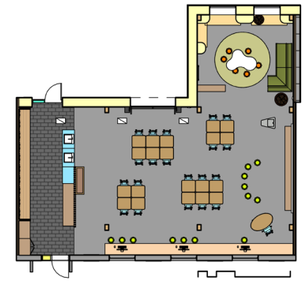
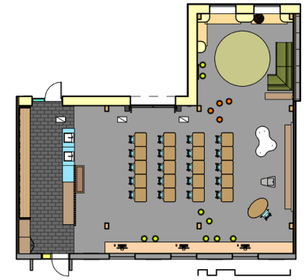


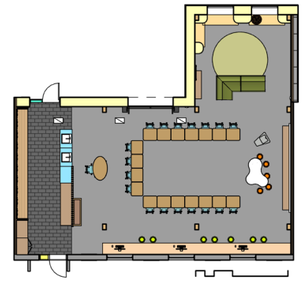
Figure 5.70 - 1:250 Connectivity Diagram for Typical Classroom Module



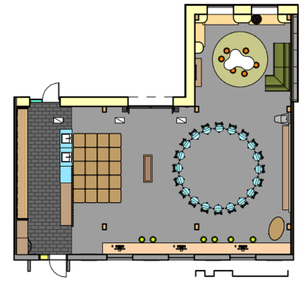
Group Work - Peer-to-Peer Collaboration



Class Instruction - Teacher-led Learning



Presentation Mode - Sharing of Information



Reflection Circle

Figure 5.71 - Diagram of Potential Classroom Furniture Arrangements



Figure 5.72 - Perspective view of typical Grade 1-8 classroom. View looks across the room from active board wall towards the mudroom at the other end.



KEY PLAN

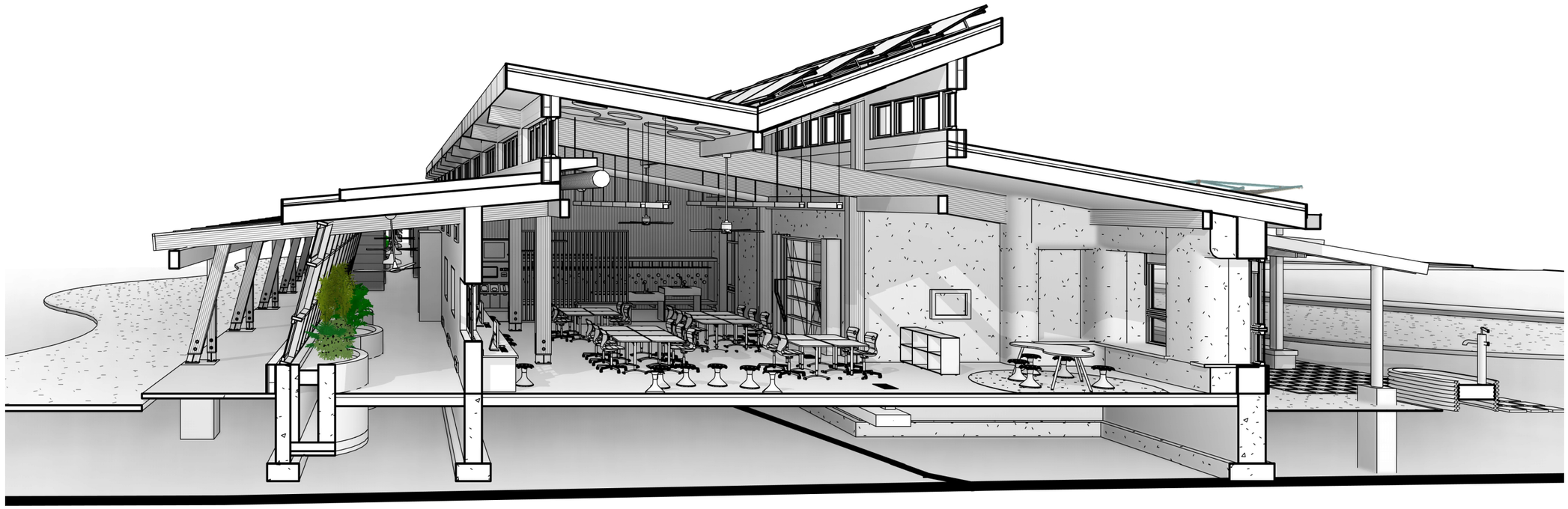


Figure 5.73 - 1:150 Sectional Perspective of Typical Classroom Module



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Wellness

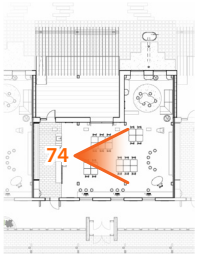
It was vital for the classroom to have a positive impact on student's mental and physical wellbeing, as this is not only one of the pillars of green school design, but necessary to allow students to reach their fullest potential. In response to this the classroom was designed to provide increased opportunities for daylighting, and natural ventilation, high indoor air quality, and good acoustical qualities within the space. Ample levels of daylighting are provided through ground floor level windows and upper clerestory windows on either side of the classroom that bring in balanced levels of daylight. Light shelves and operable blinds provide control of solar levels. All windows are operable, and classroom occupants are notified when outdoor conditions are favourable for natural ventilation by the BMS through a green notification light located on the active marker board wall. Trickle vents installed into the window sill of the windows in the breakout space help maintain background ventilation levels. Acoustical conditions are improved in the space through acoustical ceiling tiles, the high insulative qualities of the thick straw bale walls, and the use of solid wood CLT panels as partition walls between classrooms.

Biophilic design principles are introduced into the space through the extensive use of natural materials such as wood, stone and clay plaster for the structure, envelope and furniture finishes. The natural textures of these materials are left exposed to touch. Students can brush their hands over the slightly dusty plaster walls, feel the roughness of the board-formed concrete mass wall, and trace with their fingers the natural grain of the wood. Organic shapes are distributed throughout the space by way of the rounded corners of the strawbale wall, the circular form of the ceiling tiles, the sinuous curves of the desk in the breakout space, and round stools, among other interior details. Elements such as indoor potted plants, a recycled natural fiber rug, and the use of natural colours such as shades of green, yellow and blue further introduce biophilic elements into the interior.

A connection between the indoors and outdoors was a key driving factor of the design, as it helps occupants feel connected to nature while indoors. Each of the classrooms has both a visual and physical connection to the exterior through generously sized windows and doors. Direct access to the outdoors is provided through a glazed garage door, that when opened allows for the free flow of students between the indoor and outdoor classroom. The window seat is an example of a space that facilitates the experience of "prospect and refuge" on a smaller scale, one which helps connect those on the interior with the outside space. Formed as a niche within the thick straw bale walls, the enclosure of the seat offers students a sense of protection, while its position next to the windows allows them to look out and survey the activity taking place in the courtyard, or observe the ever-changing landscape.



Figure 5.74 - Perspective view of typical Grade 1-8 classroom looking across the room from mudroom towards the active board wall on the other end.



KEY PLAN



Figure 5.75 - Perspective view of typical Grade 1-8 classroom towards the outdoor classroom and breakout space.



KEY PLAN



Figure 5.76 - Perspective view of breakout space and window seats.
The thickness of the strawbale wall was utilized to create a niche where students can retreat to for private reflection. The windows look out onto the activity taking place in the main courtyard. Note the strawbale truth window that reveals the layers underneath.



KEY PLAN



Figure 5.77 - Perspective view of classroom mudroom.

The Wet Zone

One of the spatial divisions of the classroom is that of a wet and dry zone. The wet zone encompasses the mudroom and entry area, and serves to support the activities that are messy, involve water, as well as to handle the tracking of dirt and water from foot traffic between the indoors and outdoors. This space is important to the classroom, as with an environmentally-based curriculum it is expected that part of the learning will take place outdoors and with students constantly flowing between indoors and outdoor, the space has the potential to become dirty fast. The mudroom hopes to contain much of that dirt and wetness to this zone, to help maintain cleanliness in the other parts of the classroom. The mudroom is located in close proximity to the two entry doors to the classroom – the entry door from the main corridor and the exit doors to the outdoor classroom. Materially it is distinguished from the rest of the space with a stone tile floor, allowing the floor surface to be cleaned more easily. Two sinks are provided next to doors to the outdoor classroom for ease of cleanup, with one sink installed at children's height, and the other at adult height. The counter top of these sinks is made from a recycled plastic composite material. The mudroom is visually separated from the dry zone of the classroom by a wood lattice screen made out dimensional lumber. The screen helps distance the activities taking place in each zone, so that students working in the main classroom space are not distracted by students coming in from outside.

The mudroom provides space for storage of students' personal belongings and outdoor clothing. This part of the mudroom is configured as a long, low bench with rounded hooks for the hanging of coats and backpacks, the provision of an individual overhead cubby for each students, and room below the bench to store a change of shoes. The bench is constructed out of CLT panels, using leftover material from the manufacturing of the CLT panels used in the structure. Additional storage is provided through a low cabinet below the wood screen, and open shelving attached to the screen. The low cabinet doubles as seating.

Each classroom contains a millwork unit referred to as the 'Energy Cabinet.' Within this cabinet are integrated several components that support the environmental education curriculum. The cabinet contains controls for the environmental systems in the room: it holds the electrical light switch, a thermostat, the switch to open/close the motorized clerestories, and an energy dashboard screen that displays the current conditions both inside and outside the room, relayed through the many sensors installed throughout the school. This allow the building occupants control over their indoor environment as well as involving them in operating the building. Above it is a poster which explains how the classroom is able to be operated by the occupants through a large visual diagram. The lower half of the cabinet contains a waste collection system consisting of three separate collection bins, one for garbage, recycling and compost.



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Next to it is another full-height storage cabinet that holds classroom cleaning equipment – brooms, mops, buckets, towels and green cleaning products – and is necessary as students are expected to be involved in taking care of their classroom. The cleaning equipment is kept close at hand to make this chore easier, and the cabinet is situated next to the doorway.

The Outdoor Classroom

Each classroom has their own private outdoor space that connects directly to the larger scale shared courtyard program. This space has no prescribed function so it can be utilized in many different ways by the children. The outdoor classroom is divided into two parts: a covered deck area physically connected to the classroom through the garage door, and an open terrace underneath a pergola. Both spaces have their own character. These spaces are somewhere between being indoor and outdoor, not fully one or the other, more like transitional spaces, that lead occupants to make a graduated passage to the outside.

The covered deck area is a cooler, more enclosed space that offers students a sense of refuge from larger courtyard it opens up on. The roof above the covered deck features a skylight oculus, functioning both to bring daylight to the space and acting as a solar calendar. Students can follow and measure the movement of the sun by watching the circular beam of light move throughout the day and year. A ramp lets student access the terrace just below the deck.

The lower terrace consists of permeable paved area situated underneath a pergola. A concrete block sitting wall is integrated as footing for the columns of the pergola. The wood rafters of the pergola are covered with plant vines during the warmer months, shading the area below and creating a cooler microclimate within the courtyard. Alternatively during the winter the space receives more sunlight as the deciduous plants lose their leaves. Each classroom is allocated their own garden bed located below the wall of the breakout space; the class can chose what vegetation they wish to plant in it each year and students are responsible to tend to it. Next to this is the interactive rainwater feature consisting of a manual hand pump and small collection basin connected to a large roof scupper that channels rainwater into the basin. This feature highlights and makes visible the rainwater harvesting system of the building. The hand pump allows students to draw water from the main cistern and use it for washing dirty hands, to water plants in the classroom garden, or for class experiments, among many other uses.

The exterior frames of the windows on the north façade are painted in cool colours – shades of green, blue, and purple – as a way of representing the colder conditions of the north orientation. The windows frames on the exterior south-facing elevations are painted in warm colours – red, magenta, orange and yellow – to represent the high levels of solar radiant energy that is received from the south direction. This visual tool helps orient students on the site, and teaches them about the importance of building orientation in sustainable design.



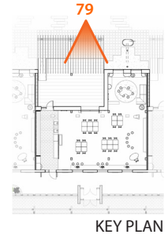
KEY PLAN



Figure 5.78 - Perspective view of the covered deck area of the outdoor classroom.



Figure 5.79 - Perspective view of north classroom facade and outdoor classroom.



KEY PLAN

Kindergarten Classroom

The kindergarten classroom is a variation on the L-shaped module, with the addition of a block of ancillary spaces shared between two classrooms. This block of spaces consists of a washroom, a teacher preparatory area, and an outdoor equipment storage room on the ground floor, and above them a mezzanine that serves as a breakout space. The addition of these spaces helps the kindergarten classrooms function as more of a self-sustained unit, reducing the distance that the childrens' small legs have to travel to reach the washroom. The kindergarten wing is also the classroom wing that has the most direct link to the building's front entry and the multi-use cafeteria and gymnasium spaces for this same reason.

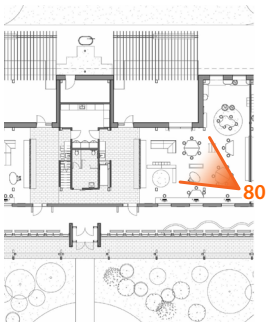
The mezzanine space provides the classroom with one additional zone that is suited to a variety of activities, as it provides a degree of separation while maintaining a visible connection to the main classroom space. This allows for two tasks of a very different nature to take place simultaneously without disrupting each other, with both areas remaining in the teacher's field of vision. Potential ways the space can be used includes for collective activities such as story time, for disruptive activities such as playtime where some students would be partaking in it while other students are still completing their assignments, for personal reflection, and as a space for naps for those young children that may still need them.

The mezzanine is constructed out of solid CLT panels. The exposed ceiling structure of the butterfly roof which is closely overhead takes on the form of tree branches, lending this elevated space a tree-house like feeling. The students can access the small mezzanine by taking the stairs up and then taking the slide back down. Underneath the mezzanine is a space for waste bins and a sink alcove that is accessible from the mudroom.

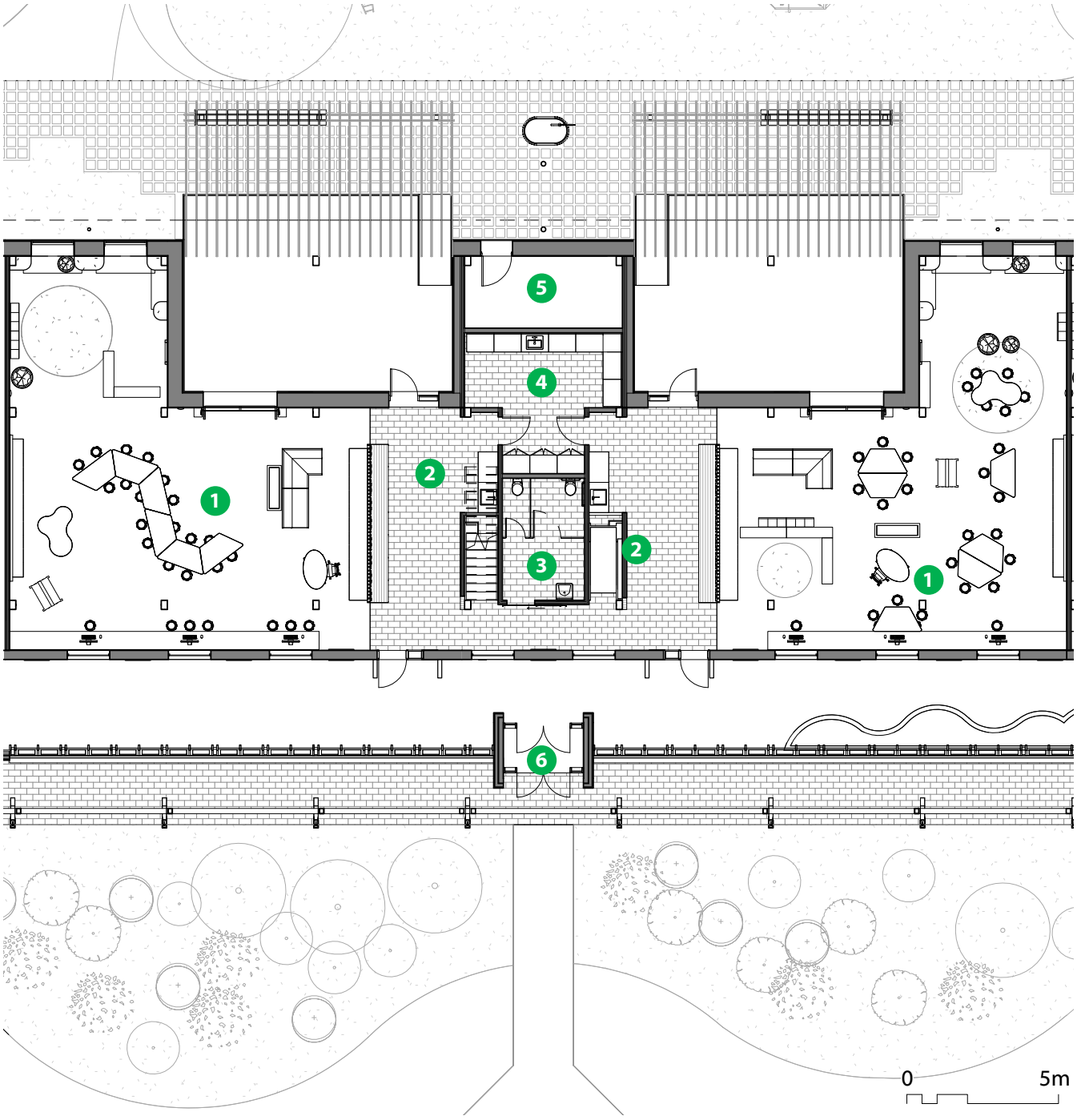
The flexibility of the L-shape plan in regards to allowing for a multitude of classroom setting arrangements is further demonstrated within the space of the kindergarten classroom. The kindergarten classroom is set up as a collection of smaller activity zones including group workstations, play areas, a small classroom reading area and a computer learning area. Shelves, planters and boards are used as dividers to help define each space and the children move between the activities freely.



Figure 5.80 - Perspective view of kindergarten classroom.



KEY PLAN



1 Main Flexible Classroom Space

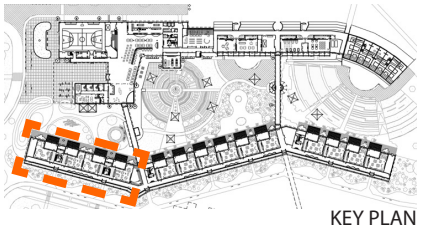
2 Mudroom & Sink Alcove

3 Washrooms

4 Teacher Prep Space

5 Outdoor Equipment Storage

6 Front Entrance Vestibule

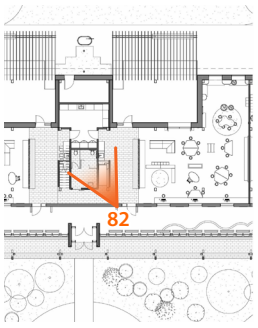


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Figure 5.81 - 1:200 Floor Plan of typical Kindergarten classrooms



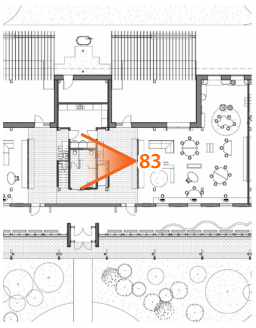
Figure 5.82 - Perspective view of Kindergarten classroom breakout space. The students can access the small mezzanine by stairs on one side and take the slide back down the other.



KEY PLAN



Figure 5.83 - Perspective view of Kindergarten classroom breakout space and sink alcove.



KEY PLAN

The Corridors – A "Living" Street

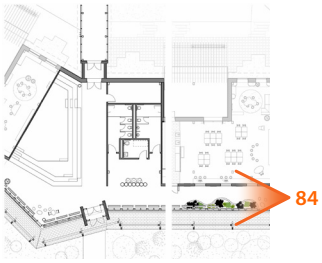
At Creekside Valley EcoSchool the quintessential locker-lined school corridor is re-imagined as a bright sunlit space that is brimming with life as it is filled with vegetation and children busy at work and play. The south wing corridor space which is also referred to as the "thermal flux zone" has the triple function of acting as a circulation space, a supplementary passive solar heating system to the adjacent classrooms, and as additional classroom space. Taking inspiration from how sunspaces within homes are utilized as an extended living room, the corridors of the classroom wing are designed to be used as an extension of the classroom module. This is facilitated by making the corridors 3m wide, which provides enough space to allow for seating to be placed alongside one wall while maintaining sufficient clearance space for the movement of people up and down the circulation space. A visual connection between the corridor and classroom is provided through window openings in the common thermal mass wall, letting teachers supervise the activity in the halls and giving them a level of control over the space. The monotony that often tends to accompany long and straight corridors that connect a series of classrooms is broken up by the undulating form of the concrete planter/open aerobic cell. Exterior entrance vestibules which project into the space (half-in, half-out) and the articulated entry cove to the classroom help to further reduce this.

One of the focal points of this space is the Living Machine cells whose lush vegetation canopy and sinuous form bring biophilic elements into the corridors and make it an attractive space to occupy. Water flows through these cells which function as the aerobic reactor component in the wastewater treatment process, making visible to the occupants the building system operations that usually are hidden away from sight. The living machine cells are an example of how the building connects to natural systems and reveal how elements of nature are utilized to support the functions of the building. The large south-facing windows along the exterior wall bring in the high level of daylight that these plants need to thrive.

As previously described in section 5.3, the corridors in the south wing act as a sunspace. The large south-facing windows bring in large quantities of radiant solar energy, which is collected and stored in the thermal mass of the thick solid concrete common wall and concrete floor during the day, and radiates back into the spaces later. The operable vents in the common mass wall allow for heated air from the sunspace to be circulated into classroom acting as supplementary air heating. The sunspace while not mechanically conditioned itself, is comfortably warm during the cold months, making it a desirable location for students to occupy (though not so much in the summer when the space becomes uncomfortably warm). Students can relocate to the corridors to work on projects, while the sustainable features of the space can be integrated into classroom lessons, and the length of the hallway can be utilized for science experiments that require more uninterrupted linear floor areas. It also creates a pleasant space to linger in between periods and socialize with classmates. With the large amounts of daylight, uninterrupted views to the outside environment, and planters overflowing with vegetation the corridors of the classroom wing feel like a space that is somewhere between the inside and outside, an advantageous quality in a cold climate as it allows for children to play "outdoors" even when it's too cold outside.



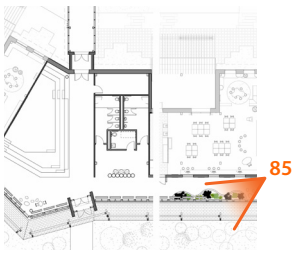
Figure 5.84 - Perspective view of the south wing corridor at noon on a sunny day.
The large south-facing windows and poured concrete solid walls are key components of this direct gain passive solar heating system which improves the comfort of the corridor with minimal energy requirement.



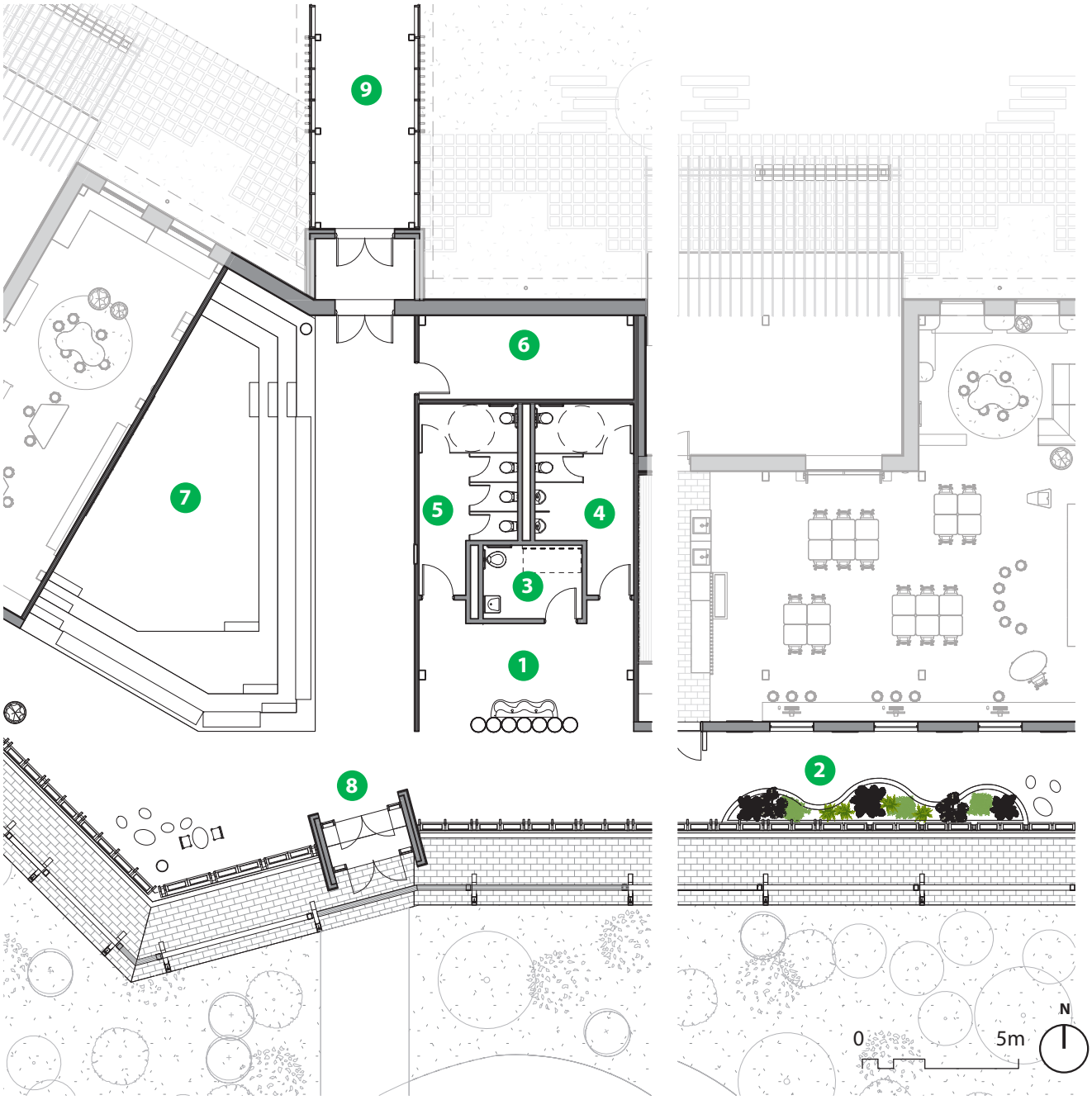
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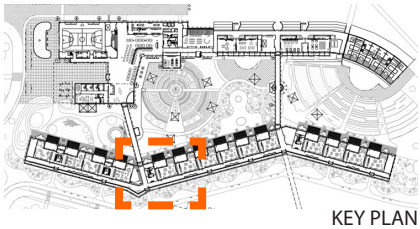
Figure 5.85 - Perspective view of Living Machine aerobic reactor cells that line the corridors of the classroom wing.



KEY PLAN



1 Washroom Sink
2 Living Machine Cell
3 Barrier Free Washroom
4 Boy's Washroom
5 Girl's Washroom
6 Janitor's Closet
7 "Campfire" Breakout Space
8 Exterior Entry Vestibule
9 Glazed Walkway Link

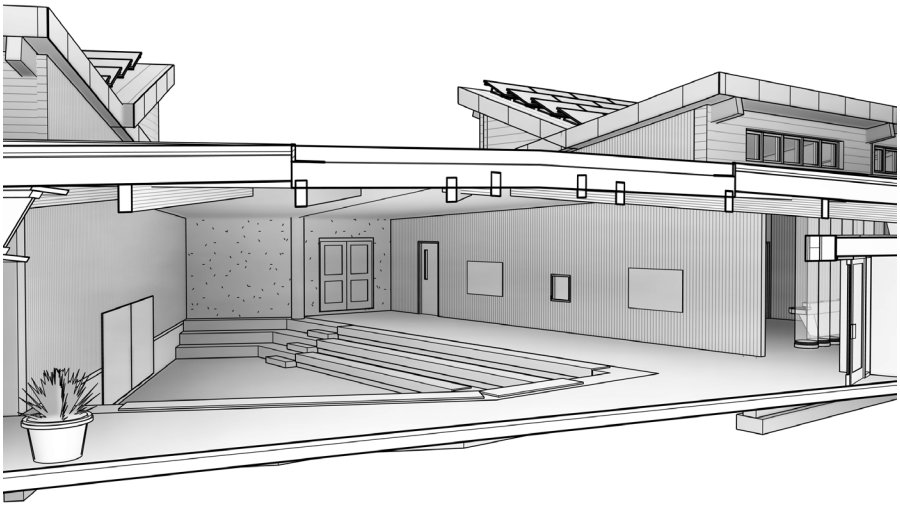


KEY PLAN

Figure 5.86 - 1.200 Ground Floor Plan of Typical Corridor in the Classroom Wings

Circulation Routes as In-between Learning Spaces

The circulation areas throughout the rest of the school are designed to be used not just as a space that assists in the movement of people through the building, but as flexible learning spaces that can act as informal classrooms. Breakout spaces which are outfitted with seating, furniture, marker boards and in some cases sinks, are placed along the circulation routes, allowing students to use them as small group learning areas and informal gathering spaces. Collaborative learning and socializing is supported by these spaces. In other areas, nodes of interest are placed at the center of the route, giving occupants a reason to linger in circulatory space. Two such spaces are the glass-enclosed breezeways which connect the two wings and provide a sheltered circulation route across the courtyard.

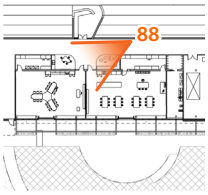




KEY PLAN

Figure 5.87 - Perspective view of breakout space in the classroom wing, next to the washrooms.





KEY PLAN

Figure 5.88 - Perspective view of small group learning areas situated along the length of the science lab corridors, which provides additional seating for group work, a sink and counter for washing up when coming in from the outside classrooms located to the right of the space, and storage for outerwear.

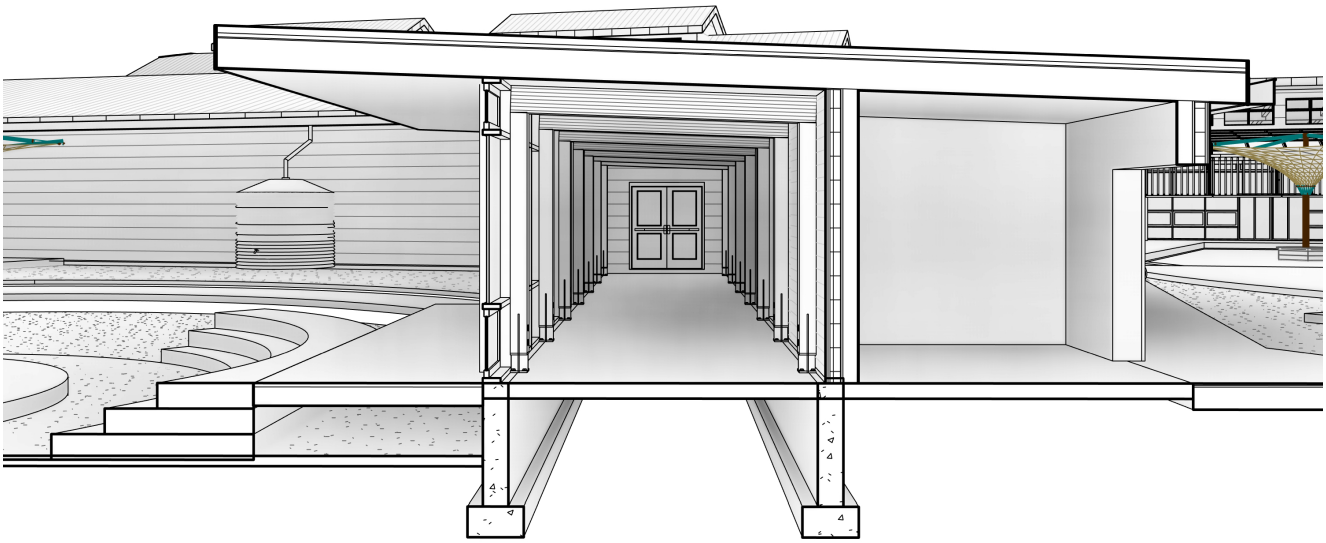


Figure 5.89 - Sectional perspective view of enclosed breezeway that separates the kindergarten and primary grades courtyards. At the centre of the corridor is a small amphitheater and stage, and on the other side is a shed for the storage of gardening equipment. Sliding doors on the exterior glazed walls of the breezeway make the courtyards accessible from the circulation space, and allow for transition between individual courtyards. During the warmer months, the sliding doors can be left open.

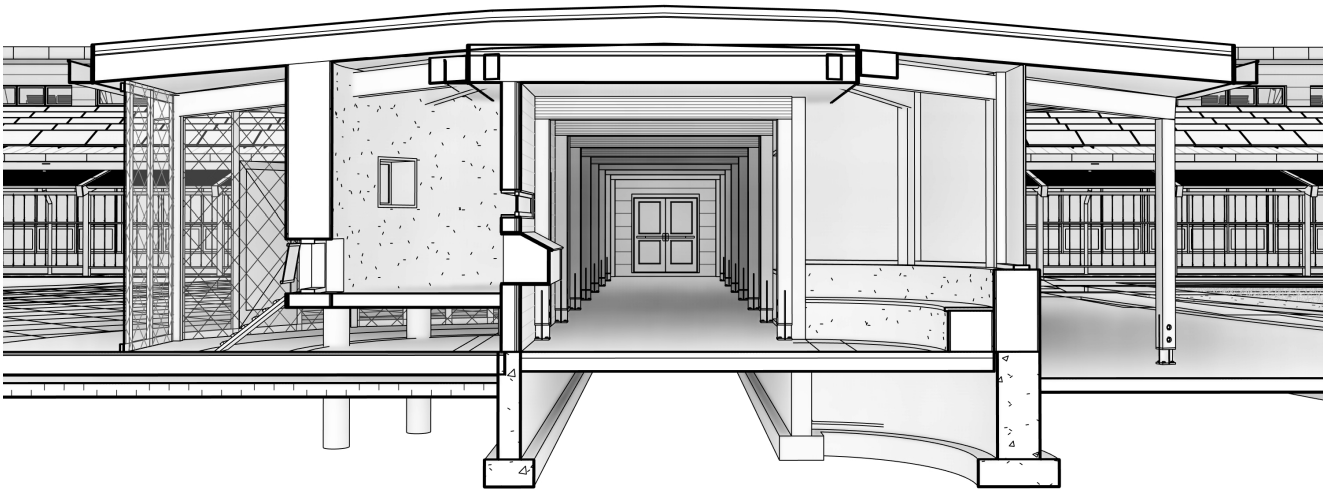
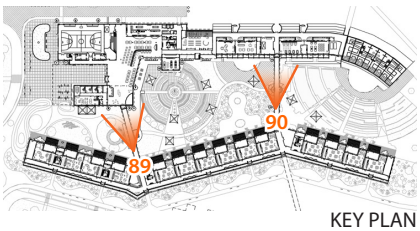


Figure 5.90 - Sectional perspective view of enclosed breezeway that separates the primary grades and upper grades courtyards. At the centre of the corridor is an attached chicken coop which can be accessed from the interior of the corridor, and a circular seating area. The shared wall between the coop and corridor has viewing windows to the inside of the coop and contains the nesting box. The seating area that overlooks it is constructed out plastered straw bales.



KEY PLAN

Multi-use Community Spaces

The school was designed with the intention that it would act as an environmental education-focused community centre that is accessible to the public for after-school use on evenings, weekends and in the summer months. This allows the school to strengthen its connection with the community, and allows for a more sustainable use of space rather than letting a whole building sit empty for large parts of the day. The spaces that are to be accessible to the public are housed in the north wing and include the gymnasium, cafeteria, front entrance lobby, library and science lab programmes. The design of the front entrance lobby, gymnasium and cafeteria in relation to their connection to community will be explained in more detail as public accessibility informed the design of these areas of the school.

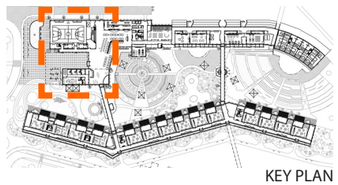
Front Entrance Lobby

The front entrance lobby is the first space people encounter as they make their way into the building, so it is designed to be both a welcoming and inviting space to the community, and to announce to people what the culture and values of the school are through the use of "signature elements."[2,3] At Creekside Valley EcoSchool that special theme is sustainability and environmental stewardship education, with a focus on these themes within the local context of the site. The theme of the school's special curriculum is communicated through the incorporation of several sustainable design features at the front face (west-facing exterior façade) of the school. The glass canopy with integrated PV modules that shelters the front entrance courtyard is one such element and is a symbol of the school's green building design. Several other sustainable design features are made visible at the front face of the school such as the vertical sun-shading fins, the large above ground rainwater collection cisterns and the earth tube air inlet tower that is located in front of the gymnasium. Within the interior of the front entry lobby, features and graphic elements are employed to similar effect like a local watershed map painted on the floor of the lobby (an idea first employed in the UEC precedent), the polishing pond, and student work displays to name a few. The lobby is made more welcoming through the employment of an open layout with multiple seating areas distributed throughout the space. Ample daylighting is brought into the space through the use of skylights which brightly illuminate the lobby. The administration area is located off of the lobby for surveillance and security purposes; the reception desk is positioned so that the main entry is visible from it.

Gymnasium

The close proximity of the gymnasium and cafeteria to the front entrance allows them to be easily accessed by the community. The gymnasium forms the front face of the school and is designed in relationship to the community and cultural history of the site. As the front face of the school the gymnasium is designed with a glazed façade to invite people in, thereby differentiating it from the typical school gymnasium that is for the most part without windows. The gymnasium takes on

1 Gymnasium
2 Change Rooms
3 Equipment Storage Room
4 Stairs to Bleachers and Upper Mezzanine
5 Mechanical Room
6 Vertical Lift to Mezzanine
7 Forum Stairs
8 Front Desk
9 Finishing Pond
10 Copy Room
11 Health Room
12 Staff B/F Shower and Washroom
13 VP Office
14 Principal Office
15 Conference Room
16 Staff Room
17 Bicycle Racks
18 Front Entry Covered Courtyard
19 Front Entry Vestibule
20 Foyer



KEY PLAN

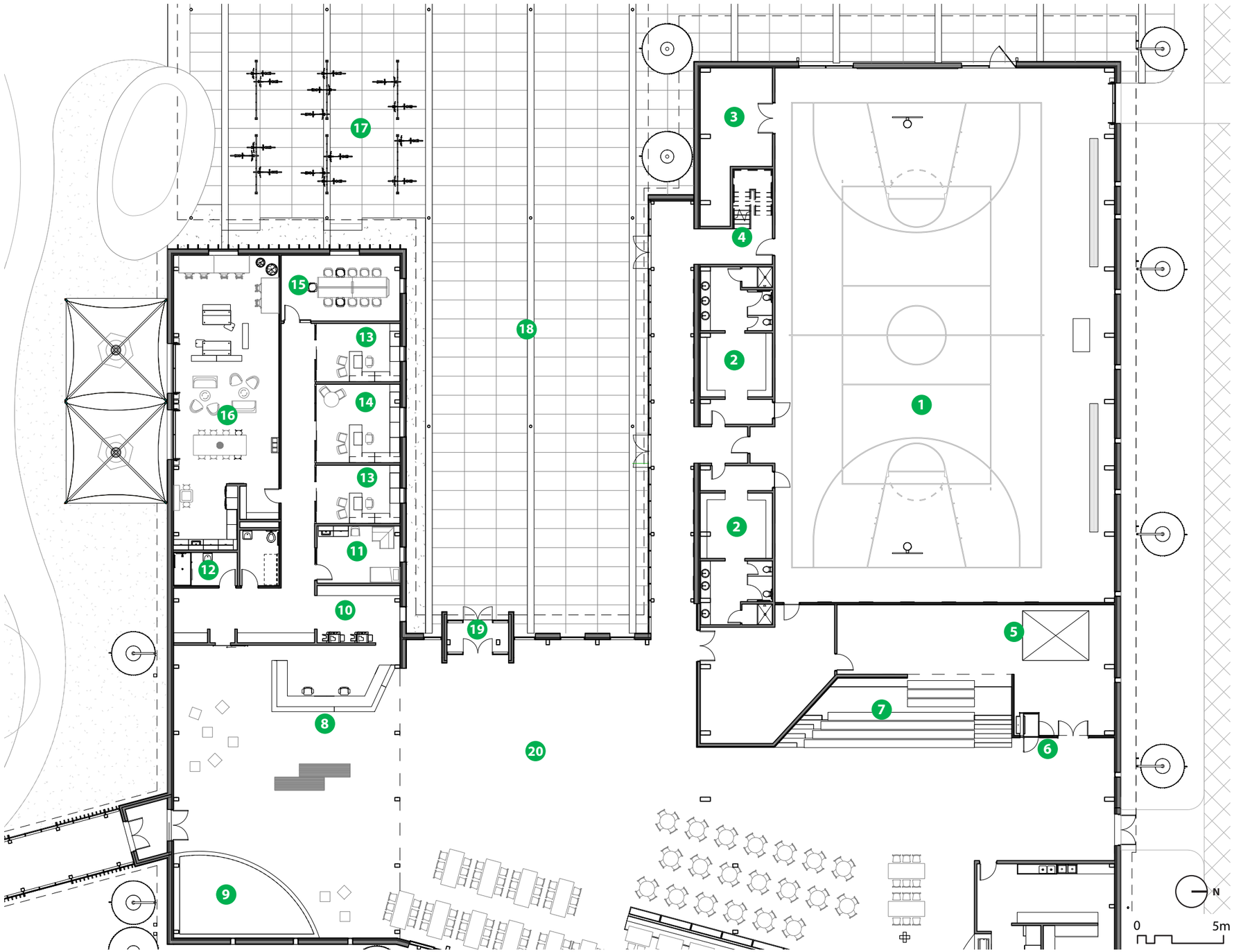


Figure 5.91 - 1:250 Floor Plan of Gymnasium, Front Entry, and Administration Areas

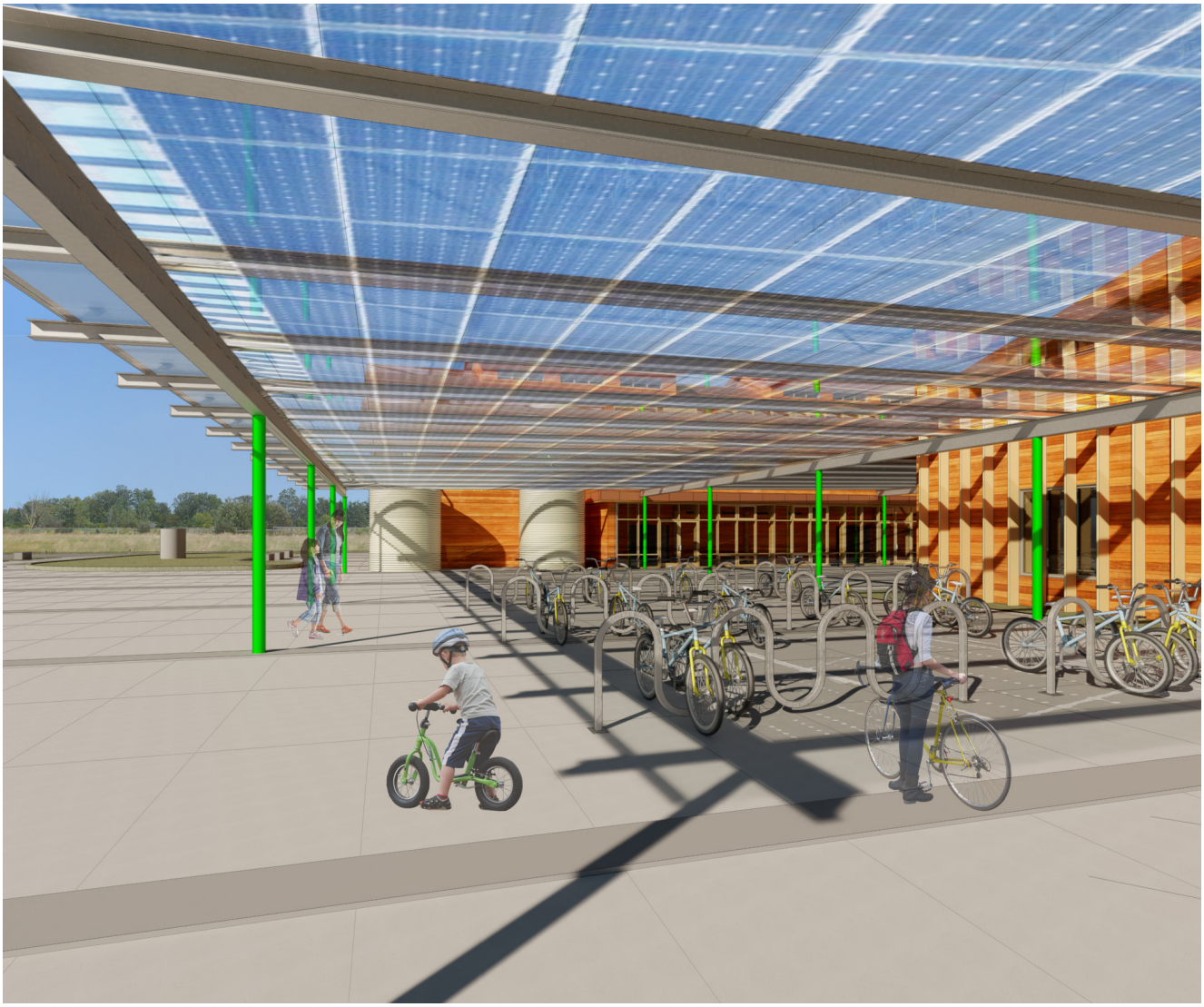
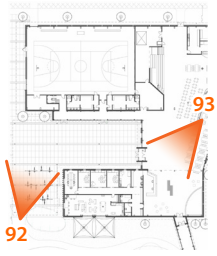


Figure 5.92 - Perspective view of the front entrance courtyard. The view is taken from beneath the canopy and looking towards the bicycle parking racks and the gymnasium beyond. Several of the sustainable design features are made visible at the front face of the school. In addition to the PV modules integrated into the canopy, this includes the vertical sun-shading fins on the west-facing exterior facade, the above ground rainwater collection cisterns and the earth tube air inlet tower (located in front of the gymnasium).



KEY PLAN

an agrarian-inspired architectural form, reflecting the local culture and rural history of the site. Some elements of the space that directly reference agricultural buildings such as the barn across the street include the pitched gable roof, the exposed timber frame structure, the hayloft-inspired mezzanine, the material palette, and the vertical fin wood screen which imitates the light effect produced by permeable time-worn timber cladding. These elements help contribute to the school's overall "sense of place" and connect it to the site's rural identity.

Cafeteria

Generally the cafeteria whose primary use as a service space is to feed large groups of children at lunchtime means that it is generally fully occupied for only a few hours each day, and is then unused for the remainder of the school day. To alleviate this problem the cafeteria is opened up to other uses. Both the gymnasium and cafeteria are designed as multipurpose rooms with the open floor area required to support large assemblies of people, which allow them to accommodate a variety of activities. Designed as attractive spaces, both areas are able to be utilized as a venue for school, social and community events. The programmatic flexibility of the cafeteria is enhanced by its close proximity and relationship to other programmes.[4] Its adjacency to the washrooms, a kitchen and the gymnasium increase its potential uses. For example, after a school or community meeting in the gymnasium concludes, people can easily move to the cafeteria for refreshments. This is facilitated by the connection formed between the cafeteria to the gymnasium through the staircase bleachers and vertical lift leading up to the mezzanine. The cafeteria's programmatic flexibility is further strengthened through the provision of a variety of seating situations: large rectangular tables, smaller round tables, small portable ottomans, a padded banquette seating area that is separated from the rest of the cafeteria through vegetation planters, and the staircase seating. The furniture can be rearranged to form zones, or stowed away in the storage room beneath the gymnasium mezzanine.



Figure 5.93 - Perspective view of front entry foyer; view looking from the cafeteria seating towards the reception desk and entrance vestibule.

"This is not just a gym…We want this to be a place where our students can learn about being environmentally responsible, so that later in life, when they are making choices, they can say, 'It's possible. Our gym at school did it this way'."[i]



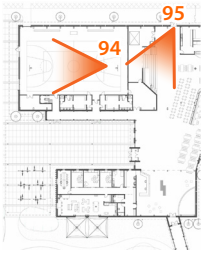
Figure 5.94 - Perspective view of gymnasium.

The gymnasium was designed as one of the key programmatic spaces which support student wellness and health, as its provision encourages students to be physically active. The large open area of the space allows for a wide variety of sports and fitness classes to take place. This wellness goal is supported through a design that creates a healthy indoor environment in the space. Ample daylighting is brought in through clerestory windows situated on both the north and south exterior façade and through a clerestory cupola down the middle. Natural ventilation is provided to the space via operable windows and the earth tubes ventilation system, which introduces earth-tempered fresh air at the floor level of the space. Large ceiling fans aid in facilitating air movement in the space. Thermal mass is introduced through the concrete floor surface to store solar energy admitted into the space. Views to the outdoors are provided through the large glass wall on the west face, maintaining a connection to the natural environment from the space.

[i] Randy Smith, CFO, The Putney School, explain the intention behind the net-zero energy design of the school's new Field House; and why it matters that the design of every space/building on the campus is sustainable. https://living-future.org/lbc/case-studies/the-putney-school-field-house/



Figure 5.95 - Perspective view of tiered seating/staircase that connect the gymnasium mezzanine to the cafeteria space.



KEY PLAN

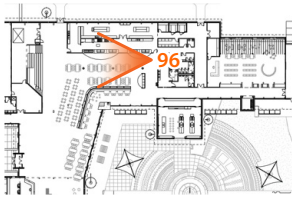
The Cafeteria as a Space that Promotes Healthy Eating Habits

A second key driver of the design of the cafeteria is based on its role as space that supports nutrition, with the goal of enhancing students' health and well-being by providing nourishment to their bodies, teaching them healthy behaviours, and encouraging them to make healthy choices. The design of the cafeteria is based on a study called the "Healthy Eating Design Guidelines for School Architecture," by the Center for Disease Control and Prevention that found that the spatial design of the cafeteria and its supporting spaces can have a positive effect on promoting the formation of healthy eating habits and increase food literacy.[5] The conclusions of the study – a set of design guidelines – serve as the design principles upon which the Cafeteria at the proposed school is based upon.

Just as the school makes the environmental building system transparent and involves building occupants in its operation, the "system" that supports students' health is made also made visible. The cafeteria is designed as an open space with the focus of engaging the senses. The cafeteria kitchen is open to the dining area making visible the process of food preparation and encouraging interaction between the staff and students, thereby increasing the space's pedagogical potential.[6] Students are sensorially involved in the preparation of their lunch: visually they can observe the cooking staff in action, they can smell and hear the food being prepared, and their sense of touch is engaged when they themselves learn how to cook in the Learning Kitchen which is accessible right off of the cafeteria. The dining space of the cafeteria is also visually and physically connected to the produce garden, so that students can see where their food comes from. The food that is grown on-site is incorporated into lunchtime meals, with the idea that if students are involved in growing and harvesting the food, they will be more likely to eat it and try new fruits/vegetables. The cafeteria provides healthy food options, serving meals prepared with locally-sourced ingredients with a focus on using seasonal ingredients in cooking. This helps teach about sustainable food practices, exploring the "connection between seasonally fresh foods from local farms and school gardens and the local economy,"[7] which is relevant to the project site due to the region's agricultural history. Students are guided in making healthy food choices through the incorporation of nutritional information signage within the dining hall and a visible menu that highlights what ingredients have been incorporated into each meal. Students learn concepts such as food waste through a waste sorting station located next to the washrooms. The concept of healthy options extends not just to food choices, but also through the multiple "seating options and social arrangements" available to students, giving students a choice based in personal preference. An outdoor dining area on the deck adjacent to the cafeteria is also provided and accessible through sliding doors.

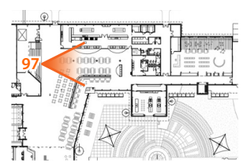


Figure 5.96 - Perspective view of servery and dining area.
The kitchen is open to the dining area allowing students to be sensorially involved in the preparation of their lunch. The tree shaped glulam columns in combination with the vegetation of the green wall and planters and natural materials such as stone, contribute to the biophilic design of the space. The green wall further serves to improve the indoor air quality of the space by filtering smells coming from the kitchen.



KEY PLAN

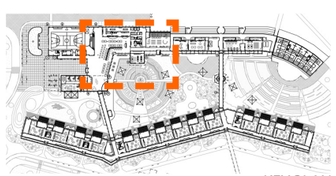




KEY PLAN

Figure 5.97 - Sectional perspective looking across the cafeteria towards the washrooms and waste bins.

1 Main Dining Area
2 Servery
3 Banquette Seating
4 Waste Bin Station
5 Washroom
5a Girl's Washroom
5b Boy's Washroom
5c B/F Washroom
5d Communal Sink Area
6 Cafeteria Commercial Kitchen
7 Kitchen Prep Area
8 Dish Washing Area
9 Storage and Service Area
9a Pantry
9b Freezer
9c Storage
9d LAN Room
9e Janitor's Closet
9f Kitchen Office
9g Staff WC & Changeroom
9h Receiving Area
10 Forum Stairs
11 Learning Kitchen Classroom
12 Learning Kitchen Pantry
13 Library
14 Library Workroom
15 Seed Library
16 Outdoor Dining Terrace



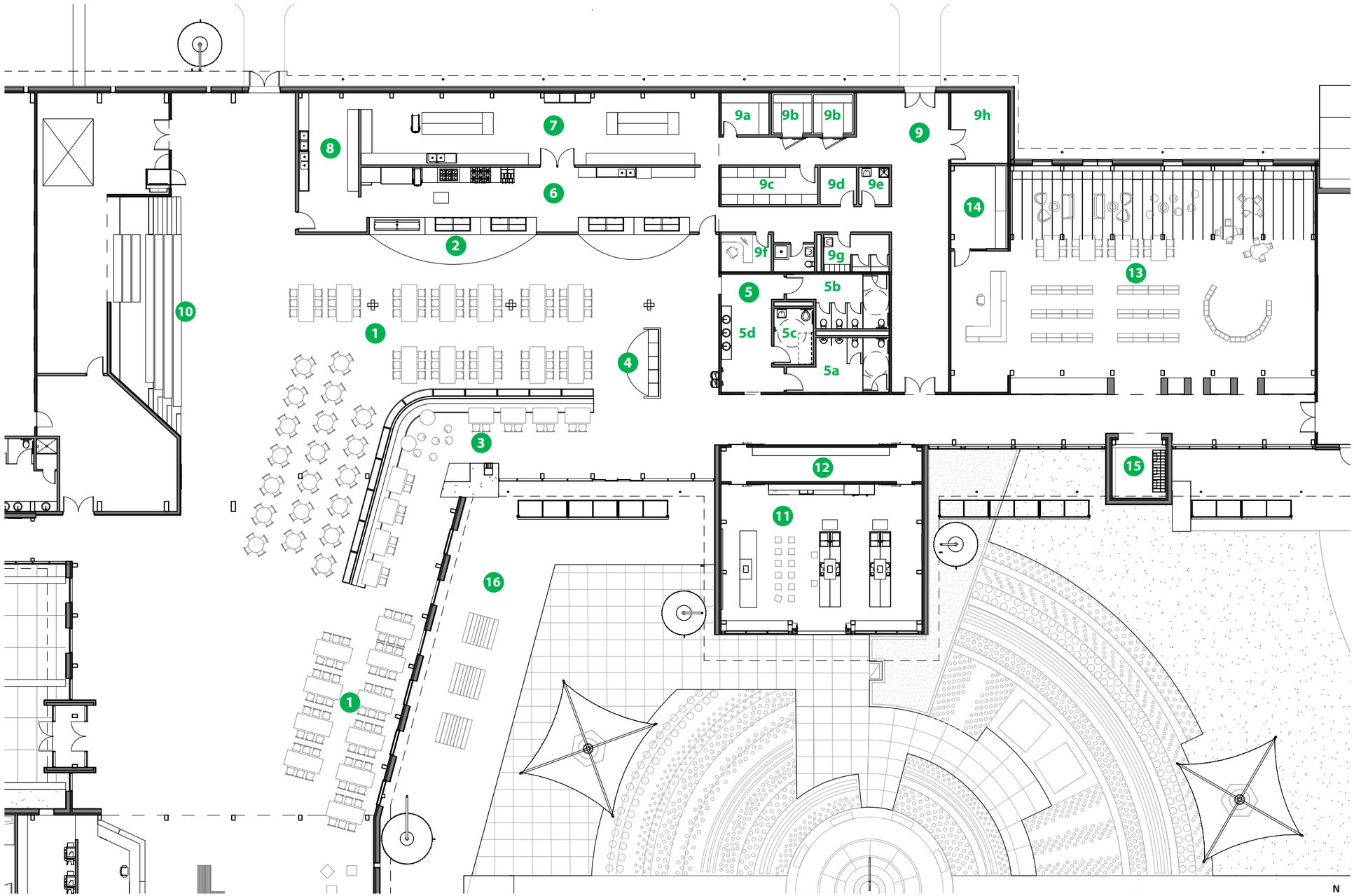
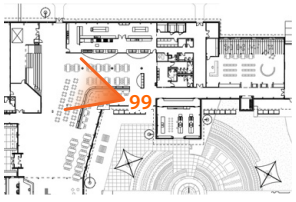


Figure 5.98 - 1:250 Floor Plan of Cafeteria and connected programs





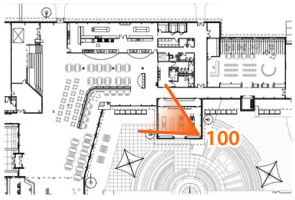
KEY PLAN

Figure 5.99 - Perspective view of banquette seating in cafeteria next to the fireplace, and looking towards the forum stairs which provide additional seating to the space. Students have lots of options to choose from.



Figure 5.100 - Perspective view of the Learning Kitchen.

It is in this space that students learn the important life skills of preparing food, with produce they grew and harvested by themselves from the on-site garden. Counters are adapted to children's smaller height, with one adult sized island at the front of the class to serve as a demonstration area. The volume of the Learning Kitchen projects out into the courtyard as a expression of its connectedness to the food education program. An operable garage door swings open, offering ease of movement between indoors and outdoors.



KEY PLAN

Library

The traditional function of a library as "a place for the storage of books," as well as quiet place for study and personal reflection[8] informed the main programmatic divisions of this spaces. The central floor area of the library serves as the book storage zone, and the zone on the north exterior wall serves as an individual and group study area. The eastern end of the space contains the children's book section and smaller child-sized furniture. The west side holds the checkout desk and library staff workroom.

The library is designed to be a bright and attractive space to support the quiet study programme. Ample daylighting is brought into the spaces through the north and south clerestories. The signature feature of the space is an OSB wood frame canopy that is used to divide the book stacks from the sitting area. The profile of the wood frame takes on a tree-like form mimicking the feeling of being underneath the forest canopy. The frame forms bookshelves and nooks for sitting and looking out the windows to the real forest beyond. Students can hide in these "cave" spaces which provide the degree of enclosure necessary for students to privately reflect and meditate.[9] A collection of seating situations facilitates group work and socialization.

The library maintains a special collection of books dedicated to supporting the environmental curriculum of the school. Within the design, the tradition of the library as being a place for the storage of information also takes on a digital turn. Interactive screens on the wall display data about the operations of the school building. The data displayed include metrics such as the amount of energy the building's solar panels produce in a given month, how much water and electricity the building is using, and so forth. Students are welcomed to add information to this collection through the "Nature in my Neighbourhood" interactive screen, where students can input animal sightings or rare plants they have encountered in and around their neighbourhood, contributing to the development of an ecosystem database. Surveillance cameras dispersed throughout the site, connect to the outdoors and allow students to "read" and observe the site in a different way. The collection of information extends to seeds, through the creation of a small seed library across the hall from the library. Just like with books, students and people from the community can borrow seeds to plant in their gardens at home, and then they return new seeds from the harvested plant. This helps preserve plant species biodiversity and make them increasingly resilient to the climate.[10] The seeds of the crops from the school garden would stock this library.

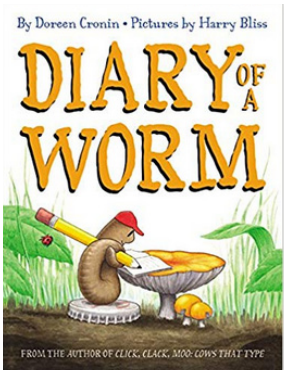


Figure 5.101 - Books in the library are curated to relate to the environmental education curriculum.



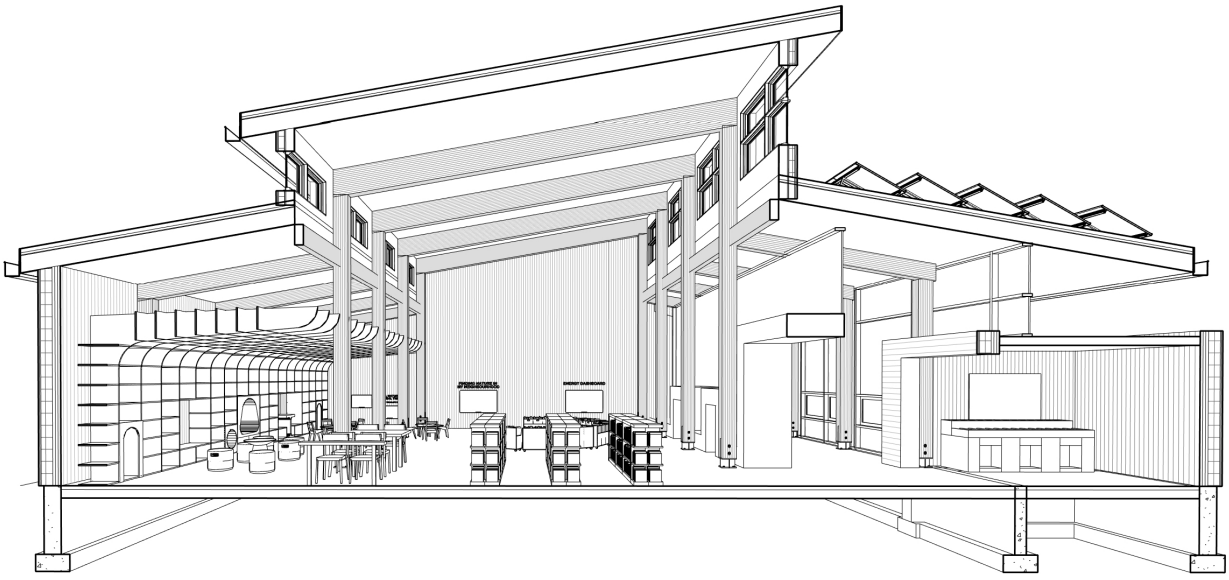
Figure 5.102 - The idea of an interactive nature map where students can record animal sightings was inspired by the one installed at the LA Natural History Museum 'Nature Lab' exhibit.

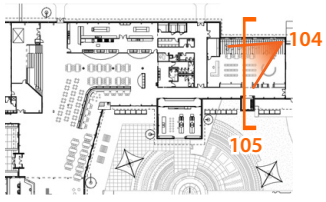


Figure 5.103 - Wildlife surveillance cameras can be installed throughout the site. The above picture is also from the 'Nature Lab' exhibit at the LA Natural History Museum.



Figure 5.104 - Perspective view of the Library. View is taken underneath the OSB wood frame canopy.





KEY PLAN

Figure 5.105 - Sectional perspective view of the Library space.
The following zones starting from left to right: 1) Wood Frame Bookshelf Canopy 2) Student Sitting /Informal Work Area 3) Study Desks 4) Interactive Digital Screen Wall 5) Book Stacks 6) Entryway 7) Corridor 8) Seed Library

Science Labs

The inclusion of science laboratories as part of the building programme was in order enhance the school's science curriculum. The labs serve as dedicated spaces that provide the necessary equipment to allow for specialist activities. There are four laboratory spaces provided, one oriented towards each of the four science strands of the Ontario science curriculum. The labs are split into two categories: local ecology and building systems which is reflected by their separation between two courtyards. However, in a sense the whole school is a laboratory for these subjects through its demonstration of sustainable building design practices and the incorporation of these elements of the building into lessons. The laboratories all have a direct connection to the outdoor courtyards through a partially-covered deck area that is separated from the courtyard through a planter trellis privacy screen. The landscape and garden within the courtyards serve as an outdoor laboratory for science, encouraging exploration and investigation of features such as the constructed wetland, the native species pollinator garden or the science of the soil in the produce garden.

The science laboratories are the area of the school that is located closest to the natural features of the site, with access provided to the site from the north side of the building through the outdoor classrooms embedded into the berm. By locating the science labs closer to the 16 Mile Creek and woodland, the distance required to walk to them is decreased, thereby increasing the time that can be spent outside learning about the local ecology of the site, and increasing the chance that these natural features will be harnessed as educational resources.

All four labs were designed based on the same bioclimatic design concepts with direct solar gain from south-facing windows, high upper clerestories that bring daylight deeper into the space as well as allow for natural ventilation through stack effect, and the incorporation of thermal mass into the space to collect heat and radiate it back. What differs between the labs is the equipment provided, as it relates to the science strand that the lab is dedicated to. A general note: all labs were designed for a flexibility of use with mobile furniture so that the rooms have both a lecture and active learning capability. The special features of each lab are as follows:

Four Strands of Ontario Grades 1 to 8 Science & Technology Curriculum:

- Life Systems
- Structures and Mechanisms
- Matter and Energy
- Earth and Space Systems [11]

Energy Lab

- Mobile Laptop Carts
- Floor-to-ceiling Whiteboard Wall
- Projectors
- Conference-style layout of desks

Maker Space

- Power tools access and supervision
- Digital Fabrication Tools
- Sustainable Material Display
- Opens to large deck area to allow students to work outdoors

Wet Lab

- Sinks
- Water Tables
- Mobile Lab Benches
- Visibility to aquariums in adjoining native aquatic species room

Dry Lab

- Large stationary lab benches with incorporated double sinks
- Close proximity to Greenhouse

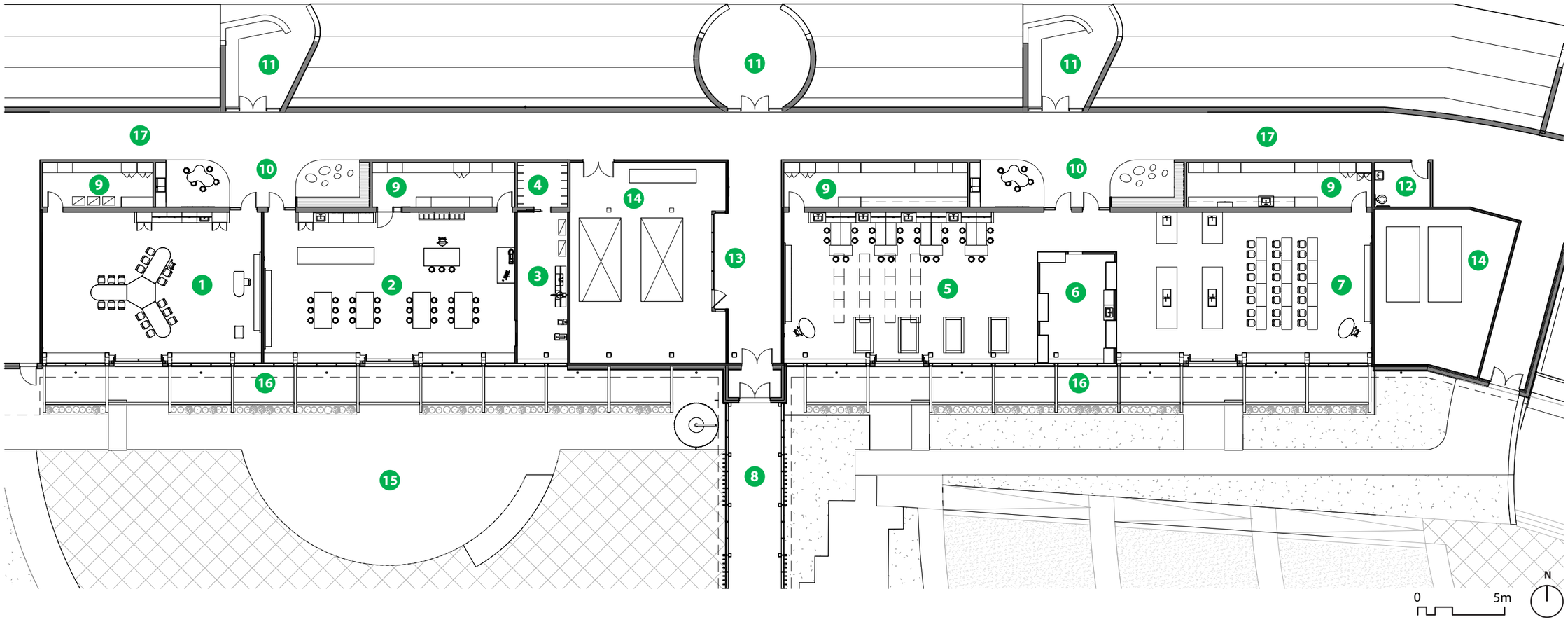
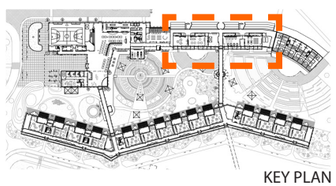


Figure 5.106 - 1:250 Floor Plan of Science Lab Wing

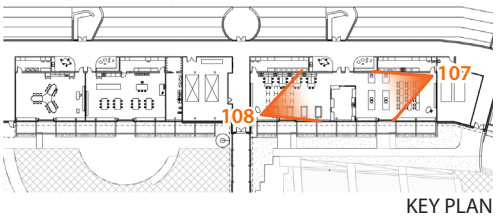


KEY PLAN

1 Energy (Computer) Lab
2 Maker Space & Workshop
3 Workshop
4 Wood Storage Room
5 Wet Lab
6 Native Species Room
7 Dry Lab
8 Glazed Walkway Link
9 Preparatory & Storage Space
10 Small Group Learning Area
11 Outdoor Classroom
12 Compost Toilet
13 Mechanical Room Viewing Gallery
14 Mechanical Room
15 Maker Lab Deck
16 Sheltered Deck Area
17 Corridor



Figure 5.107 - Perspective view of the Biology Science Lab



KEY PLAN



Figure 5.108 - Perspective view of the Wet Lab.
The Species Room is visible in the background. This laboratory is provided with wet tables for students to perform more advanced experiments and investigations with water. The laboratory benches are not fixed in this room, but moveable wood tables on wheels to allow for flexibility of lessons and experiments.

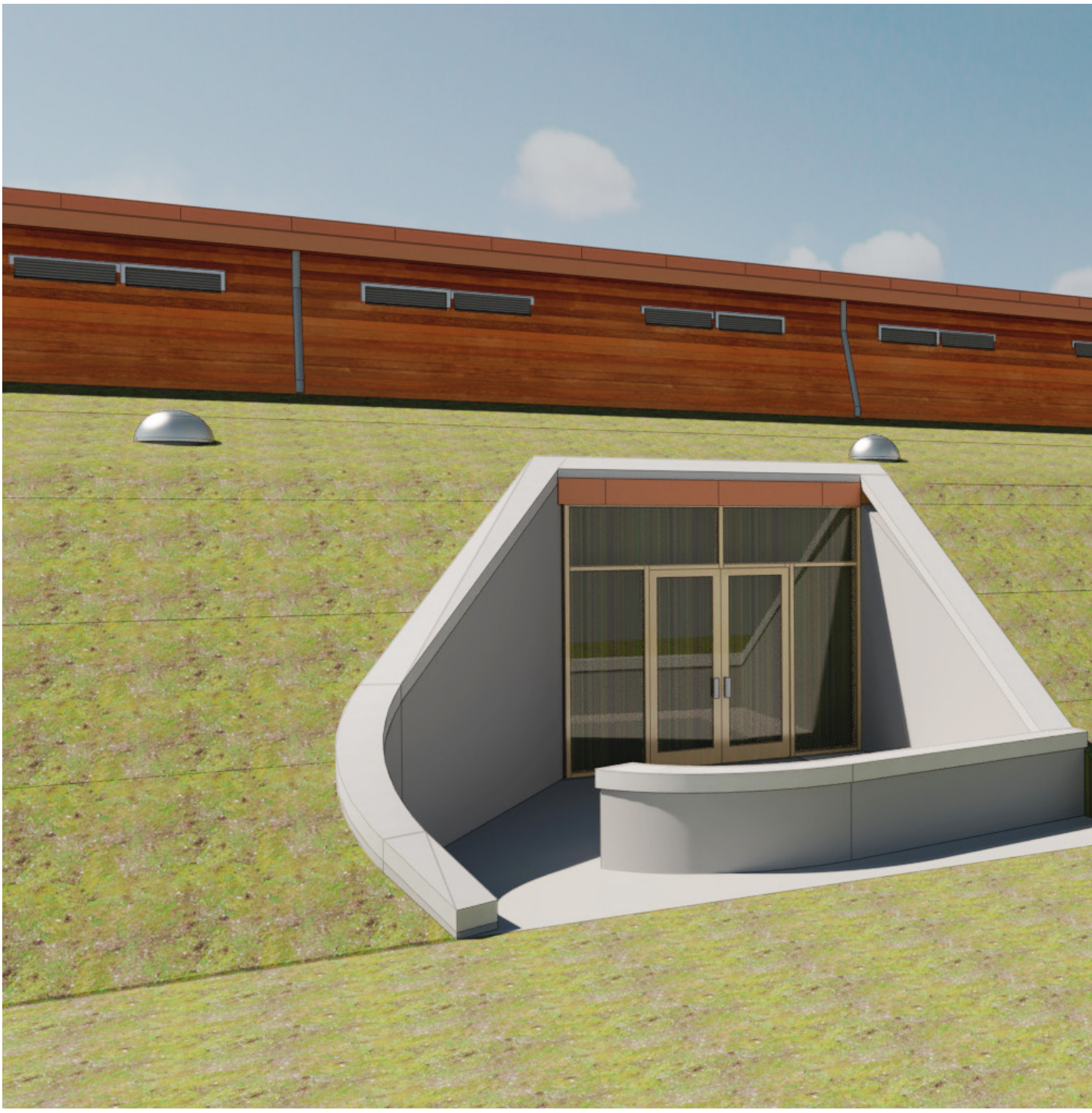
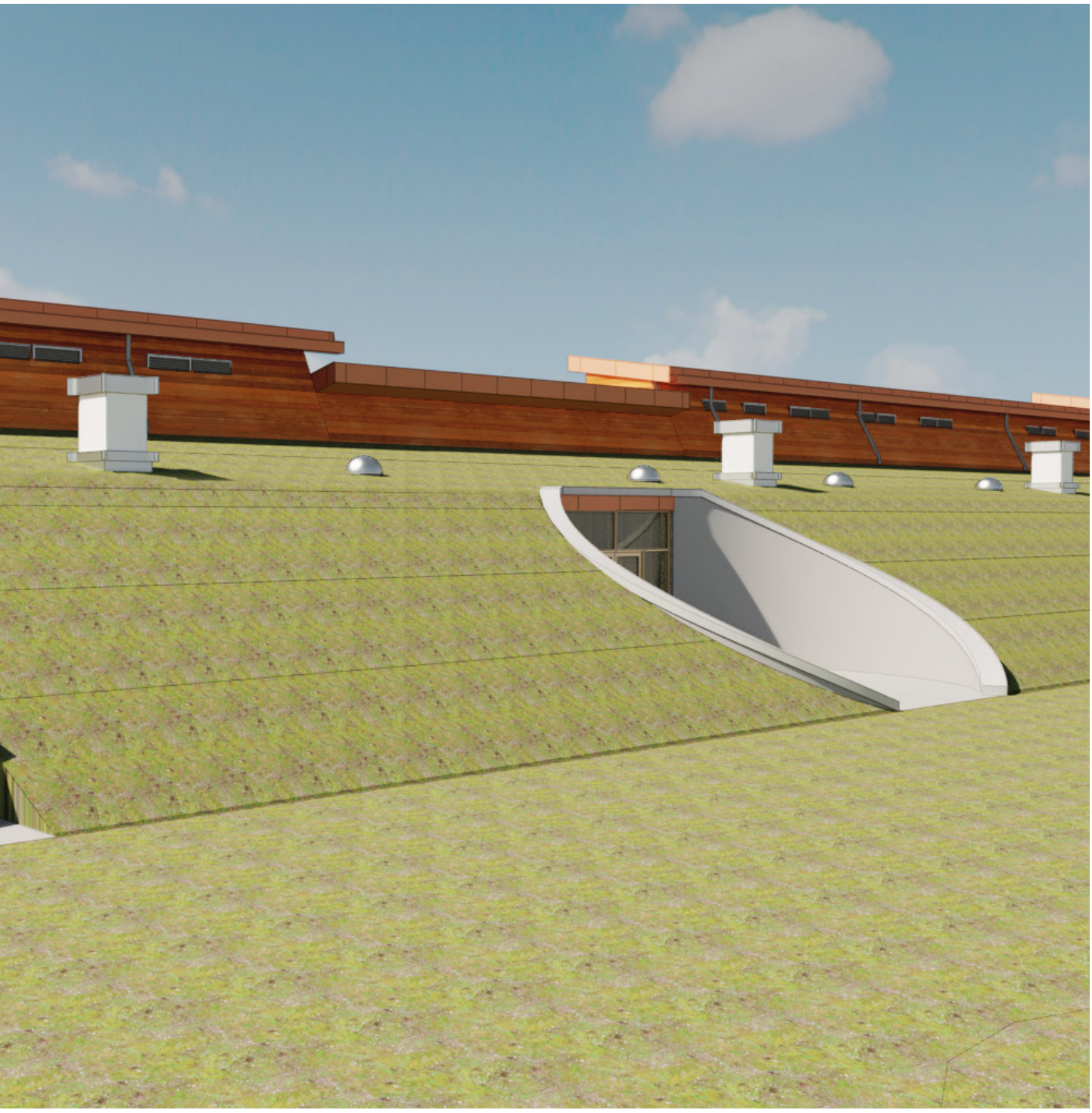
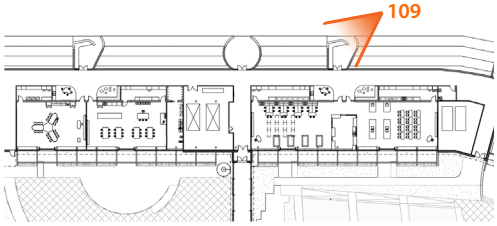


Figure 5.109 - Perspective view of the outdoor classrooms.
The classrooms are built into the berm on the north side of the science lab wing and look out onto the site's meadow and forest. The berm is planted with native vegetation - grasses and wildflowers - to merge the building with the adjacent meadow.





KEY PLAN

The Greenhouse

A SPACE FOR TESTING & PRODUCTION

An on-site greenhouse allows for the availability of fresh produce year-round for the cafeteria kitchen, extending the growing season into the winter. The addition of a greenhouse to the school's program also creates a space where students can undertake experiments. As a controlled environmental setting, the space is an ideal laboratory for science experiments and student projects such as hydroponic and aquaponic systems, experiments with soils such as vermicomposting, as well as providing hands-on food education opportunities and teaching about urban farming techniques.

These two separate functions of the greenhouse are expressed through the division of the enclosure into two spaces: a mezzanine (the lab) and the gallery (production field) below. They are joined by a series of meandering ramps and stairs. The greenhouse mezzanine allows students to experience the concept of convention first-hand as they are able to feel the difference in temperature between the cooler lower level and the warmer mezzanine (as heat rises). This makes the greenhouse a pleasant space to occupy during the winter.

The undulating form of the greenhouse is constructed out of curved glulam beams, that are covered with and ETFE skin. The ETFE cushions allow the skin of the greenhouse to closely follow the curvature of the glulam structure, while admitting the high levels of daylight that the plants require to thrive.



Figure 5.110 - Perspective view of the Greenhouse

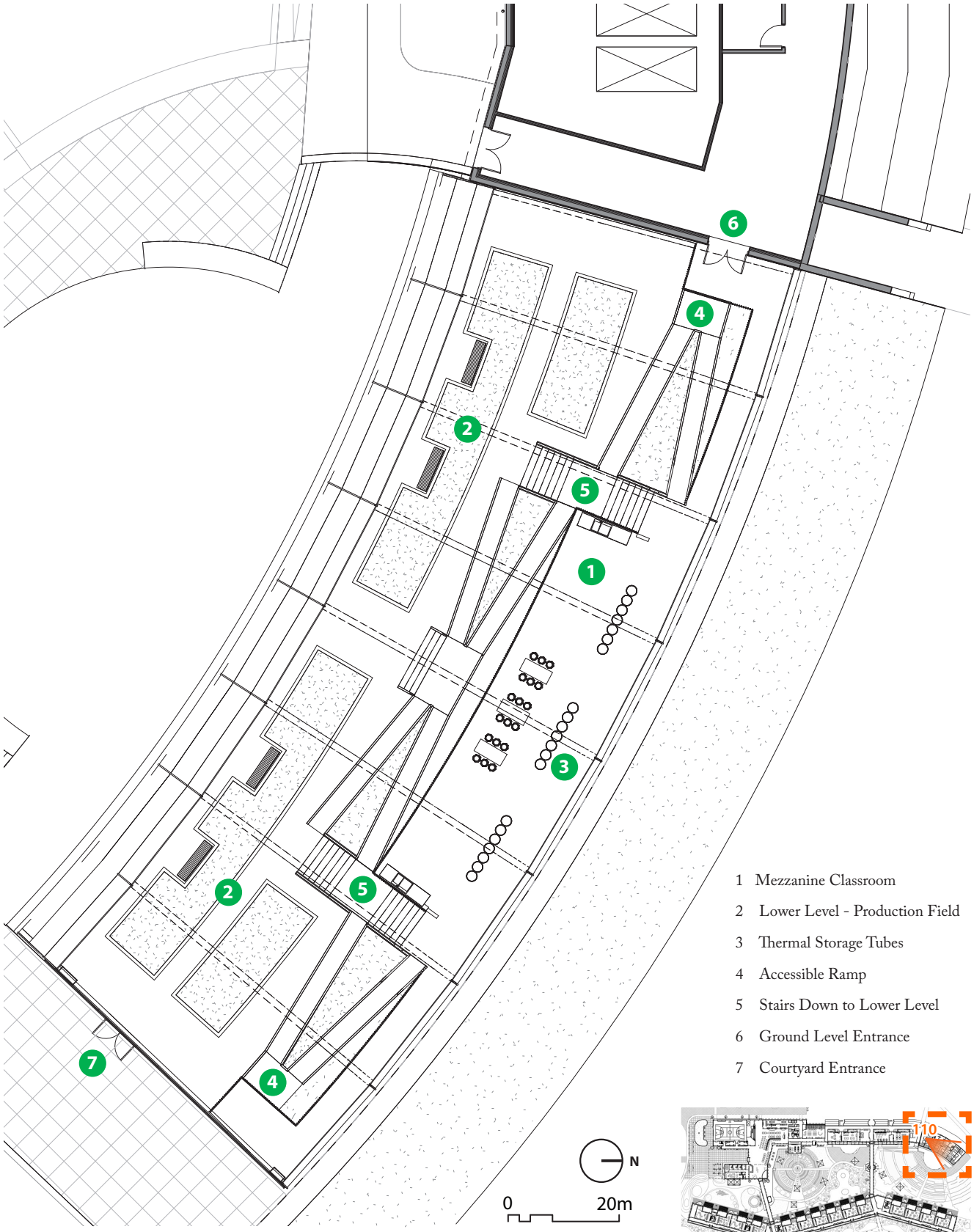


Figure 5.111 - 1:250 Floor Plan of Greenhouse

Kindergarten Courtyard

A NATURAL PLAYGROUND

The kindergarten courtyard is designed as a natural playground, created using site elements such as berms, logs, native plants, loose parts materials, sand and water to create a landscape for play. The elements encourage creativity as they do not have a prescribed play use, allowing children to choose how they interact with the element. This allows for young children to play safely in an environment with controlled risks.

The playground is divided into three separate areas, with each area supporting the development of a different skill. The small amphitheater connected to the glazed breezeway is focused on social and speech-language development, allowing classes to gather as a group in the space for performances and storytelling. The second area includes play equipment such as log climbing frames, wood balancing logs and a log tower, which supports the development of gross motor skills in young children. The third area is a sand pit and shallow pool built into the berm that aids fine motor skill development. The provision of loose parts materials within the sandbox and distributed throughout the courtyard further aids in the development of fine-motor skills.



Figure 5.112 - Perspective view of Kindergarten courtyard looking across the length of the courtyard from the sand pit to the stage and amphitheater.



1 Stage

2 Amphitheater

3 Log Climber

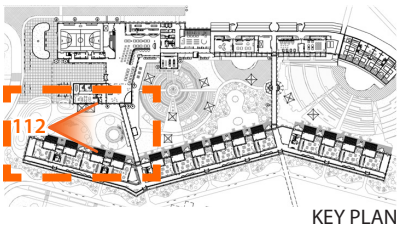
4 Water Pool

5 Sand Pit

6 Berm

7 Staff Room Patio

8 Hand Pump



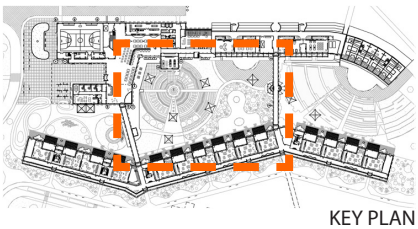
KEY PLAN

Figure 5.113 - 1:500 Plan of Kindergarten Courtyard

Primary Grades Courtyard

A SPACE FOR GARDENING AND FOOD PRODUCTION

The middle courtyard is a lively space that forms the center of activity for the school as the home of the campus's on-site productive garden. Food is placed at the heart of the school just like a kitchen is the heart of a home. The garden is located adjacent to the cafeteria and learning kitchen both because of the inter-relationships between the programs, and to create a visual connection to the food one is eating and/or preparing. Time is one of the main themes of the courtyard. The crops are organized in a circle according to harvest season: this helps concentrate the gardening work to one smaller area, and visually differentiates them helping students learn about which foods are in season. A sundial at the centre of the garden tracks time throughout the day. The sundial also acts as a reminder that all life is dependent on the sun. "The Sun Powers Everything" is another theme of this courtyard design. Other elements visible in the courtyard support this theme are the evacuated tube vertical screen and the rooftop PV array that is visible from the ground when looking up. The inverted umbrella shade canopies provide relief from the sun and have integrated hoses that are connected to the cisterns below, making irrigation of the plants an easier task as they are spread out around the courtyard in proximity to the garden. The other programs in the courtyard are a pollinator garden, a composting area, and a chicken coop off of the glazed walkway that bridges the classrooms with the other volume. Both features are in line with the food education program of this courtyard. The reliance of our food supply on pollination from bees is a human-nature interrelationship that is highlighted by positioning the pollinator garden so that it occupies the same courtyard as the produce garden.



KEY PLAN

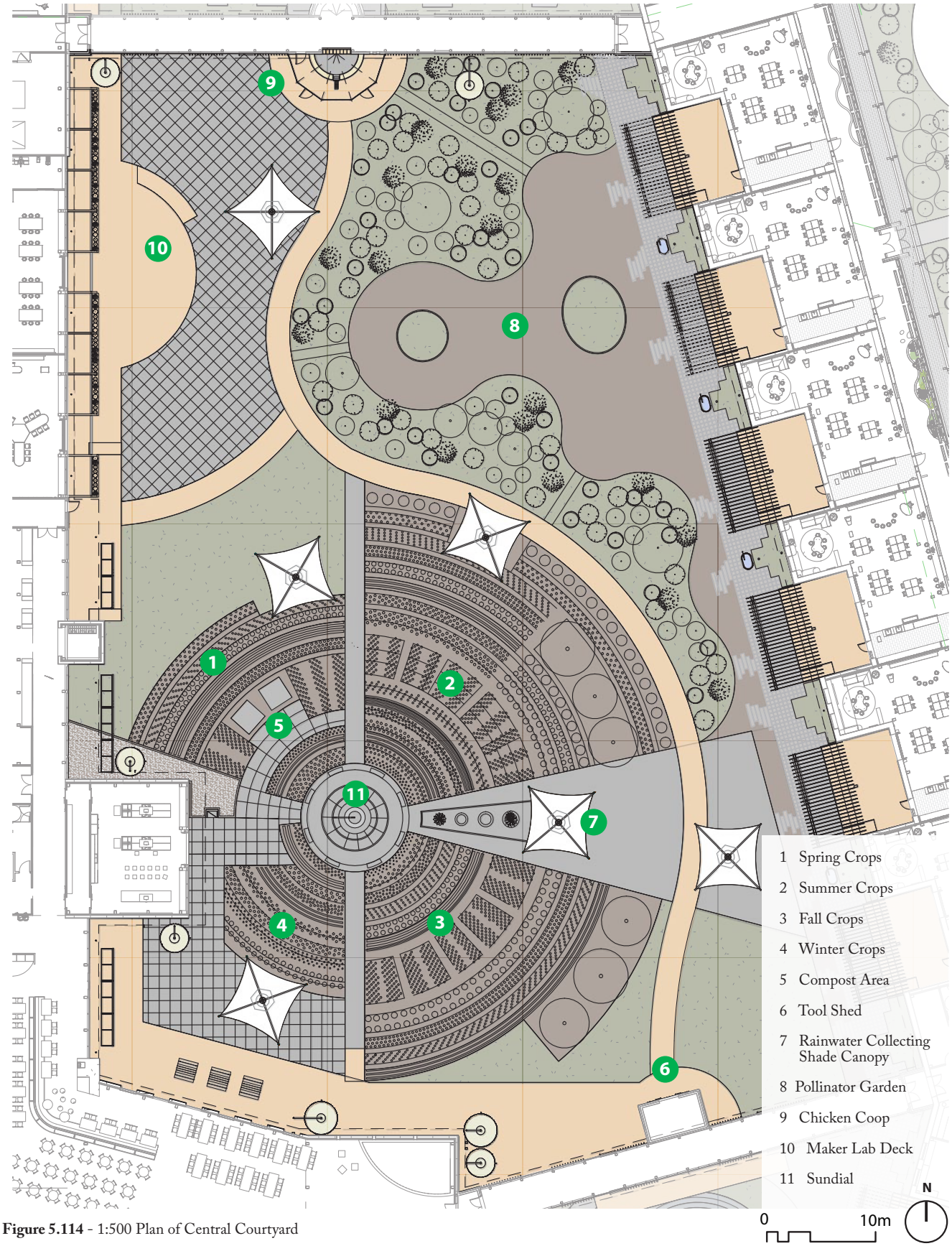


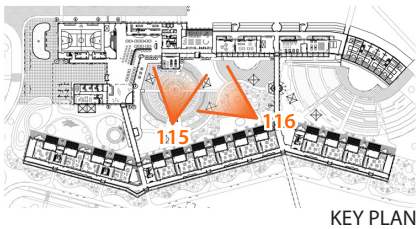
Figure 5.114 - 1:500 Plan of Central Courtyard



Figure 5.115 - Perspective view of the productive garden and exterior of the learning kitchen classroom.



Figure 5.116 - Perspective view of the pollinator garden in the primary grades courtyard.



KEY PLAN

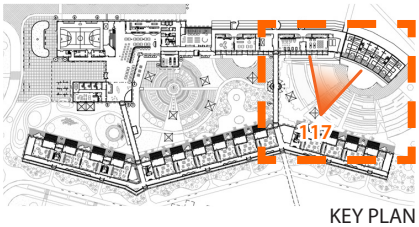
Upper Grades Courtyard

A SERIES OF TERRACES

The decrease in topography of the site is worked to its advantage in the design of the third courtyard. The experience of the series of courtyards culminates in an downhill progression through a series of terraces and amphitheater seating which meet around a central podium and the greenhouse. The podium and greenhouse, which mark the lowest topography point in the courtyard, and the courtyard elements radiate uphill from it. As this courtyard is nearest to the creek, it features a constructed wetland and vegetated filter strip terrace as a reference to the "wild" nature on the site just beyond. The constructed wetland terrace cells are adjacent to the biology and wet lab and are designed as a highly visible component of the wastewater treatment process, that also becomes a landscape feature that can be incorporated into students' science classes. Pedagogically it is the central focus of the courtyard. The raised seating of the amphitheater is able to accommodate large groups of people and would be able to be utilized for school plays, large assemblies, and by the community during after hours. The landscape strategy of this courtyard is much more naturalized with native wetland species contained within the wetland cells, and native grasses and wildflowers in the filter strip terrace.



Figure 5.117 - Perspective view of the terraced courtyard looking across the amphitheater towards the constructed wetland.



KEY PLAN

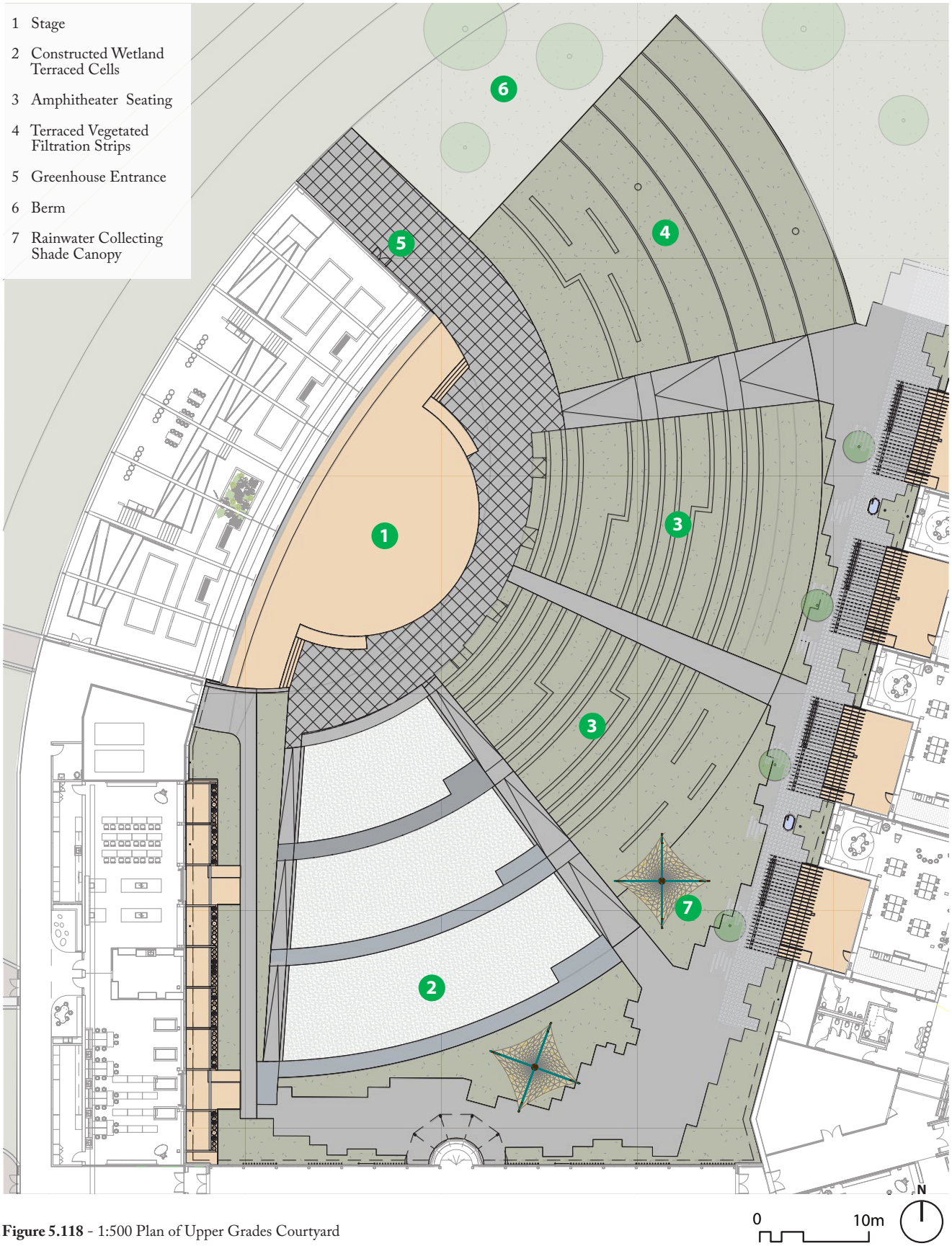


Figure 5.118 - 1:500 Plan of Upper Grades Courtyard

Outdoor Pavilion

MAKING THE SITE ACCESSIBLE

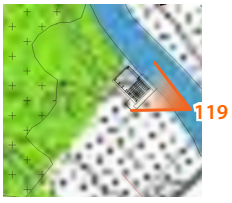
By building a school on a site containing significant natural features such as the 16 Mile Creek and its surrounding woodland and meadows ecosystems, the environment becomes a resource that can enrich student's classroom studies, with direct experiences in nature. To encourage their incorporation into lessons, these natural features of the site are made more accessible through a proposed a series of ramps, staircases, and an outdoor pavilion. Care is taken during construction to preserve the existing natural features as they are. These outdoor structures are something that doesn't have to be constructed at the same time as the rest of the school, and can be added over time, creating a special community project for the school.

The small pavilion would be situated right on the edge of the water of the 16 Mile Creek. Its proposed location is next to the meadow clearing, in the north-east direction from the school, and gives access to the portion of the creek that is next to the bridge underpass. The pavilion is oriented so that it looks onto the water, with a get-down platform provided to allow the creek to be more safely accessed. The outdoor structure is able to serve as shelter for a class of up to 30 people, extending science learning outside of the classroom. Its purpose is to provide a comfortable space that provides shelter from the elements thereby allowing teaching to take place within the outdoor context, and encouraging the study of nature on the site through hands-on direct contact with it. The pavilion is open to the community, providing an outdoor classroom space that can be utilized by the anyone as well as a shelter space for outdoor recreation that takes place in the valley (for example as a rest stop for people canoeing up the creek).

In regards to construction, pavilion is expressed in the same architecture language as the rest of the school, identifying it as a belonging to the school. The branch-like timber columns that were utilized on the south facade of the classroom wings are carried over to this outdoor structure, and the use of natural materials connect the structure visually to the woodland. The pavilion itself is programmatically flexible with and open plan that is adaptable to suit different needs. A wood lattice bird screen forms an exterior wall on one side, and a wooden table and bench are provided. One half of the roof is constructed out of a glass canopy for daylight access, while the other half is made out of a solid metal-clad roof deck. This feature gives the pavilion a light and airy feel.



Figure 5.119 - Perspective view of proposed outdoor pavilion situated right on the water's edge of the 16 Mile Creek.



KEY PLAN

Endnotes for Chapter 5

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Conclusion

Education: The School Building as a Teaching Tool for Sustainability

This project was designed as a demonstration of what a green school could look like. Its advancement of sustainability is measured by how successfully it meets the three pillars of green school design, through its progress in: (1) decreasing the negative impact of the facility on the environment, (2) improving the health, wellbeing, and performance of its students and staff, and (3) promoting the development of ecological literacy and sustainability behaviour in its graduates.[1] Of these three pillars, the third one is arguably the most important, as ultimately the success of a green school in its sustainability endeavours is weighed in terms of its impact on students' environmental education. In its conception as a green school the overarching goal of the proposed school design was to harness the power buildings have to teach people, to design a school facility that can be utilized as an effective tool in helping foster lifelong environmental stewardship behaviour in children when they are at a malleable age. At the first level the school facility supports sustainability by being designed as a green building that is constructed and operates in such a way that it leaves a lighter environmental footprint, thereby modeling the environmental awareness it seeks to promote. While important to its goals, as practicing unsustainable environmental behaviour would be hypocritical for a green school, no matter how well the school functions from an environmental performance standpoint in order for the building to be able to become a teaching tool it must demonstrate how it does so. That is, demonstrate how it reduces its environmental impact and how it forms a more closely connected relationship to the nature of the site. It is for this reason that the three pillars of the green school framework are effective in measuring an educational facility's sustainability progress, as they acknowledge the importance of the building being able to contribute to teaching environmental education.

To go from a passive mode of teaching to an active one, the project was designed with strategies in place that help students understand how their school is different. This allows it to act as a "three-dimensional textbook"[2] for sustainability, and thereby be woven into the curriculum to support environmental education. Much like a real textbook is an interpretation of the curriculum that has been written by experts to create learning opportunities, when the school is designed as a 3D-textbook it functions as the educational context and students "read" it by interacting with and exploring sustainability concepts integrated into the space.[3] The following strategies were incorporated into the proposed design to ensure that the building succeeds in its mission of educating for sustainability.

Visibility and Transparency

Much of the success of the "3D-textbook" depends on the use of the visual cues.[4] Creating transparency of building operations and assembly was important to the design proposal so that students can study how the building works and come to understand the natural and mechanical processes that make the space habitable and support the daily functions of the school. The idea of transparency is one of the principles of ecological design and was incorporated into the proposed design with the goal of attempting to increase students' awareness of the processes and flows of energy that occur within one's environment. Ecological design calls for making these natural processes visible and highlighting the flow of resources across the site – this includes the sun, wind, rainwater, human waste, and food.[5] Within the proposed green school, they are made visible to the students and not hidden from view as they often are.



Figure 6.1 - An example of a manifold cabinet where the tubing on its inside is revealed and made into a visible feature in the corridor.

Exposing the Inner Workings

The school's operational systems and building elements are designed to be transparent and proudly visible, so that they can be viewed, investigated and touched by students. In this way, how the school works is brought to light to curious minds, letting them see the parts of the "organism" that is the school.

- The ceiling structure (SIPs) is left unfinished, exposing the HVAC ducts, electrical wiring (encased in copper conduits), and sprinklers pipes. Each element is brightly painted and colour coded to highlight its function and be highly visible within the space.
- The mechanical rooms are designed with a "Viewing Gallery," an alcove off of the corridor where a glazed window wall allows occupants to look in at the machinery. The colour-coding of the overhead systems is carried over into this space, the colours highlighting the pipes coming into the room.
- Truth windows and reveals are another visual tool, one which uncovers what is behind the wall and floor surfaces. Students come across these in various locations around the school.
    - A glazed panel in the floor reveals the radiant floor heating tubing embedded in the concrete floor.
    - Manifold radiant heating cabinets are uncovered with glazed doors and made visible in the breakout space
    - Straw bale wall truth windows in the classrooms
    - Window and door openings in the CLT walls are left untrimmed, revealing the alternating layers of wood of the panel.



Figure 6.2 - Example of truth window revealing the embedded radiant floor heating system. Pictured example is at the Amber Trails Community School in Winnipeg by Prairie Architects.



Figure 6.3 - Example image of how the piping of the mechanical system would be painted in bright colours to highlight their presence and how the school works. The pictured example is within a science classroom at Pope Elementary School in Texas by VLK Architects.

Ecological processes are not only made visible, but the flow of nature across the site is highlighted. Within the design proposal examples of this include:

- Processes like wastewater treatment which are generally hidden from view, are placed out in the open for all to see. The use of the Living Machine® system makes this possible and the system parts become attractive architectural features; within the proposed design the corridors of the classroom wing are lined with the treatment cells, as well as forming one of the landscape features of the courtyard.



Figure 6.4 - Perspective image of the "Viewing Gallery" to the mechanical room. As students circulate through the corridors they are able to look-in and observe the machinery. This is coupled with an electronic monitor that display the metrics on the building's performance.

- Rainwater collection from the rooftops is highlighted through over-sized gutters and above ground water storage tanks distributed across the site
- How the school harnesses the energy of the sun is made more perceptible through the architectural integration of PV panels into the front entrance canopy and rooftops, and the collector tubes of the solar hot water heater into a vertical screen.

Real-time Data Collection and Display

Transparency of building operations is also demonstrated in another sense. The building's sustainability performance is measured through data and metrics that are collected, and made readily accessible to students and the general public. The collection of data would provide quantifiable evidence that shows that the green school indeed performs more environmentally efficiently than a non-green school. Tracking both positive and negative changes in the data helps students understand the impact of one's actions within the larger scheme of the facility in relation to the environment. The numbers can be powerful, as they also allow for the school to identify actions that are working well, and areas where additional measures could be implemented to further reduce the building's consumption of resources.[6]

Real-time data on the building's energy production and consumption, rainwater storage levels, etc., is displayed graphically on electronic screens installed in select locations with a lot of traffic around the school. These energy dashboards are touch-screen monitor displays which engage students and allow them to participate in the monitoring of the building performance. Data and metrics can be incorporated into lessons with ease – subjects such as math or computer science can be connected to this when students graph the information.

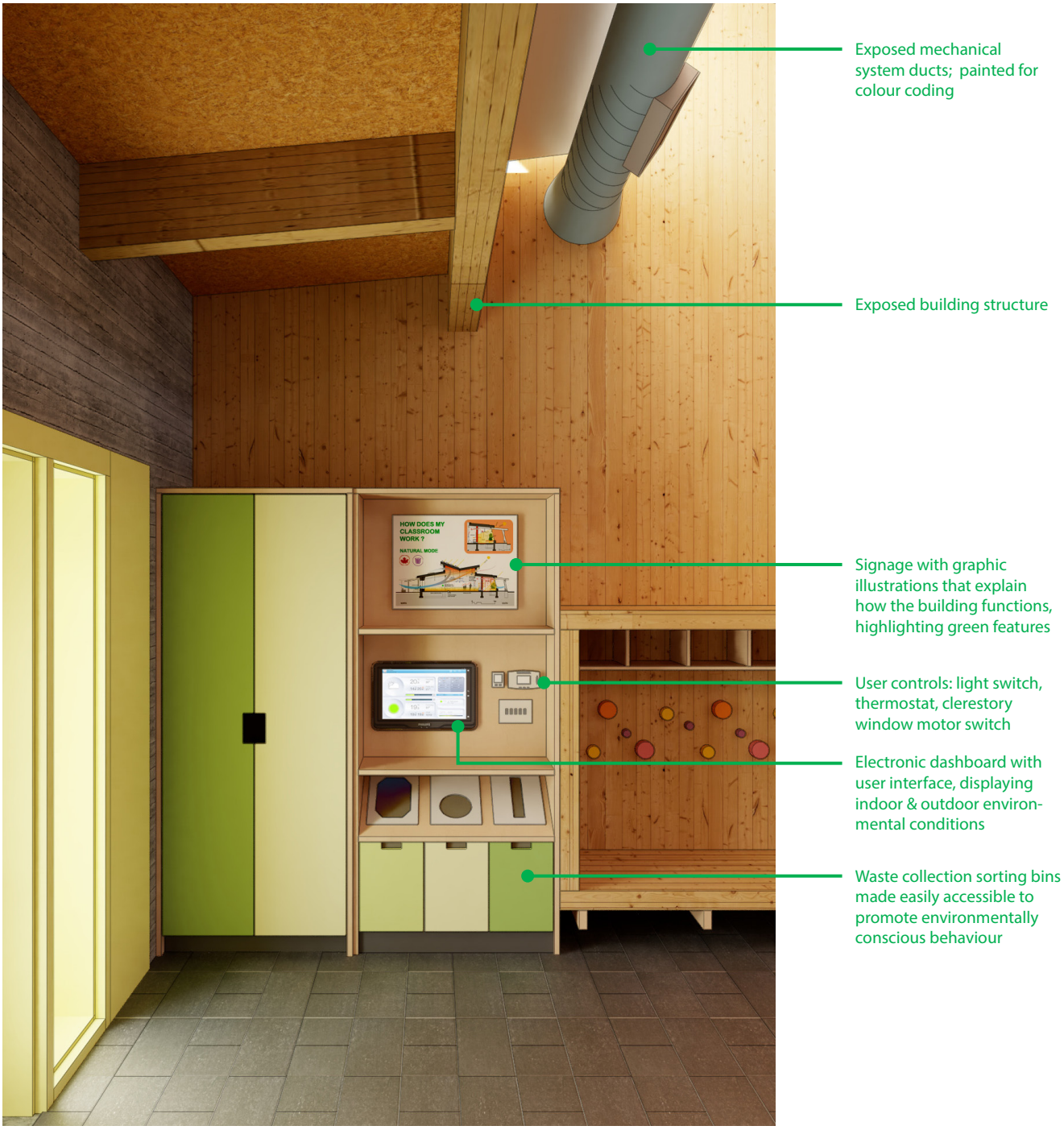


Figure 6.5 - Face-on perspective view of "Energy Wall Unit" located in the mudroom of each classroom. Energy dashboard, graphics explaining green features of building, exposed ducts and building structure.

The interface is accessible across the building through devices with an internet connection, so it can be connected to cellphones and on school computers. A smaller monitor screen is incorporated into the "Energy Wall Unit" of each classroom where, based on similar principles, data feedback from the many sensors inside and outside the building is displayed.

Illustrating the Flows of Energy and Resources

Art is used as a tool for education within the proposed green school, helping effectively communicate scientific and sustainability concepts to the students. Visual graphics and signage are one format that this strategy takes. Large-scale colourful diagrams similar to the ones featured in section *5.3* of this document illustrate how components of the building work, identify elements within the building and site that contribute to making the school more sustainable, and depict how energy and resources flow through the building (i.e., the rainwater and natural ventilation air flow paths).



Figure 6.6 - Fish symbol next to the sink drain, brings awareness to the final destination of the water that goes down the drain - the local watershed, and that anything that is washed down the drain can affect the local ecosystem. The example pictured is the sinks at IslandWood.

It is envisioned that artwork pieces would be incorporated throughout the building and landscape. This was a strategy that was used with great effectiveness at the IslandWood campus, one of the precedents looked at in Chapter 3, where art features such as such as sculptures, paintings, objects found in nature, and interior details and furnishings were commissioned and installed in its building to help teach.[7] The artwork acts as a visual symbol that denotes that something is happening at that area, bringing notice to the sustainable components of the building, calling attention to a potential educational opportunity embedded in the element,[8] or communicating information about the local site. Some art pieces that are included within the proposed design are:



Figure 6.7 - Example of sculptural bicycle racks that are functional but artistic features that communicate information about the site.

- The local watershed map painted on the floor of the front lobby that teaches students about the natural features of the site
- Bicycle racks designed as sculptural art in the shape of bicycles, native wildlife, and natural elements, which visually support the sustainability theme of the school and represent the natural character of the site
- A sculpturally-designed sundial in the school garden
- Signage in the cafeteria that illustrates the menu, healthy food choices, and what is in season
- Student artwork: Students can contribute to being designers of their learning environment by creating some of the signs around the school, and by having their artwork displayed around the school.



Figure 6.8 - Example of sign painted by students which identifies the crops in the vegetable garden, while doubling as artwork.

Involving Students in Building Operations

Actively involving students in the operation of the building was important to the project as a method of teaching environmental education. Engaging students in the processes that support the functions of the school makes them more "transparent." By giving students a role in maintaining thermal comfort and cleanliness of the learning environment, it helps them understand how their school works through learning by doing, and gain a sense of control and responsibility over their environment. Furthermore, students are able to practice sustainable behaviour.[9]

Within the proposed design, students are made to feel that they contribute to the flows of energy and resources across the site – such as by powering the living machine, reducing waste in landfills by choosing to recycle, carrying food scraps themselves to the outdoor compost bins, controlling the admittance of heat from the sun by opening/closing vents, and opening windows when signalled. These elements of the school that are manipulatable are part of the "3D-textbook," allowing for students to interact with objects within the building and landscape, thereby using them as teaching tools.[10]

Building User Guide

Occupants must be educated on how to use a green building in order for it to work successfully and as efficiently as intended. This is especially important to the operation of the passive design features of the building.[11] The importance of educating the occupants and public about the building – the features that make it sustainable and support the health of occupants and the environment – is reflected in the LEED for Schools rating system. It offers a point under the *Innovation in Design* category for Green Building Education.[12] The strategy that the proposed green school would take to support this is the development of a building user guide that describes and illustrates through diagrams and pictures how the school building is to be operated. Three information packages would be created as a manual for the school: one for the students, one for parents (how will my kids learn about sustainability?), and one for the staff and janitors. They would vary in detail based on the level of involvement expected of each group, and have the benefit of being a reference for new students and staff to quickly come to understand how the building is designed for user operation.

Community Outreach

The proposed green school is designed with the intention that it would become a visible symbol of sustainability within its community. Given the rapid population growth of the town of Milton where the project is sited, the school's mission and curricular theme is especially applicable to the issues playing out within its immediate community. Its environmental ethos serves as a reminder to the growing city that sustainable development is important in order to minimize the negative effects of urbanization on the natural ecosystems, and thereby to maintain the health of the environment. The school's location right at the intersection of the new development, the town's rural community, and the rich natural ecosystems of the 16 Mile Creek Greenway, allows it to serve as a connecting point between these three communities, as well as help preserve the landscape of the site. The proposed school would be Milton's first green school, that is the first LEED-certified school in the Halton region, and so the city would be able to use the project to promote further sustainable building practices and development in the growing community. The school facility would demonstrate principles of green building design to members of the community, serving as a reference for future projects (including new schools) who could study it and pick and choose components that would suit their project needs.

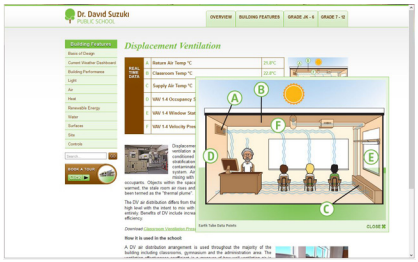


Figure 6.9 - A screenshot of the interactive website created to showcase to the public how the many green technologies of the Dr.David Suzuki Public School work. Website url: http://www.suzukipublicschool.ca/index.html

Furthermore it has the potential to become an environmental community centre for the town, playing a role in educating the whole community on being environmentally aware and responsible citizens. One strategy for supporting green building education within the wider community would be by offering student-led tours of the school to the public, an action that involves students in community outreach, and furthers their own knowledge of their school. An interactive website much like the one that was created at the *Dr. David Suzuki Public School*,[13] one of the precedents looked at in Chapter 3, could be used as an education and outreach tool. The website would explain features of the building through interactive visuals, videos, and text, as well as make real-time energy performance data accessible to the public, which is also part of the transparency of operations strategy. The third strategy is to increase the school's connection to the community through the provision of community education programs that run in the school during the afterhours and off-season periods. Community accessibility and programming opens up the school to all children in the neighbourhood, so that everyone has an opportunity to experience hands-on environmental education on a more regular basis, even if they attend a different school.

Financial Considerations

The higher initial capital cost of constructing a green school compared to a typical school is generally perceived as the biggest barrier preventing green schools from being more commonplace, as this misconception has made many school boards hesitant about investing in them.[14] However, the idea that they cost a significantly greater amount to construct has been proved false by a major study conducted in 2006 by Gregory Kats. While on average the initial upfront cost to design and construct a green school is slightly higher, it has been proven that they are a more financially viable option over the long-term period of their life, as the energy efficient operations of the building, due to green building design principles and technologies, results in lower operational expenses.[15] Furthermore, the benefits of green schools are not only economical, but also include improved health for the occupants and the environment, a learning space that bolsters academic performance, and a facility that increases opportunities for environmental education, as previously discussed. These factors together make green schools an investment that pays off for communities.

The proposed project was designed to operate as a private school, which means that within the educational framework of the province of Ontario its construction and operation would not be funded by the government.[16] Thus, *Creekside Valley EcoSchool* would operate as a non-profit organization, charging a tuition fee to support the operation of the building. As the upfront costs of the design and construction of the building would be high, especially with the numerous sustainable technologies incorporated within the design, fundraising would be required. While the proposed school was designed outside of consideration of financial constraints, some strategies have been identified that would help fund its operation and reduce its maintenance expenses.

One source of energy cost savings as well as revenue is the 225kW grid-tied photovoltaic panel system installed on the rooftop of the proposed school. The re-

newable energy produced by the panels supplies most of the school's electricity demand, reducing its operational expenses. Though the installation of the solar panels would be a large expense, the school would sell the energy produced by the panels back to the grid through the province of Ontario's Feed-in-Tariff program.[17] The money earned from this would cover the cost of the solar panels, and after the payback period is over, the system would become a source of income for the school.

Some of the green building design principles incorporated within the school proposal would result in savings that offset the higher upfront cost of the building. These include:

- Limiting the required interior finish material volume by leaving many of the interior surfaces such as the ceiling, some interior partitions (CLT, concrete), the concrete floor slab as well as the structural system exposed for educational purposes and/or to support their function within the passive system (i.e. as exposed thermal mass). However this also helps reduce the construction costs associated with interior finish materials, as they are not necessary in many places.
- The reduced mechanical system size as a result of the elimination of a central HVAC system, and the dispersal of multiple mechanical rooms throughout the school which reduces the running length of ducts.
- The use of inexpensive "waste" material for the classroom straw bale wall enclosure, as well as volunteer assistance in plastering the walls reduces material expenses
- Prefabrication of the engineered wood structural system and SIPs off-site, which speeds up construction time onsite lowering labour costs

The selection of materials with increased durability and a longer life cycle gives the building a 100+ year life span, allowing the shell and structure of the building to serve the community much longer than the typical school building, which has a shorter estimated life span. More durable materials may be in some case more expensive to install, but will not need to be replaced as often, and so is more cost effective.

The flexible character of the spaces within the school, as a result of the L-shaped classroom floor plan, the multi-use potential of the spaces, the use of non-load bearing interior partitions, are strategies designed in anticipation of the future changes to the curriculum and methods of learning, and allows the school to accommodate them without requiring extensive and costly renovation.

One major source of income for the school to support its daily operational expenses would be renting out spaces within the facility to groups in the community for afterhours programming such as evening classes, recreational sports, and social events, as well as for summer day-camp programs. The design qualities of the proposed school supports this function, giving it the ability to be rented out throughout the whole year. The programmatic flexibility, ability to accommodate large assemblies, and thermal zones division of the many of the multipurpose spaces are some of design elements that encourage community use of the school. The school facility would be a particularly attractive space to rent out during the

summer as it is designed with passive environmental design strategies in place that help it maintain thermal comfort for most of the summer without requiring much energy input. In addition to bringing in extra revenue, it would be a more sustainable use of space rather than letting a whole building sit empty and closed down for a part of the year, as is necessary of many existing public schools in the region (as generally without the use of large amounts of energy to cool the space, they are otherwise too uncomfortable).

Concluding Remarks

While this project was designed as a demonstration of how the architecture of the school facility can be a source of environmental education, the *Whole School Sustainability* framework acknowledges that a green school's success in its sustainability endeavours depends on the transformation of all aspects of the school.[18] Simply providing a sustainable building is not enough, if it is not coupled with changes to and equal commitment of the school at an organizational and curricular level. While curriculum changes towards increased environmental education are generally the easiest and most likely to be implemented, as has been the case to date within the formal education framework of Ontario, the proposed school design illustrates how integrating sustainability concepts into the physical environment of the school supports environmental education as it backs up what is being taught within the classroom with a physical representation of those concepts. By using the school building and landscape as a demonstration tool, the proposed school uses an approach to environmental education that does not concentrate on what is wrong, but rather focuses on the positive, hope and what actions can be taken towards living a more sustainably-minded life.

Endnotes for Conclusion

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4 Ibid, 181.

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APPENDICES

Appendix A - LEED-Certified K-9 Schools in Ontario

The following chart is based on data from the CaGBC's online database *LEED Project Profiles*, which documents existing projects in Canada that are registered and certified by LEED. This search through the database was conducted as a method of identifying K-9 school projects that are Platinum-certified, so that they can be studied as precedents for Green School design. Data is accurate as of January 2019. Link to database: https://leed.cagbc.org/LEED/projectprofile_EN.aspx.

Table A.1: List of LEED-certified Elementary Schools (K-9) in Ontario

Certification Level	***Project***	***Location***	***Certification Date***	***Project Type***
Platinum	Dr. David Suzuki Public School	Windsor, ON	2011	New Construction
Gold	Brookside Public School	Scarborough, ON	2008	New Construction
Gold	Mundy's Bay Public School	Midland, ON	2009	New Construction
Silver	Alliance Française Toronto	Toronto, ON	2015	Addition
Silver	Bridgewood Public School	Cornwall, ON	2018	New Construction
Silver	Gardiner Public School	Georgetown, ON	2011	New Construction
Silver	École Ronald-Marion	Pickering, ON	2015	New Construction
Silver	Thomas L. Wells Public School	Toronto, ON	2006	New Construction
Certified	St. Matthew Catholic Elementary School	Binbrook, ON	2014	New Construction

Table A.2: Comparison of LEED-certified Elementary Schools (K-9) in Ontario by Province

	Number of K-9 School Projects that are certified -			
Province	*Platinum*	*Gold*	*Silver*	*Certified*
Alberta	-	21	44	1
British Columbia	-	15	4	-
Manitoba	1	3	7	2
New Brunswick	-	3	2	2
Newfoundland and Labrador	-	-	-	3
Northwest Territories	-	-	-	-
Nova Scotia	-	2	3	7
Nunavut	-	-	-	-
Ontario	1	2	5	1
Prince Edward Island	-	-	-	-
Quebec	-	1	1	4
Saskatchewan	-	7	10	-

Appendix B - LEED BD+C: Schools v4 Scorecard

Attached for reference purposes is a copy of the LEED for Schools v4 rating system scorecard. Source: U.S. Green Building Council, "LEED BD+C: Schools | v4 - LEED v4," LEED Credit Library, accessed October 20, 2019, https://www.usgbc.org/dopdf.php?q=scorecard/schools---new-construction/v4.

Table A.3: LEED for Schools (New Construction) v4 Rating System Scorecard

LEED for New Construction in Schools (v4)

		POSSIBLE: 1
Credit	Integrative process	1

LOCATION & TRANSPORTATION		POSSIBLE: 15
Credit	LEED for Neighborhood Development location	15
Credit	Sensitive land protection	1
Credit	High priority site	2
Credit	Surrounding density and diverse uses	5
Credit	Access to quality transit	4
Credit	Bicycle facilities	1
Credit	Reduced parking footprint	1
Credit	Green vehicles	1

SUSTAINABLE SITES		POSSIBLE: 12
Prereq	Construction activity pollution prevention	REQUIRED
Prereq	Environmental site assessment	REQUIRED
Credit	Site assessment	1
Credit	Site development - protect or restore habitat	2
Credit	Open space	1
Credit	Rainwater management	3
Credit	Heat island reduction	2
Credit	Light pollution reduction	1
Credit	Site master plan	1
Credit	Joint use of facilities	1

WATER EFFICIENCY		POSSIBLE: 12
Prereq	Outdoor water use reduction	REQUIRED
Prereq	Indoor water use reduction	REQUIRED
Prereq	Building-level water metering	REQUIRED
Credit	Outdoor water use reduction	2
Credit	Indoor water use reduction	7
Credit	Cooling tower water use	2
Credit	Water metering	1

ENERGY & ATMOSPHERE		POSSIBLE: 31
Prereq	Fundamental commissioning and verification	REQUIRED
Prereq	Minimum energy performance	REQUIRED
Prereq	Building-level energy metering	REQUIRED
Prereq	Fundamental refrigerant management	REQUIRED
Credit	Enhanced commissioning	6
Credit	Optimize energy performance	16
Credit	Advanced energy metering	1
Credit	Demand response	2
Credit	Renewable energy production	3
Credit	Enhanced refrigerant management	1
Credit	Green power and carbon offsets	2

MATERIAL & RESOURCES		POSSIBLE: 13
Prereq	Storage and collection of recyclables	REQUIRED
Prereq	Construction and demolition waste management planning	REQUIRED
Credit	Building life-cycle impact reduction	5
Credit	Building product disclosure and optimization - environmental product declarations	2
Credit	Building product disclosure and optimization - sourcing of raw materials	2
Credit	Building product disclosure and optimization - material ingredients	2
Credit	Construction and demolition waste management	2

INDOOR ENVIRONMENTAL QUALITY		POSSIBLE: 16
Prereq	Minimum IAQ performance	REQUIRED
Prereq	Environmental tobacco smoke control	REQUIRED
Prereq	Minimum acoustic performance	REQUIRED
Credit	Enhanced IAQ strategies	2
Credit	Low emitting materials	3
Credit	Construction IAQ management plan	1
Credit	IAQ assessment	2
Credit	Thermal comfort	1
Credit	Interior lighting	2
Credit	Daylight	3
Credit	Quality views	1
Credit	Acoustic performance	1

INNOVATION		POSSIBLE: 6
Credit	Innovation	5
Credit	LEED Accredited Professional	1

REGIONAL PRIORITY		POSSIBLE: 4
Credit	Regional priority	4

TOTAL	110

40-49 Points	50-59 Points	60-79 Points	80+ Points
CERTIFIED	SILVER	GOLD	PLATINUM

Appendix C - Review of Recommended Floor Area

The following chart was compiled as a way of determining what an appropriate floor area would be for the various programs within the proposed design. The first source reviews recommended gross floor areas as determined by an expert panel on capital standard for Ontario Ministry of Education. The other two columns document the floor area of the various instructional and non-instructional areas within two existing schools recently constructed in the town of Milton, sharing the same site context as the proposed school project.

Table A.4: Review of Recommended Gross Floor Areas (m^2) by School Program

Room	Recommeded Area (m2)	Actual Area Size (m2) of Existing Halton Schools				
	From "Building Our Schools, Building Our Future" - Expert Panel on Capital Standards, Ontario, 2010.	Milton No.8 - St.Scholastica CES (constructed in 2018)		Milton No.5 - St.Benedict CES (constructed in 2014)		Calculations for Proposed School of 400
Student Enrollment #		671		671		400
Instructional Areas						
Kindergarten Classroom	111.5	ranges from 103-108		103		
No. of Classrooms			6		6	
Kinder. Storage		7		5.7		
Kinder. Vestibule		13		15.7		
Standard Classroom (Gr.1-8)	70	68		70		
No. of Classrooms			20		20	
Science Room	97.5	91		89		
Science Storage		10		10		
Art Room (Will not include because focus of school is science)	97.5	109		97		
Art Rm Storage				17.6		
Gymnasium	0.93/student (min. 371.5 when 300+ students) (Min 278.7 when <300)	515		513		0.93*400 = 372
Stage	min. 93 when <500; min. 139 when 500+	118.5		122		
Library	0.46/student (min. 223 when 300+ students) (Min. 279 when <300)	225 + 90		176		0.46*400 = 184 (MIN. 223)
A.V. Storage		13		14		
Workroom		30		17.5		
Computer Lab		71		66		
Instructional Flex Space	0.19/student (min. 70)					0.19*400 = 76
Special Education Area	0.19/student (min. 70)	124		70		/
Office		13		/		
Sensory		12.5		/		
Therapy		12.5		/		
Kitchen (Instructional)	19.5	22		/		

Table A.4 (continued): Review of Recommended Gross Floor Areas (m^2) by School Program

Non-Instructional Areas						
Cafeteria/Dining Area	0.46/student (min. 232 when <500)	/		/		
Kitchen/Servery	0.10/student	/		/		
Administration Office	0.29/student (min. 111.5, max. 140)	232		206		0.29*400 = 116
General Office/Front Desk Area	0.21/student (min. 148)	57		68		
Principal's Office		27.6		25		
VP Office		18		19		
Copy/Print Rm		16.5		18		
Conference/Meeting Room	28	23		17		
Storage		8		6.8		
Health Rm		14		9		
B/F WC		11		10		
Staff Room	0.20/student (min.70)	67		65		0.2*400 = 80
Resource Rooms	0.33/student	32 (x6)	192	35 - 37 (x6)	208	0.33*400 = 132 4*32 = 128
Teacher Work Rooms	0.33/student	25 & 32	57			
Storage Workroom				(19 & 20 & 32)	71	
Copy Room		10				
Washrooms (1 pair per flr)	0.29/student	31-35		34		0.29*400 = 116 116/4 = 29
WC				3.5		
B.F. WC		6 - 8.7		5		
Universal WC		11				
Change Rooms	37	27		34		
Academic Storage	0.09/student	16				0.09*400 = 36
Storage Rm (2nd floor)		26		20		
Gymnasium Storage	30.7	17 (2)		31.5		
Chair Storage	12	9 (2)		16		
Stage Storage		10		5.5		
Mechanical & Electrical Areas						
Mechanical	0.54/student (min. 140)	191		150		0.54*400 = 216
Electrical		20		19		
Receiving		39		32		
Sprinkler		7		6.5		
LAN/Server Rm		5.5		6		
Custodian (2 - 1/flr)	0.15/student (min. 37)	4.7 - 6.7		8		0.15*400 = 60
Safety Rm		8		9		

Appendix D - Detailed Site Analysis Report

TOWN OF MILTON ECOSYSTEM REPORT

Originally submitted for:

ARCH 623 - Ecosystem Design for Urban Landscapes

Alexandra Hucik
Winter 2017



Figure A.1 - New residential development in Milton as part of Phase 3A of Boyne Survey Plan.

TOWN OF MILTON ECOSYSTEM REPORT OVERVIEW

The Greater Golden Horseshoe, located in southern Ontario, is the fastest growing region in Canada today. Within this rapidly expanding region is the Town of Milton, which is the fastest growing municipality in Canada. Since 2001, the town's population has more than doubled going from 31,495 residents in 2001 to a population of 110,128 in 2016, and it is expected to only continue increasing. But being the fastest growing community in Canada comes with its problems. These challenges are related to providing the necessary housing, services and infrastructure to support an ever-increasing population.

However, Milton isn't only known for always growing. Overlooking the town are the cliffs of the Niagara Escarpment, a unique geological feature that dominates the skyline of the town. Within the escarpment are several large conservation areas that "are an oasis of unspoiled wilderness and open green space."[1] Associated with these lands is a green network of forests, wetlands, rivers and valleys that support a diverse range of plants and animals extending into the urban areas of the town.

In order to accommodate the growth Milton has been expanding their urban center by converting agricultural lands in the southern half of the town into new subdivisions. Not only is this threatening the availability of some of the most fertile farmland in the future, but also the health and diversity within the ecological communities located in these areas. While focusing on creating good communities, increasing business and commercial opportunities within residential areas, and trying to meet the densification rates set out by the Province, it can be easy for the Town the overlook the important role green spaces and its watersheds and play in the well-being of people.

The goal of this report is to begin to understand the complexities of the ecosystem within which the town's growth and development is happening. The aim is to recognize the land development patterns of the town of Milton and Halton region, and understand their impact on the existing natural ecosystem of the 16 Mile Creek watershed.

The first part of the report, the abiotic and biotic factors mapping analysis takes an inventory of the existing state of the ecosystem. The second section explores the land use and town's identity in both the past and present, as well as hinting at the future, through a series of "Cultural" maps. The third section briefly looks at how the flow of energy within the ecosystem is impacted by urbanization. The fourth section explains the complicated process of land use planning and development, which actors are currently governing the process, followed by a suggestion of actors who could have a greater role on the development of land use plans. The last section begins to explore strategies that could be implemented for the design of a more resilient natural ecosystem in an area undergoing urbanization.

HOLARCHY

Greater Golden Horseshoe > Greater Toronto Area > Halton > Milton

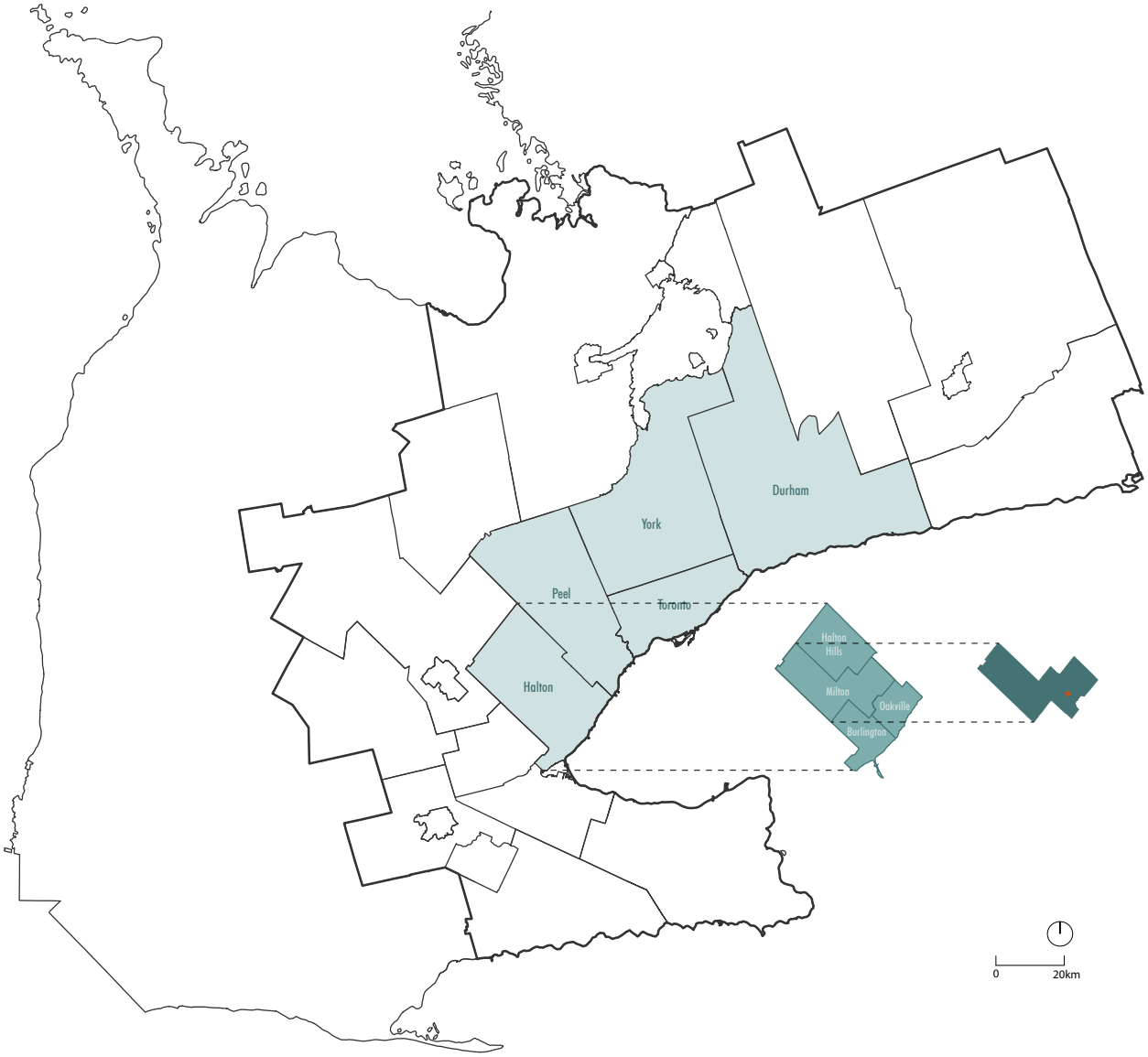


Figure A.2 - Hierarchical Boundary Map of Greater Toronto Area.

ABIOTIC:

Watersheds

Watersheds are drainage areas that catch and carry water into other bodies of waters such as lakes, ponds and wetlands, or absorb it as groundwater. The watersheds in Halton drain into Lake Ontario. The Halton watersheds "cover an area of 1,059 square kilometres"[2] and are managed by Conservation Halton. The main watersheds in this region are the 16 Mile Creek, Bronte Creek, and the Grindstone Creek. The watersheds are important to the health of the community and ecosystem as they provide a source of clean drinking water, help with flood management, enable the productivity of the soil, and provide a habitat for flora and fauna.

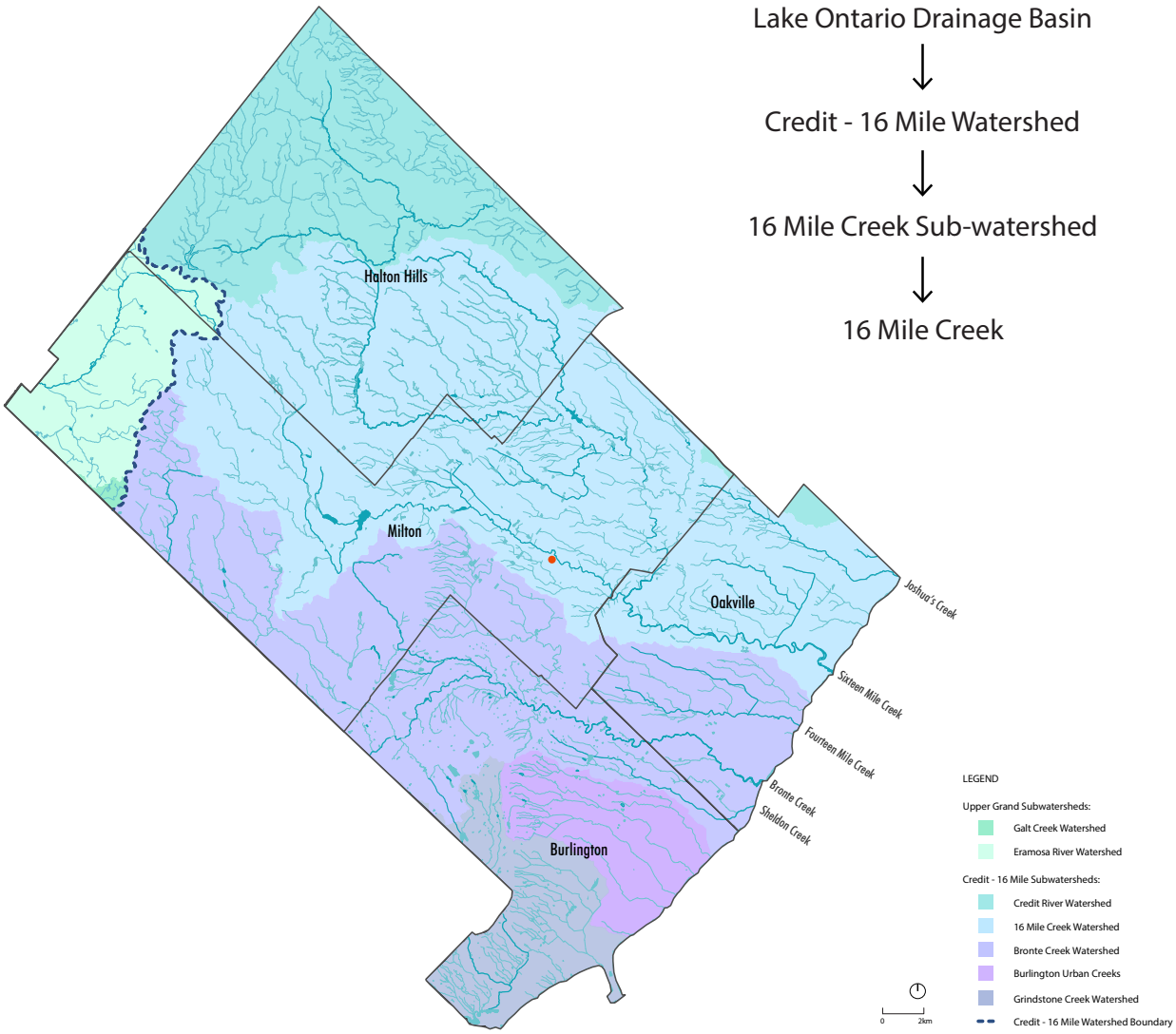


Figure A.3 - Watersheds, Halton Region.

ABIOTIC:

Ontario Greenbelt Plan

The Greenbelt Act was initiated in 2003 and passed on June 24, 2004 to protect farmlands, wetlands, watersheds and forests in the Golden Horseshoe. The Greenbelt Act protects these lands from development and helps manage the effects of urban sprawl on these lands. The Act protects unique ecological areas such as the Niagara Escarpment, and protects agricultural areas from being re-zoned.

The Niagara Escarpment Planning and Development Act originated from the public concern over the future of the Niagara Escarpment. Due to quarrying of minerals, the escarpment was damaged and its future was in jeopardy. Thus, in 1973 the Niagara Escarpment Planning and Development Act was developed. It was approved in 1985. The Act calls for continued maintenance of the Escarpment and ensures a balance between preservation and development.

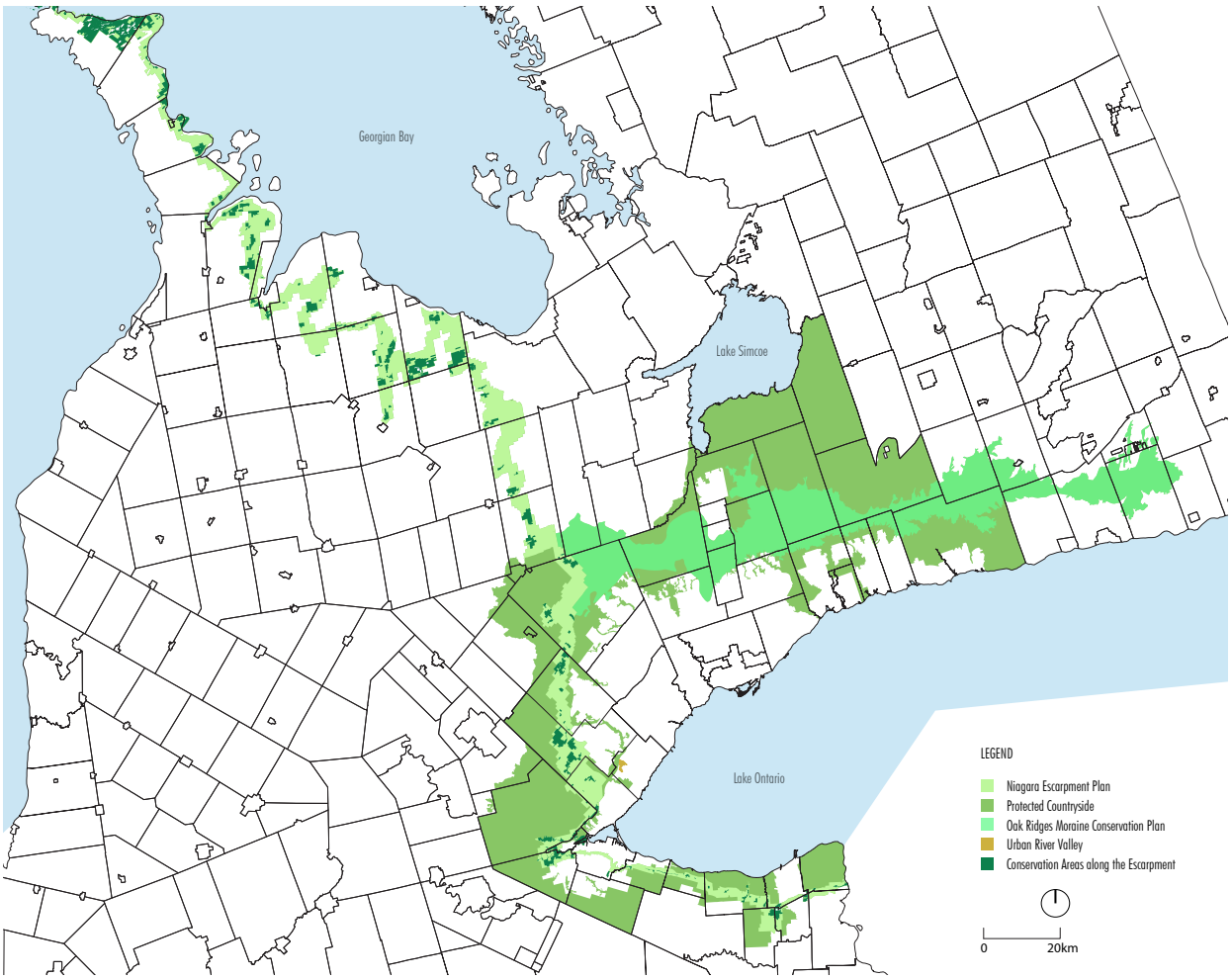


Figure A.4 - Boundary Map of Ontario Greenbelt Plan.

ABIOTIC:

Land Contours - Halton

The Niagara Escarpment is the source of the 16 Mile Creek and its tributaries. There are three major drops in elevations: at Lake Ontario, at a point "north of Queen Elizabeth Way"[3] and steep cliffs of the Niagara Escarpment The topography of the Escarpment landform limits the extent of urban development as it's height make construction difficult.

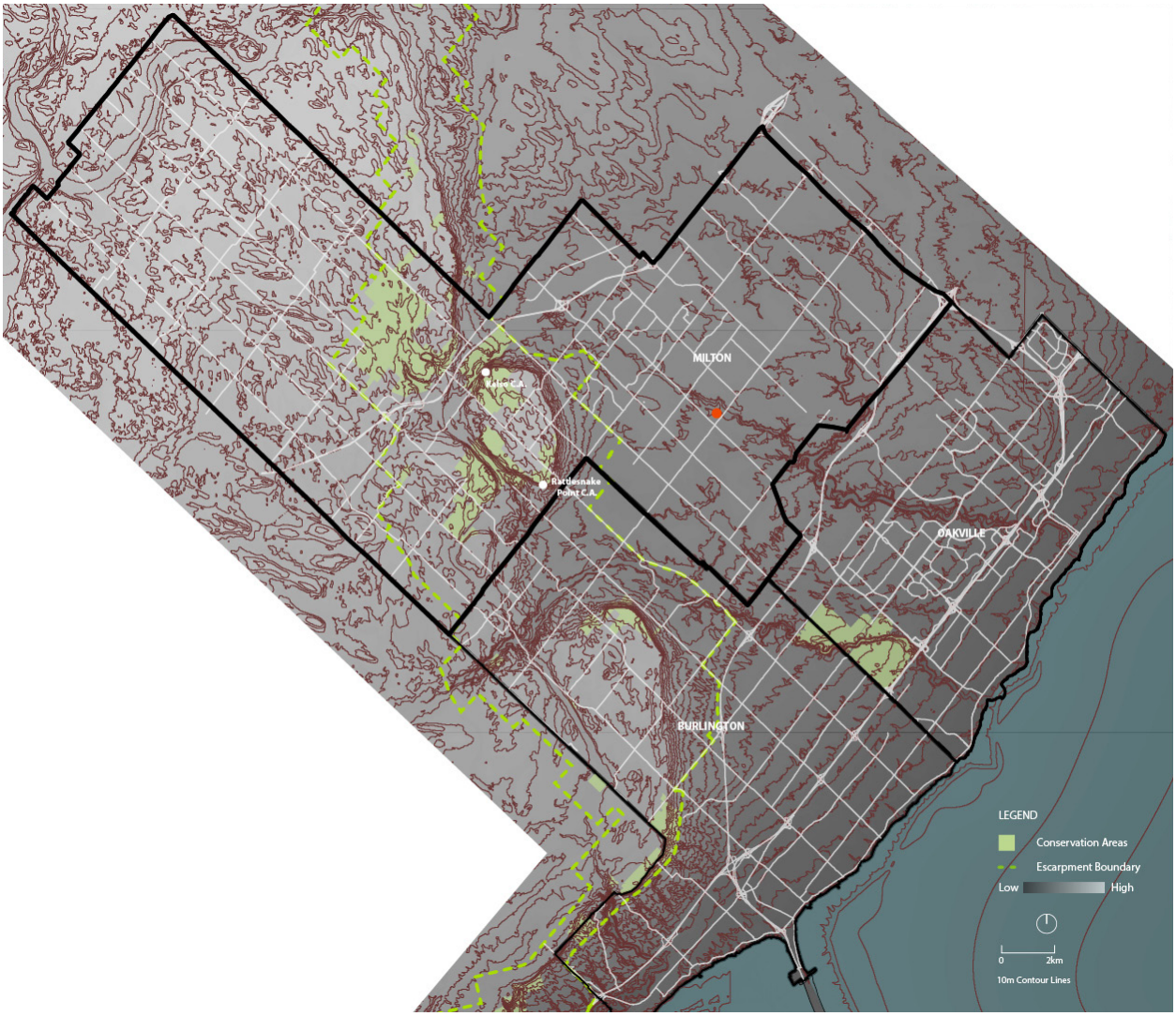


Figure A.5 - Land Contour Plan of Halton Region.

ABIOTIC:

Physiography - Halton

The movement of glaciers across the land shaped the landscape of the Halton region. The Niagara Escarpment was created about 450 million years ago at a time when a tropical sea covered Ontario. Over a period millions of years sediments were gathered and compressed into the layers of rock that make up the Escarpment today.

The areas above the escarpment was created later through glacial movement that deposited sand and gravel to form what is known as a till - the Halton Till.
The area below the Escarpment has a underlying shale formation and its surface is of a soft clay soil that is easily eroded and the reason for the formation of the deep river valleys present in that part of the region.

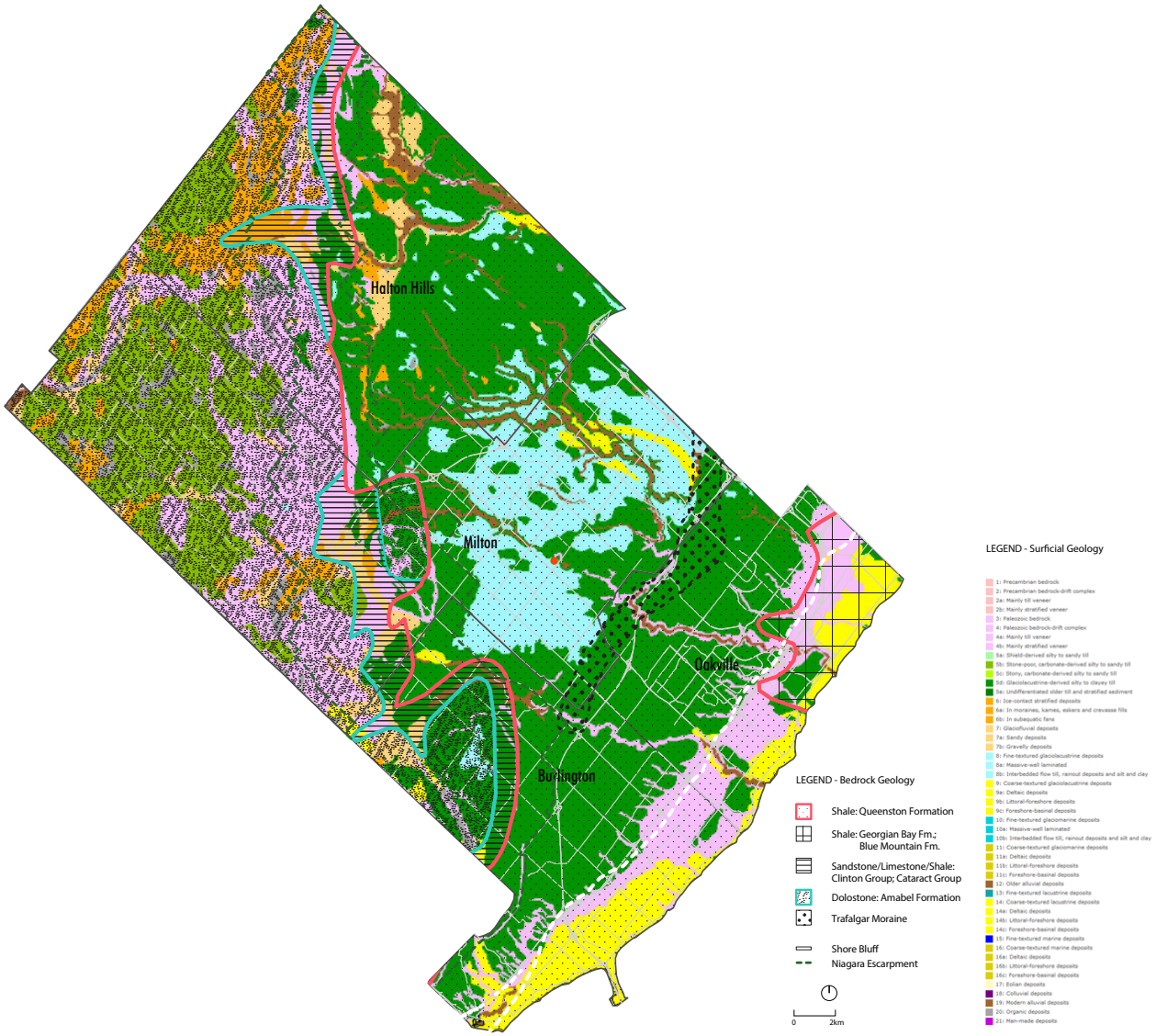


Figure A.6 - Physiography, Halton Region.

ABIOTIC:

Physiography - 16 Mile Creek

The valleys of the 16 Mile Creek sit on a underlying rock formation known as the Queenstone Shale. The material into which a watercourse forms a channel is important as this controls the form and sediment flow. Queenston Shale is composed of compressed layers "clay and silt sediment"[4] that form a reddish shale rock that is brittle and easily eroded. Due to the properties of this base material, the valleys of the 16 Mile Creek in many areas form a steep ravine, as glacial activity has eroded away the material. In many spots the face of the valley is eroded to such a degree that the red shale is exposed. The 16 Mile Creek was not directly farmed because of the steepness of the slopes and instability of the shale faces. The delicate properties of the bedrock geology has helped protect the valley, and so it is not deforested to the extent as its surroundings lands are. The profile of the 16 mile creek valley changes at different points between the journey from the creek's source in the Niagara Escarpment to the where joins into Lake Ontario at its mouth.

Mouth of 16 Mile Creek, Oakville Harbour



Figure A.7a - Aerial photograph of the mouth of the 16 Mile Creek at Oakville Harbour.

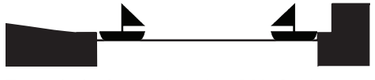


Figure A.7b - Section through 16 Mile Creek at Oakville Harbour.

Eroded Queenston Shale in 16 Mile Creek Valley, Lions Gate Park in Oakville



Figure A.8a - Aerial photograph of the 16 Mile Creek running through Lions Gate Park.

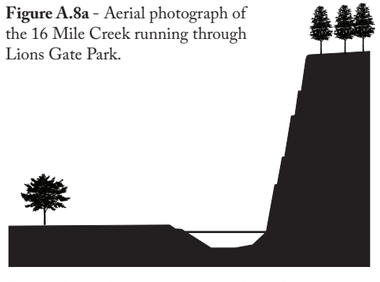


Figure A.8b - Section through 16 Mile Creek through segment with Queenston Shale cliffs.

Shallower Creek Valley Boyne Site, Milton



Figure A.9a - Photograph of the 16 Mile Creek at the Boyne Survey lands in Milton.



Figure A.9b - Section through 16 Mile Creek at the Boyne Survey lands in Milton.

Channelized Creek Milton Urban Area



Figure A.10a - Photograph of the channelized portion of the 16 Mile Creek.



Figure A.10b - Section through the channelized portion of the 16 Mile Creek.

Up in the Escarpment/Near the Creek Source Hilton Falls, Milton



Figure A.11a - Photograph of the 16 Mile Creek near the source up in the Escarpment.

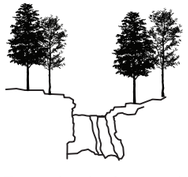


Figure A.11b - Section of the 16 Mile Creek up in the Escarpment.

ABIOTIC:

Soil Type - Halton

Majority of the soil in the Halton region (that is the areas below the Niagara Escarpment) are clay loam. Loamy soils which are a mix of clay, silt and sand, are the ideal soil type for farming because of their high nutrient content and soil retention ability. This region was primarily an agricultural community in the past two centuries because of the fertility of its soil. However the best areas for farming in the region are very rapidly being developed and built over today as the government population and density goals conflict with the interests of the agricultural community.

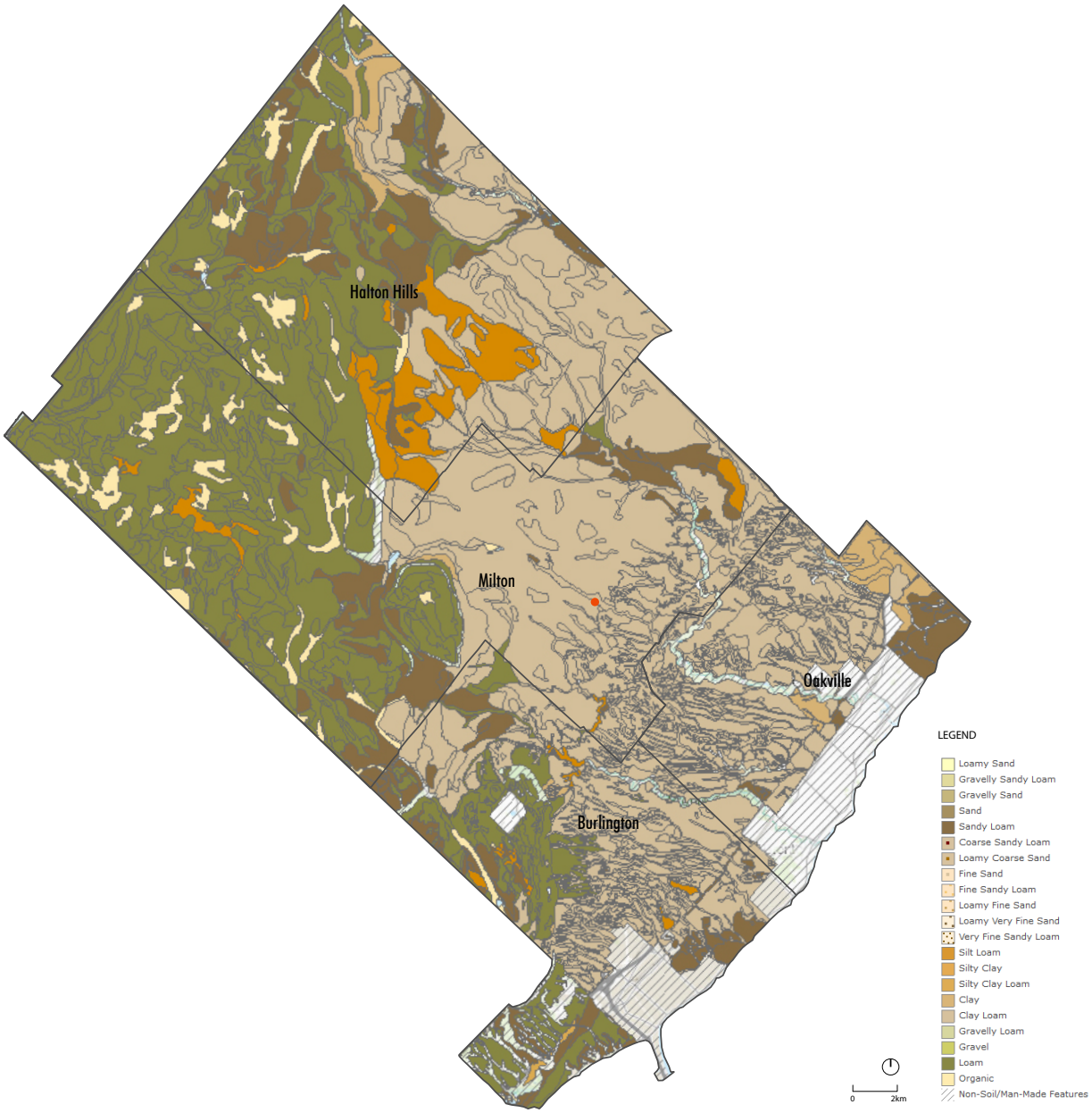


Figure A.12 - Soil Types, Halton Region.

BIOTIC:

Natural Areas - Halton

Halton Region's extensive natural area system is made up of a diverse range of ecosystems which include forests, wetlands, river valleys and the escarpment. Many of these areas are regulated by Conservation Halton who "works to protect, restore and manage (these) natural resources."[5] These natural areas support many plant and animal species, and provide many ecosystem services and health benefits to the human community. Preservation of these spaces is important, especially as rapid development and urban sprawl threatens the health of these ecological communities.



Figure A.13 - Natural Area System, Halton Region.

BIOTIC:

Forest Regions - GTA

The Carolinian Life Zone is a region located in southern Ontario (and in parts of the US). The Carolinian Life Zone is a unique ecosystem which supports a diverse range of flora and fauna, and consists primarily of deciduous trees. In fact, this region contains a greatest number of distinct species than any other region in Canada. The northernmost point of the Carolinian Life Zone is located in the town of Milton.

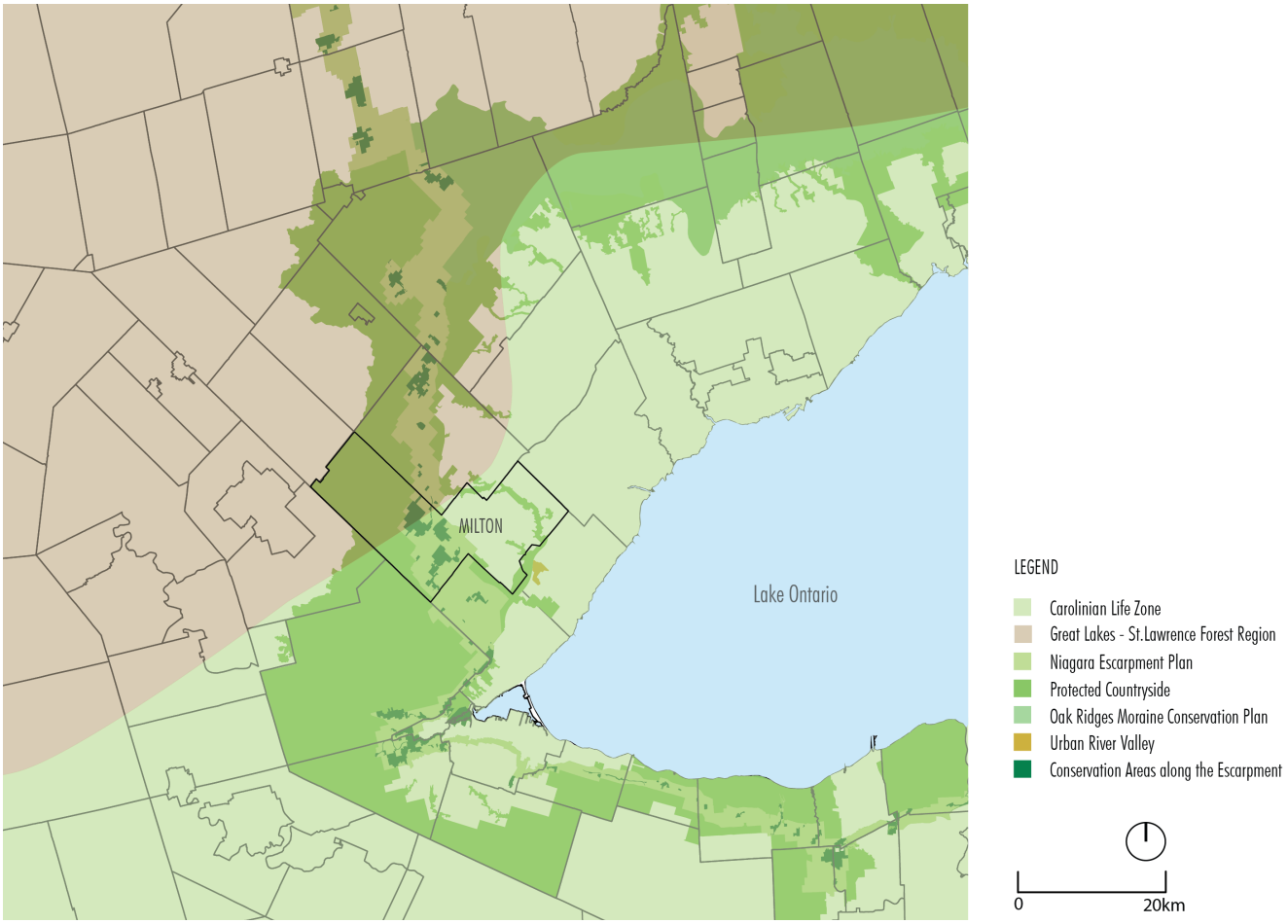


Figure A.14 - Forest Region Boundaries, Greater Toronto Area.

BIOTIC:

Animal and Plant Species - Milton

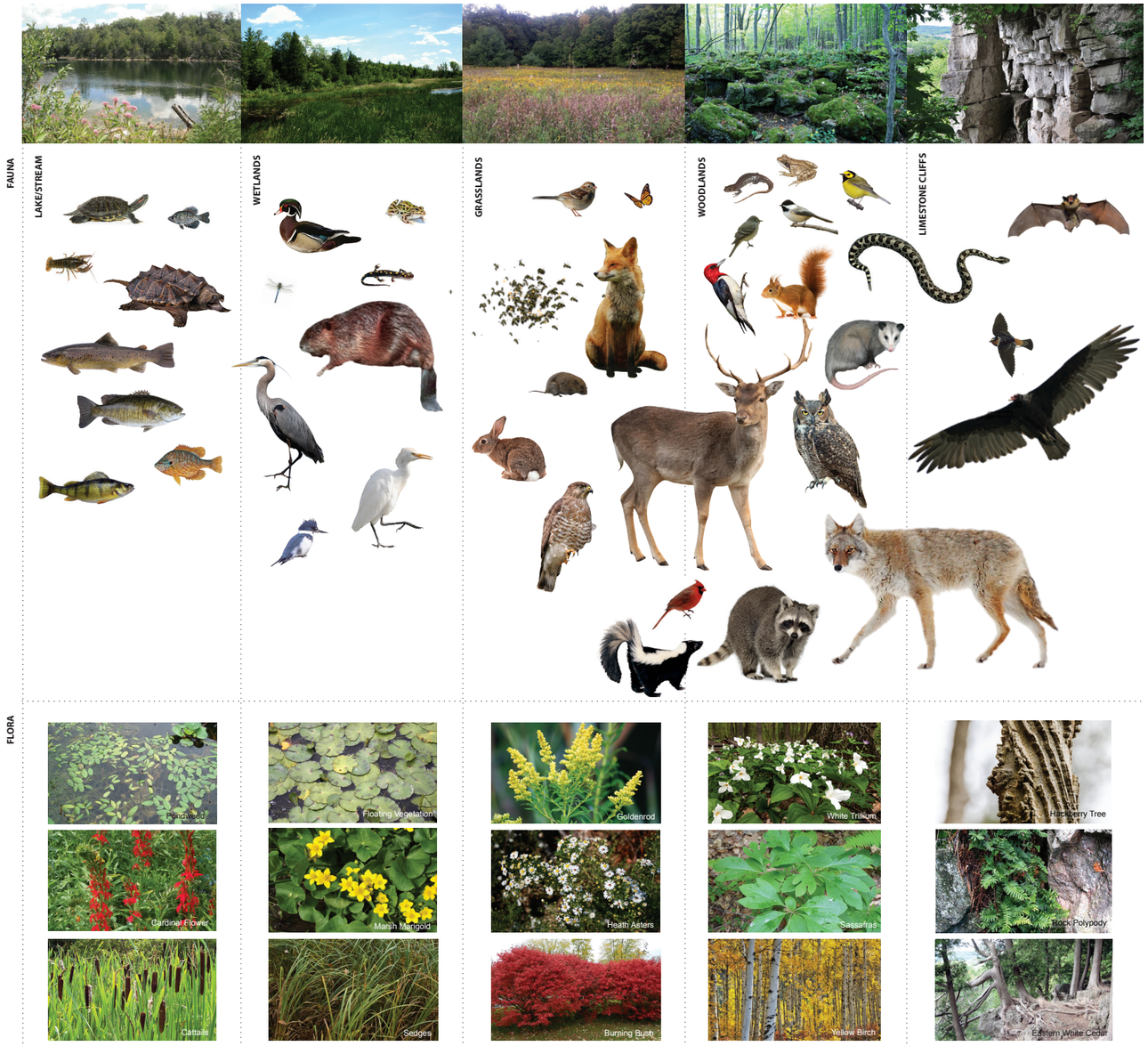


Figure A.15 - Animal and Plant Species by Ecosystem, Milton.

Animal Species in Milton

Birds:

- Turkey Vulture
- Acadian Flycatcher
- Belted Kingfisher
- Blue Heron
- Cooper's Hawk
- Red Cardinal
- Blue Jay
- Common Crow
- Screech Owl
- Chickadee
- American Robin
- Wood Thrush
- Red-headed Woodpecker
- Cedar Waxwing
- Cliff Swallow
- Field Sparrow
- Hooded Warbler
- Wood Duck

Fish:

- Rainbow Trout
- Brook Trout
- Brown Trout
- Panfish
- Smallmouth Bass
- Largemouth Bass
- Black Crappie
- Yellow perch
- Pumpkin seed
- Creek Chub
- White Sucker
- Chinook Salmon

Mammals:

- Virginia Opossum
- Little Brown Bat
- Meadow Jumping Mouse
- Red Fox
- Coyote
- Rabbit
- Woodland Vole
- Water Shrew
- Porcupine
- Eastern Chipmunk
- Gray Squirrel
- Red Squirrel
- Beavers
- Raccoon
- Striped Skunk
- White-tailed Deer

Reptiles/Amphibians:

- Northern Water Snake
- Smooth Green Snake
- Eastern Garter Snake
- Northern Ringneck Snake
- Snapping Turtle
- Midland Painted Turtle
- American Bullfrog
- American Toad
- Northern Leopard Frog
- Jefferson Salamander

Plant Species in Milton

Trees:

- White Pine
- Red Pine
- White Spruce
- Eastern White Cedar
- American Basswood
- Black Cherry
- Hickory
- Red Oak
- Sugar Maple
- White Ash
- Yellow Birch
- Hackberry
- Shagbark Hickory
- Black Walnut
- Sycamore
- Sassafras

Plants:

- Cardinal Flower
- Marsh Marigold
- Long-stalked Sedge
- Goldenrod
- Heath Asters
- Burning Bush
- Common Evening Primrose
- Wild Geranium
- Black-eyed Susan
- Wild Columbine
- Wild Leek
- Violet
- Early Meadow Rue
- Trefoil

BIOTIC:

Urban Forest - Milton

The urban forest is a term used to describe all of the trees within an urban area that create a city's green infrastructure network. The Town of Milton's urban forest consists of all of the trees within the urban zoning area which includes all street trees, trees in parks and open spaces, and the urban woodlots. These trees not only provide shelter, they make the city a healthier and more beautiful place through the ecosystem services they provide. The growth of the town in population and building development will in future years threaten the existing urban forest by putting pressures on them such as disease, land use changes and competing invasive species. Developers are required to plant new trees in the new subdivisions. In 2009 the Town of Milton took an inventory of all the Urban Trees and "estimated that the street tree population in Milton is approximately 18,729 trees."[6] About 65% of these trees are maple and ash.

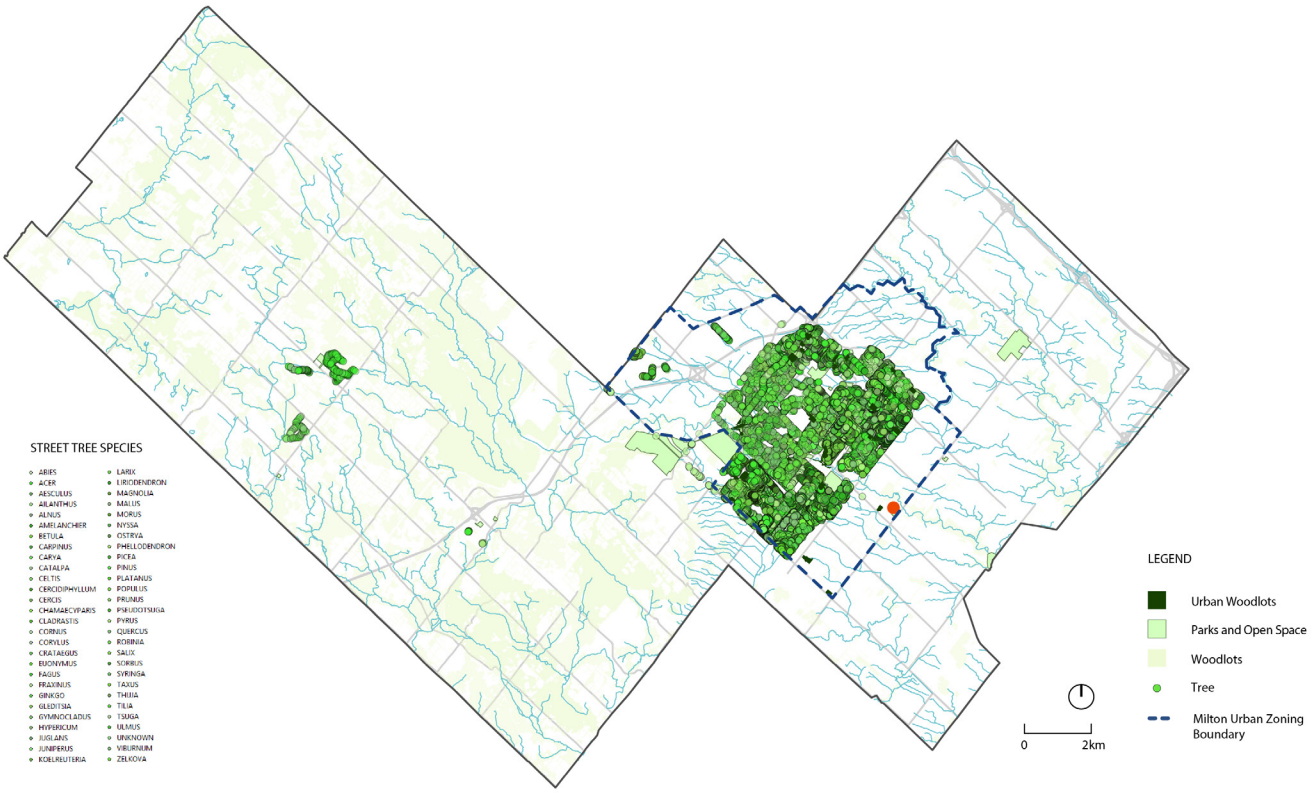


Figure A.16 - Urban Forest Extent, Milton.

BIOTIC:

Reported Coyote Sightings - Milton

In recent years there has been a increase of coyote sightings in Halton's urban areas. The map below locates some of the more recent reported coyote sightings in Milton in the past year or two. Coyotes have always been a part of the ecosystem, so it's not necessarily that their population numbers are growing. Human-coyote conflicts have increased because of urbanization. The new construction reduces the coyotes habitats, fragmenting them into smaller patches. Smaller patches contain less biodiversity and so the coyotes have a harder time hunting in these fragmented habitats. They move into urban areas because humans provide them with food sources (garbage,etc.). Over time they become accustomed to humans, and show less fear around them, thus the increase in human-coyote encounters.

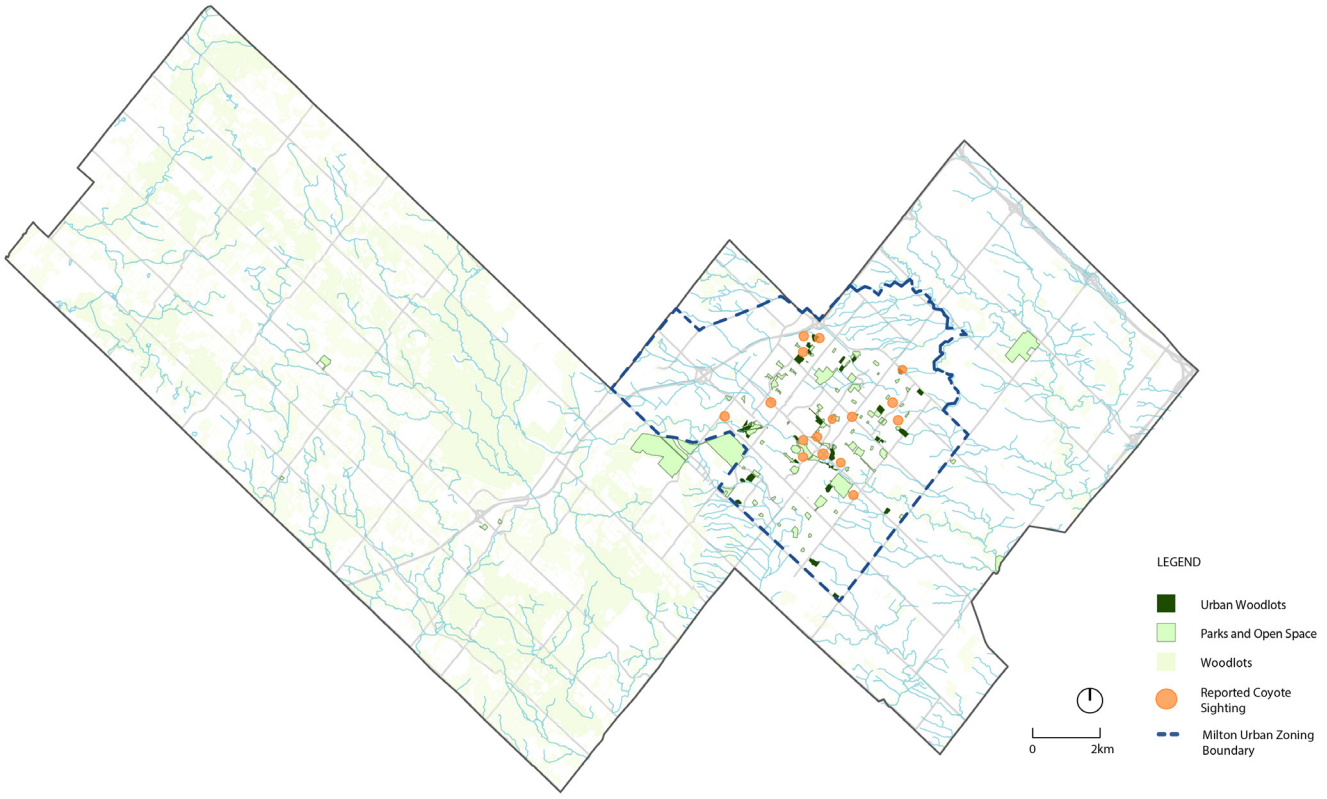


Figure A.17 - Reported coyote sightings in Milton's Urban Zone from 2016-2017.

CULTURAL:

Development Timeline - Halton

A: Pre-Colombian Era

During the Pre-Colombian Era the Halton region consisted of rich forests, abundant with pine, oak and maple trees. From 700AD to around 1650 AD, the Halton region was inhabited by Iroquoian tribes. The Iroquoians built settlements and farmed corns, beans and squash.

Early Contact Period (1610 - 1700)
Europeans started arriving to Southern Ontario in the early 1600s. Around this time the Iroquoian inhabitants were dispersed to the New York state, and were replaced by the Ojibwa, who became the Mississaugas'. The Mississauga people did not farm, but had a hunter gatherer lifestyle. They frequented the Sixteen Mile Creek, using it for fishing, hunting, transportation and shelter.

B: Settlers (1800 - 1849)

1800s - European settlement in Halton was allowed to occur after 1805, when the Mississauga people surrendered their land between Burlington Bay and the Etobicoke River. However, they retained some land at the mouths of the Sixteen Mile Creek, Twelve Mile Creek and Credit River for fishing and hunting. Surveys and land claims followed immediately.

1816 - Halton County was created.

1820 - The Mississaugas' retained land was handed over to the Crown during this time.

1821-1822 – Jasper and Sarah Martin arrived to the Milton area, and settled to what now is Martin Street and the Mill Pond. The Martin's establish a grist mill at the area that will become Milton. The mill is powered by the Sixteen Mile Creek. The establishment of the mill attracts settlers to this area.

1827- William Chisholm bought the reserve lands around the Sixteen Mile Creek launching the town of Oakville . He establishes Oakville Harbor, which becomes an important shipping hub and plays a part in Halton's economic growth.



Figure A.18 - Martin's Grist Mill, Milton, ON.



Figure A.19 - (left) The Oakville Harbour.

1820-1849 – Forests are cut down and the trees are harvested for lumber. Forests are cleared for farmland. Gristmills and sawmills are created alongside the Sixteen Mile Creek, using the water to power the mills. Villages developed around the mills, becoming bigger and more established. Settlers first produced potash and made maple syrup. After land was cleared crops such as wheat were grown.

C: Agriculture/Industry (1850 - 1944)

1850-1944 – During this period agriculture and lumber supplied raw materials for markets. Industries such as wood, lime-mortar, papermaking and clay extraction start to develop. The Niagara Escarpment is quarried for sand, gravel and limestone and clay.



Figure A.20 - Lime Plant on the Escarpment.

1853 - Milton became the county town for the Halton County.

1870 - Oakville Harbour's use as a shipping port declines.

1870-1944 – Railway development occurred in the late 1870s. The Canadian Pacific Railway and the Canadian National Railway build a line through Milton, ushering in new development. During this time waterworks, electricity and telephone systems are installed.

1908 - P.L Robertson Co. opens a socket headed screw production factory in Milton which leads to growth.

D: Development and Urbanization (1945 - Present)

1945-Present – The Halton region expands and becomes more settled. New subdivisions are developed and schools and Milton's first hospital are built. An extension of Highway 401 from Toronto to Milton is built. Reforestation efforts begin.

1960 - Concern starts to grow for the Niagara escarpment, which was being damaged due to quarrying. In 1973, the Niagara Escarpment Planning and Development Act is made to protect the escarpment and to reduce development. It came into effect in 1985.

1999 - A water pipe is built, bringing freshwater from Lake Ontario to Milton. This allows new development and urban expansion of Milton. This is the start of the Bristol Survey - Phase I development.

1999-Present – Development and urbanization of Milton continues, as the population continues to increase rapidly.

E: Future

Milton will continue to grow with the Boyne Survey- Phase III development which will bring in 50,000 new residents. Additionally, industrial and commercial development, the opening of Laurier University – Milton campus, and the expansion of the CN railway will see Milton transform into a hub of urban growth.

CULTURAL:

Population - Milton

In 2016 Milton reached a population of 101, 715 residents representing a 34% increase in residents since 2011 (when the population was 84,362).[7] As one of the fastest growing cities in Canada, and Milton's current population "is expected to double in the next 15 years to 230,000."[8] Based on the statistics, Milton has a large number of young families. "0 to 4 years old" was the second largest age group in 2011. As these children reach school age there will be a need for new schools and day cares to accommodate this large group of children.

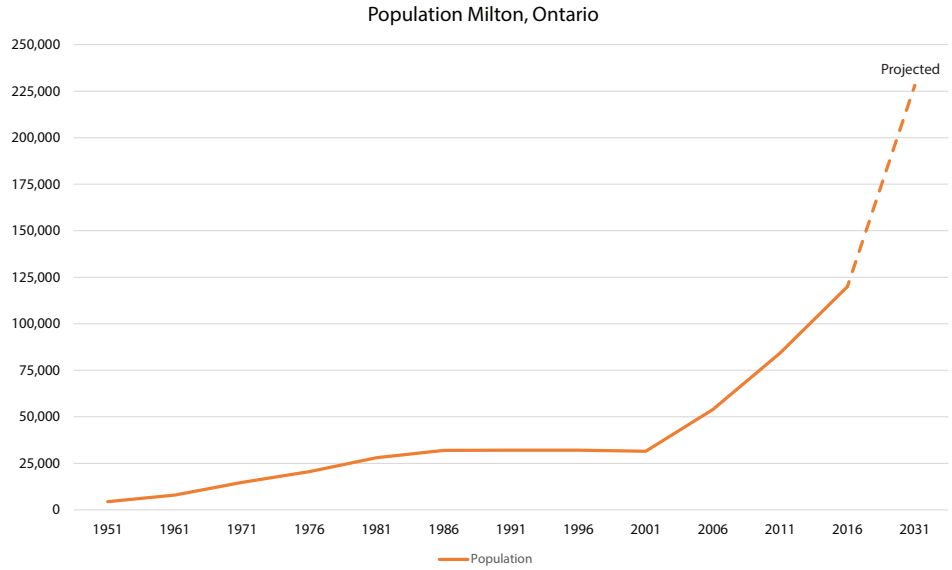


Figure A.21 - Graph is based on population data from the Halton Region and Statistics Canada.

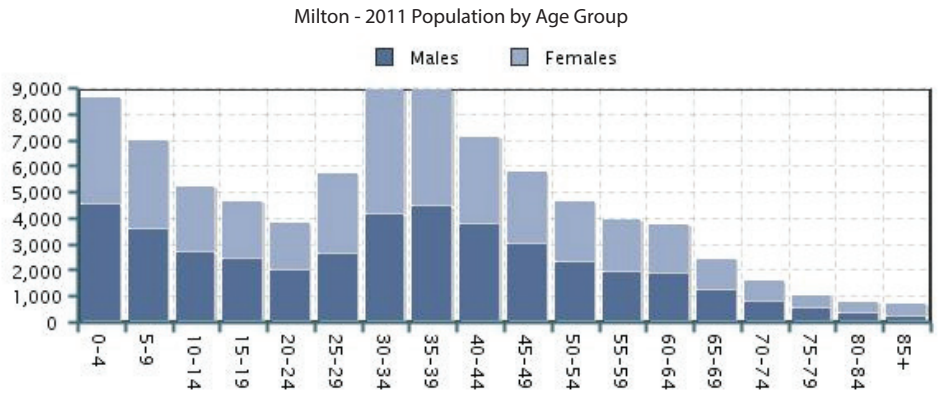


Figure A.22 - Graph of Milton's 2011 Population by Age Group.

CULTURAL:

Residents' Cultural, Economic, and Educational Background - Milton

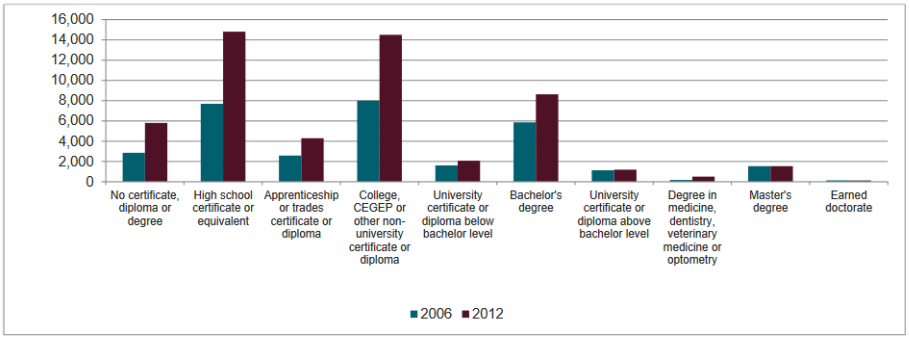
These diagrams were created as part of a Community Profile of Milton completed by Millier Dickinson Blais. An understanding of the town's residents' cultural and socioeconomic status can be drawn from them and can help inform the actions and decisions the town makes in planning and servicing the city in such a way that benefits the largest number of the population.

- The average household income in 2011 was $113,200, thus Milton could be considered a fairly affluent town.
- The total immigrant population increased in 2011 by 6%, which means roughly a third of the population in Milton are immigrants, which suggests the need for the town to offer cultural services.
- Majority of the work force has an education level equivalent to a highschool or college diploma. While the level of resident's with university degrees is rising, the number of highschool or college diploma's attained are rising at an even faster rate.
- Almost half of Milton's residents work outside the town, which means many are commuting to work on a daily basis. This suggests a need for an expansion of public transportation services to accommodate the flow of residents in and out of the town.

	Total (Households)	% Percent of Private Households	Accumulated % Of Private Households
Total	30,350		
Under $20,000	1,765	6%	6%
$20,000-$39,999	3,160	10%	16%
$40,000-$59,999	4,515	15%	31%
$60,000-$79,999	4,535	15%	46%
$80,000-$99,999	4,775	16%	62%
$100,000 to $124,999	5,920	20%	81%
$125,000 to $149,999	3,305	11%	92%
$150,000 and over	2,375	8%	100%
Average Household Income	$118,203		

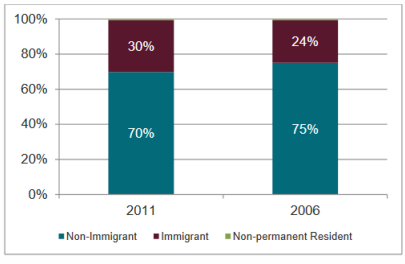
Source: Derived from and Manifold Data Mining (2012) by Millier Dickinson Blais Inc.

Figure A.23 - 2011 Household Income, Milton.



Source: Derived from Statistics Canada, Census of Population (2001, 2006) and Manifold Data Mining (2012) by Millier Dickinson Blais Inc.

Figure A.24 - Education Level of Labour Force, 2006-2012, Milton.



Source: Derived from Statistics Canada, Census of Population (2006), National Household Survey (2011) by Millier Dickinson Blais Inc.

Figure A.25 - Immigrant Population 2006 - 2011, Milton.

	2001	2006	2012
Total employed labour force 15 years and over	18,405	31,635	52,385
Usual place of work	15,500	26,310	43,101
In Milton	7,030	8,235	18,845
Outside of Milton	8,470	18,080	24,256
In Halton Region	2,020	3,325	5,003
At Home	1,495	2,440	4,294
Outside Canada	35	135	173
No fixed place of work	1,375	2,745	4,817

Source: Derived from Statistics Canada, Census of Population (2001, 2006) and Manifold Data Mining (2012) by Millier Dickinson Blais Inc.

Figure A.26 - Resident's Place of Work 2001-2011, Milton.

CULTURAL:

Population Density - Milton

Based on the data reflected in this map, the most dense areas (the darker shades) are within the urban zoning boundary and especially in the recently developed neighborhoods that are part of Bristol and Sherwood survey. This is most likely because the new neighbourhoods are being constructed more densely (generally narrower and taller townhouses) to accommodate the rapidly growing population. As is expected, the rural areas are less dense as parts of the land are used as farmland.

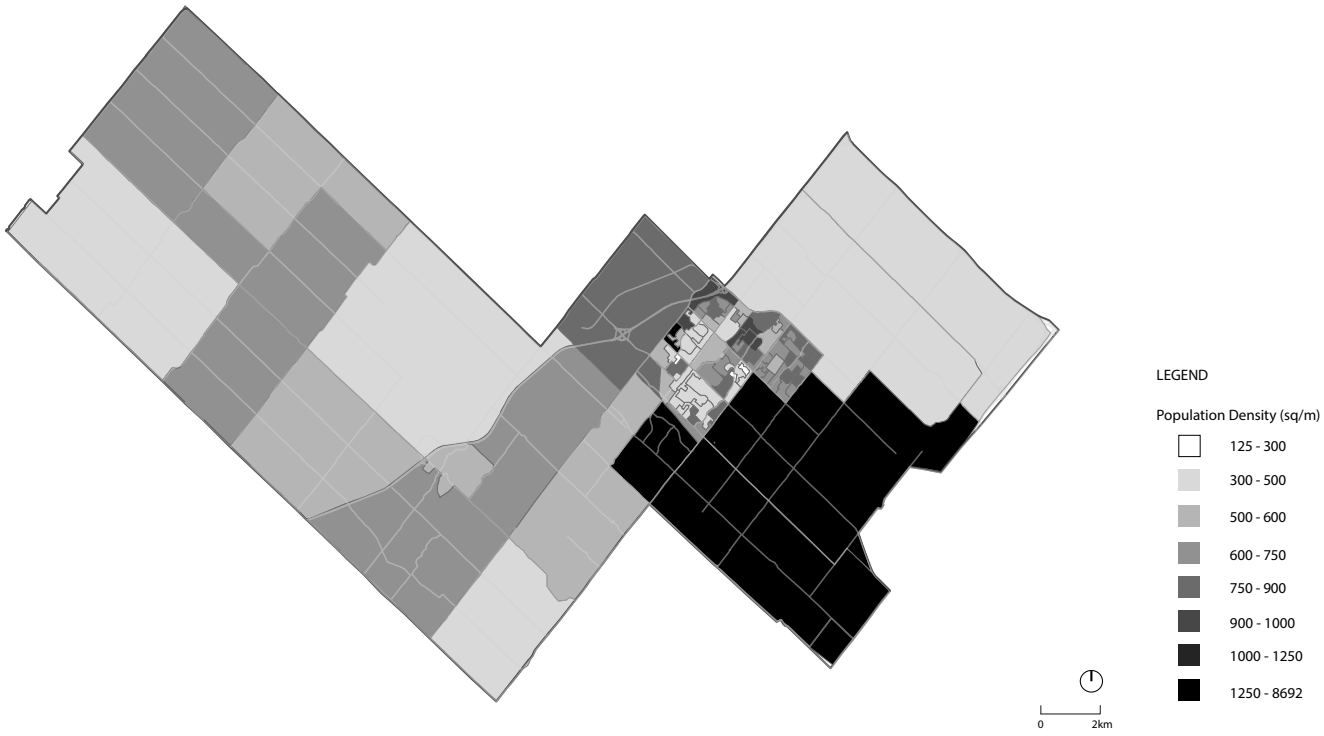


Figure A.27 - Population Density, Milton.

CULTURAL:

Median Age of Population - Milton

Based on the distribution of the population by age, it can be concluded that the young families settle in the new residential developments being built in the urban area. The newest residential subdivision are in the Bristol and Sherwood Survey which were both recently constructed as part of Residential Phase 1 and Phase 2, and as reflected by this data do indeed have the youngest residents living there. The more senior population lives in the rural zoned areas. This suggests that many of these resident's have families who have been living in Milton for more than 1 generation and still do (or once did) own the farmland in these areas. Based on this information the towns planners know in which areas to place the services that each age group requires.

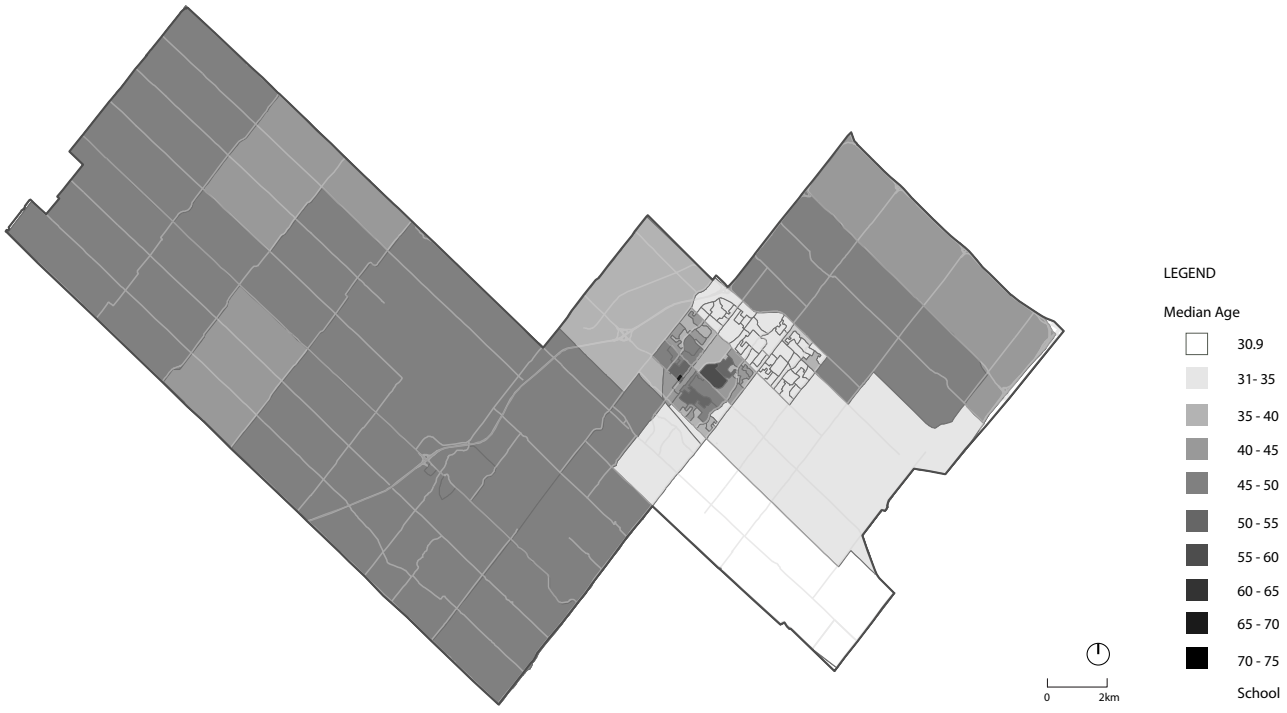


Figure A.28 - Median Age of Population by Neighbourhood, Milton.

CULTURAL:

Land Use (Zoning) - Milton

The function of zoning is to separate the areas with different land uses from each other. Zoning is also used by the municipality as planning tool to regulate construction, preserve the identity of an area or to guide future growth. The present land use zoning of Milton is represented in the map below. Most of the residential areas (orange) are grouped together and located in the town's urban area. Within this residential zoning is a small mix of institutional and commercial zoned area. The lands that are going to be developed next will be the current agricultural lands (yellow) in the south-east part of Milton as part of the Boyne Secondary Survey, which is designated as Phase 3 of residential development. The north-west half of Milton is still relatively rural, likely due to the barrier of the Niagara Escarpment which makes construction more difficult.

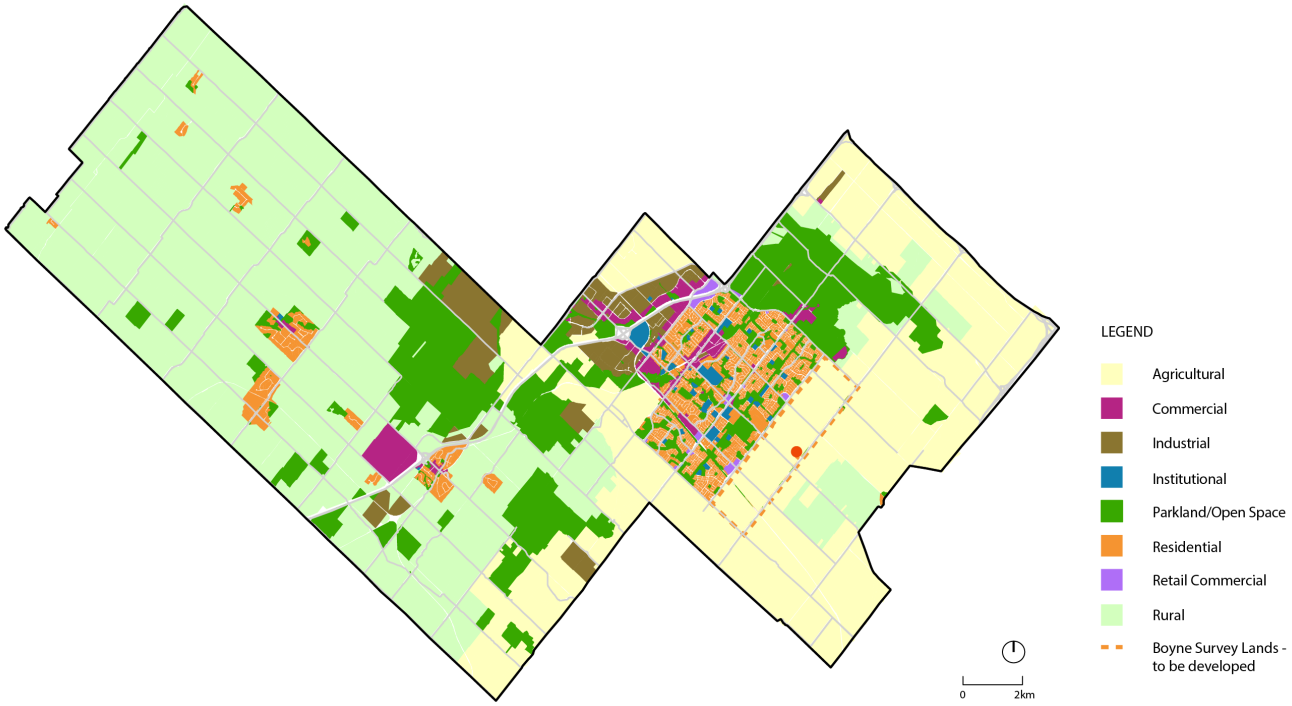


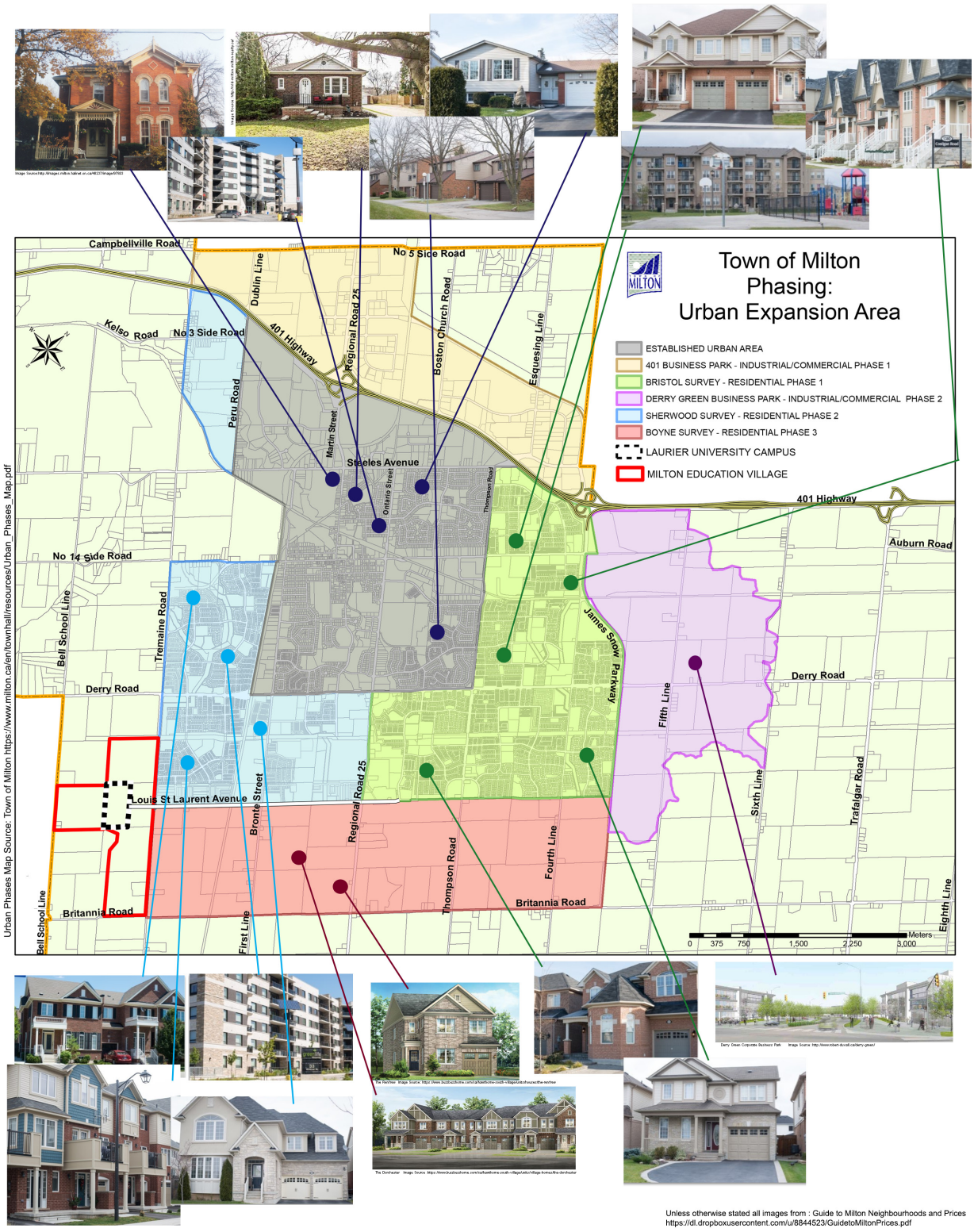
Figure A.29 - Land Use (Zoning), Milton.

Figure A.30 - (opposite page) Recent Urban Developments in Milton.

The most common building typology in Milton is the single-family house. The diagram on the opposite page illustrates the types of developments that are being constructed in the town's urban area, as well as the buildings that are being proposed for the residential subdivisions in the upcoming phases.

CULTURAL:

Urban Developments - Milton



Unless otherwise stated all images from : Guide to Milton Neighbourhoods and Prices https://dl.dropboxusercontent.com/u/8844523/GuidetoMiltonPrices.pdf

CULTURAL:

Boyne Survey Residential Phase 3 - Milton

The plans on the following page are Town of Milton documents which show the proposed redevelopment of the lands located within the Boyne Survey. Majority of the land will become residential, with node areas at the edges of the survey boundary and the intersections of the major streets. This plan on the top is from March 2013 while the plan at the bottom is a more detailed plan (as of 2015) of the first segment that will be of the Boyne survey. A new road has been proposed (the hot pink one in the plan) that would cut through the 16 Mile Creek corridor, disturbing the continuity of it and its adjacent greenlands impacting the ease of travel for wildlife along that corridor. It has been proposed that the smaller creeks that run vertically through the plan be channelized into straight corridors, in order to run parallel to the streets, which will make planning the new houses easier. The district park is located near the railway and is adjacent to two proposed new school locations. The same pattern has been proposed for the neighbourhood parks, in which they on either side of the park there is an elementary school.

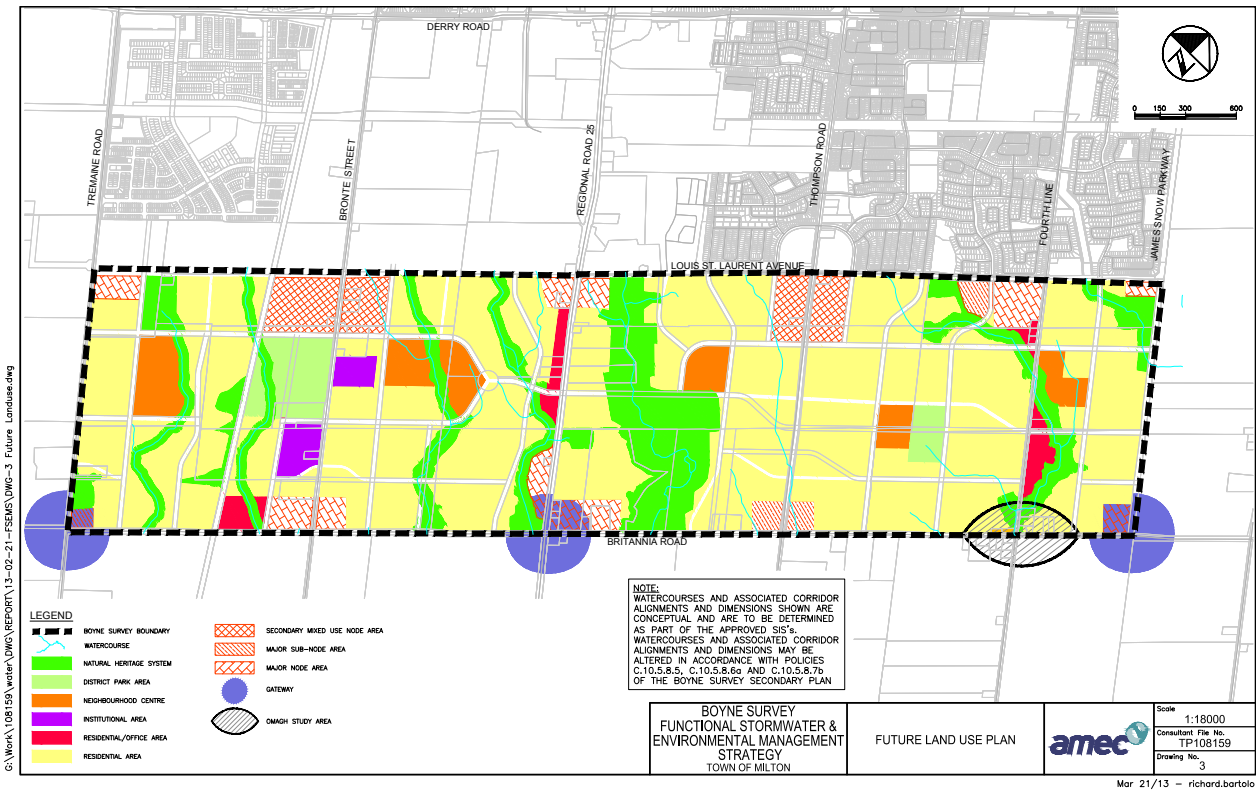


Figure A.31 - Proposed land use plan for the lands within the Boyne Survey.

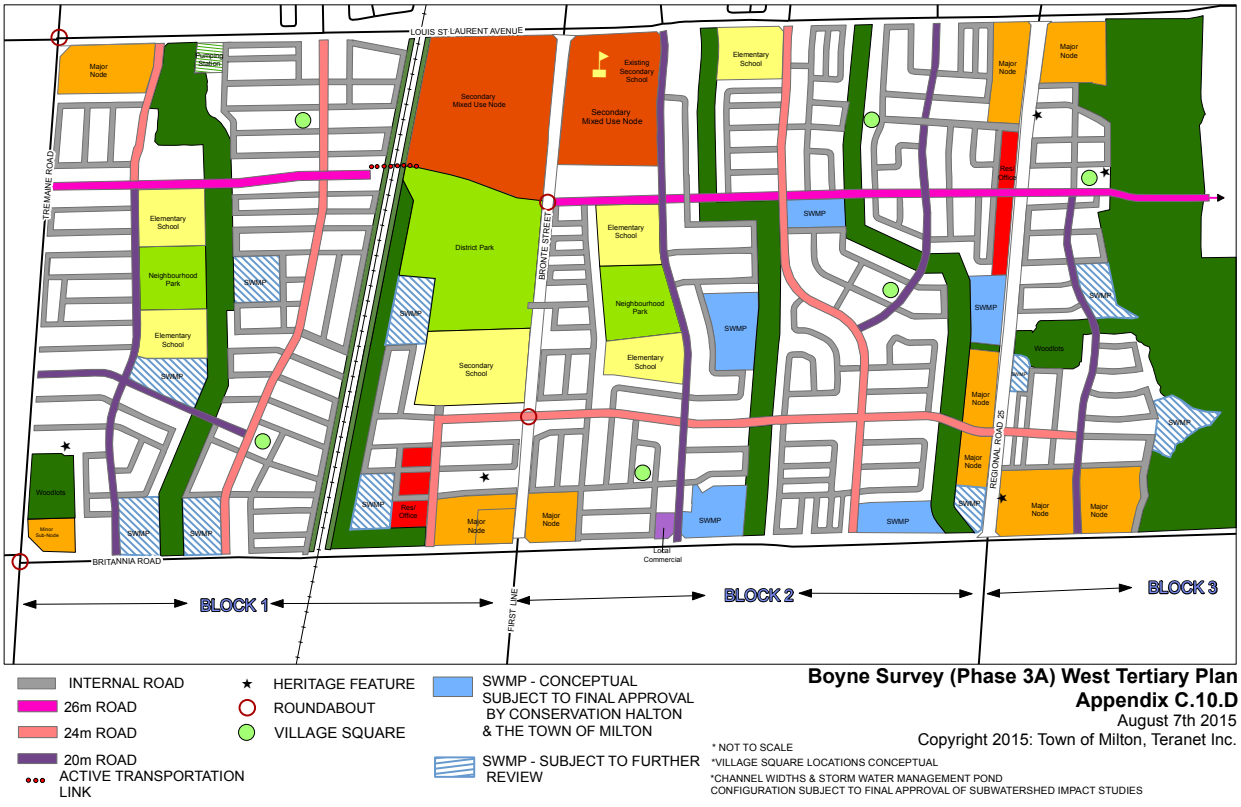
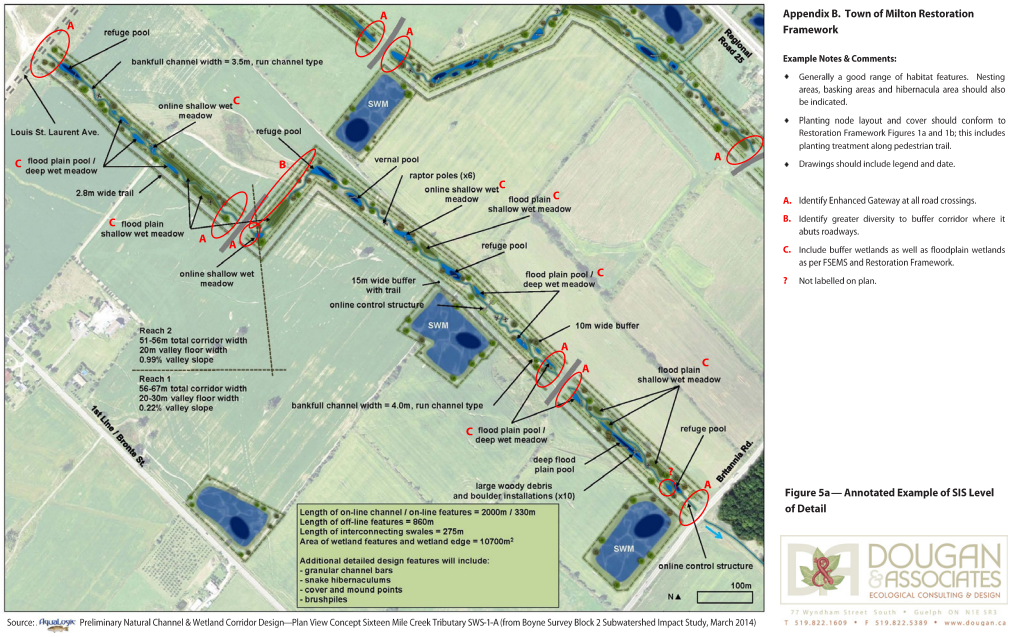


Figure A.32 - Proposed plan of Boyne Survey Phase 3A, showing a higher level of detail such as proposed roads, community nodes and parks.

CULTURAL:

Boyne Survey Residential Phase 3 - Milton

Channelization of Creeks



Source: Aquafor Beech Preliminary Natural Channel & Wetland Corridor Design—Plan View Concept Sixteen Mile Creek Tributary SWS-1-A (from Boyne Survey Block 2 Subwatershed Impact Study, March 2014)

Appendix B. Town of Milton Restoration Framework

Example Notes & Comments:

- Generally a good range of habitat features. Nesting areas, basking areas and hibernacula area should also be indicated.
- Planting node layout and cover should conform to Restoration Framework Figures 1a and 1b; this includes planting treatment along pedestrian trail.
- Drawings should include legend and date.

A. Identify Enhanced Gateway at all road crossings.

B. Identify greater diversity to buffer corridor where it abuts roadways.

C. Include buffer wetlands as well as floodplain wetlands as per FSEMS and Restoration Framework.

? Not labelled on plan.

Figure 5a— Annotated Example of SIS Level of Detail

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Figure A.33 - Detail plan of the typical conditions of the proposed channelized creek.

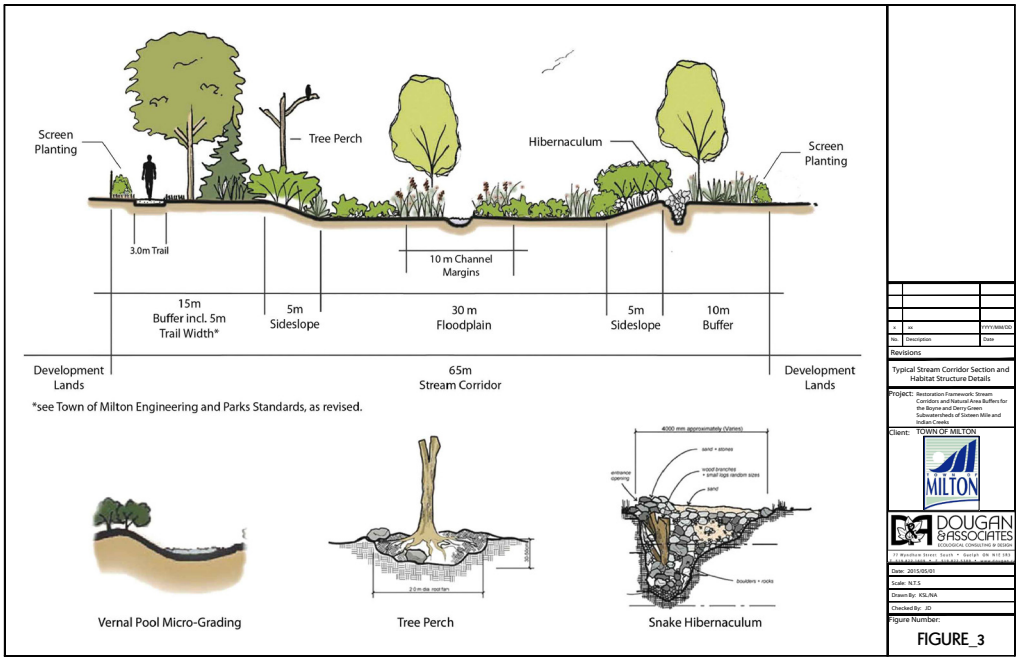


Figure A.34 - Section of the proposed channelized corridor once restored.

The two drawings on the opposite page are from a Town of Milton document of the design for the proposed channelization of 16 Mile Creek watershed corridor, and their subsequent ecological restoration. The restored creek would travel in wavy lines within the bounds of the straightened corridor. The plan includes a recreational trail that would run alongside the channel. Several habitat restoration strategies for animals are to be implemented such as trees perches, vernal pools, and small rock pits for hibernating reptiles.

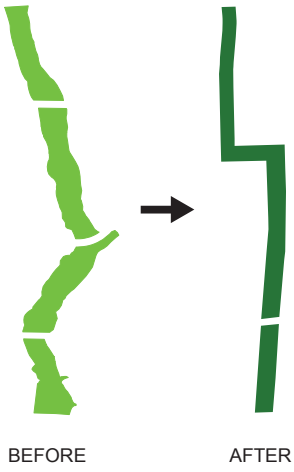


Figure A.35 - Changes in geometry of creek when it is channelized; from an organic curved geometry to straight and perpendicular.

The decision to channelize the minor creeks was most likely made to make the planning of the new townhouses in the new residential subdivisions easier. Having the creek run orthogonally rather than in its natural curvilinear path allows the new houses to be placed perpendicularly to the creek corridor and they can have straight and even lots. With the curving form of the creek in its natural state, planning the subdivision becomes more difficult because if the planners orient the lots perpendicularly to the creek edge each building would face a slightly different angle and there would be wasted space. In the other case if they align the building faces so that they form a straight street and disregard the direction of the creek corridor, there is also wasted space, or some lots have bigger backyards than others.

The channelized creek also gives the corridor a more "manicured" appearance. The creek is perceived by the public as cleaner and healthier, but it no longer looks natural.
Nor does it behave in the same way as a natural creek. Channelization can negatively impact the ecological health of a creek. When a creek is emptied, straightened and refilled, the resulting creek is one in which "all the complexities of a natural stream ecology have come to be homogenized."[9] The creek's natural curvilinear form created habitats for aquatic species within its bends and pools. The variety of habitats allows a diverse number of species to thrive in the creek. Without these natural complexities it is likely that the diversity of species inhabiting the creek will be reduced.

Often the channelization of a stream is done to help prevent flooding, but it sometimes it has the opposite effect by actually increasing the speed at which the water flows. By dredging the bottom of the stream, the stream bed becomes more uniform and smooth. The "natural irregularities"[10] of the bed of the watercourse are removed and so the sediments that used to create the friction that slowed down the water are no longer there.

CULTURAL:

Neighbourhood Connectivity - Milton

This map illustrates the various modes of public transit provided by the city. The public transportation and trails create a network for getting around the town and making the various public services accessible to people without a car. Most of the public services or points of interest are located in the urban area where the people travel to go to work or school. The public transit(city bus) routes only service the urban area including the industrial park in the north part of the urban area. Likewise, road bicycle lanes are only in the urban area, mainly on the west side. As the town grows and some of the agricultural areas are converted to residential zones, the transportation networks will be expanded into the rural zones. Until then though the residents living in the rural and agricultural areas are car-dependent.

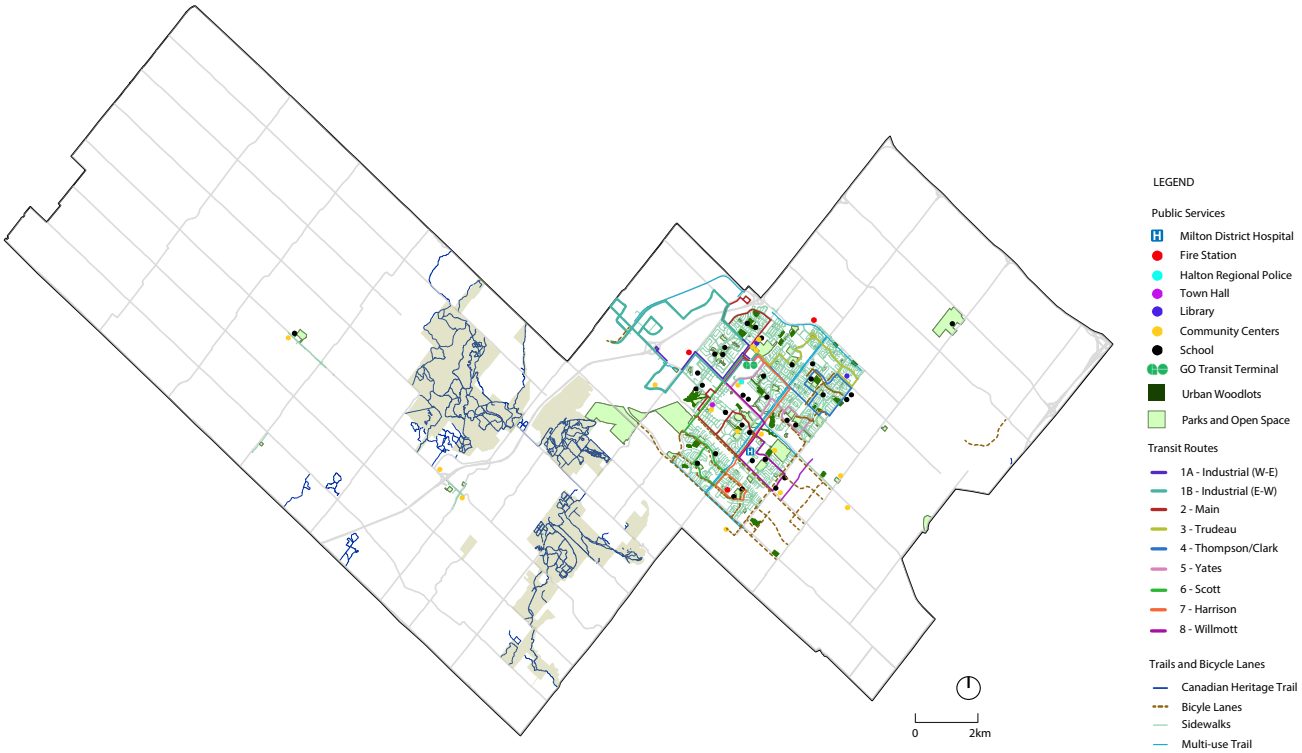


Figure A.36 - Public Transit and Public Services Map, Milton.

CULTURAL:

Transportation Networks - Halton

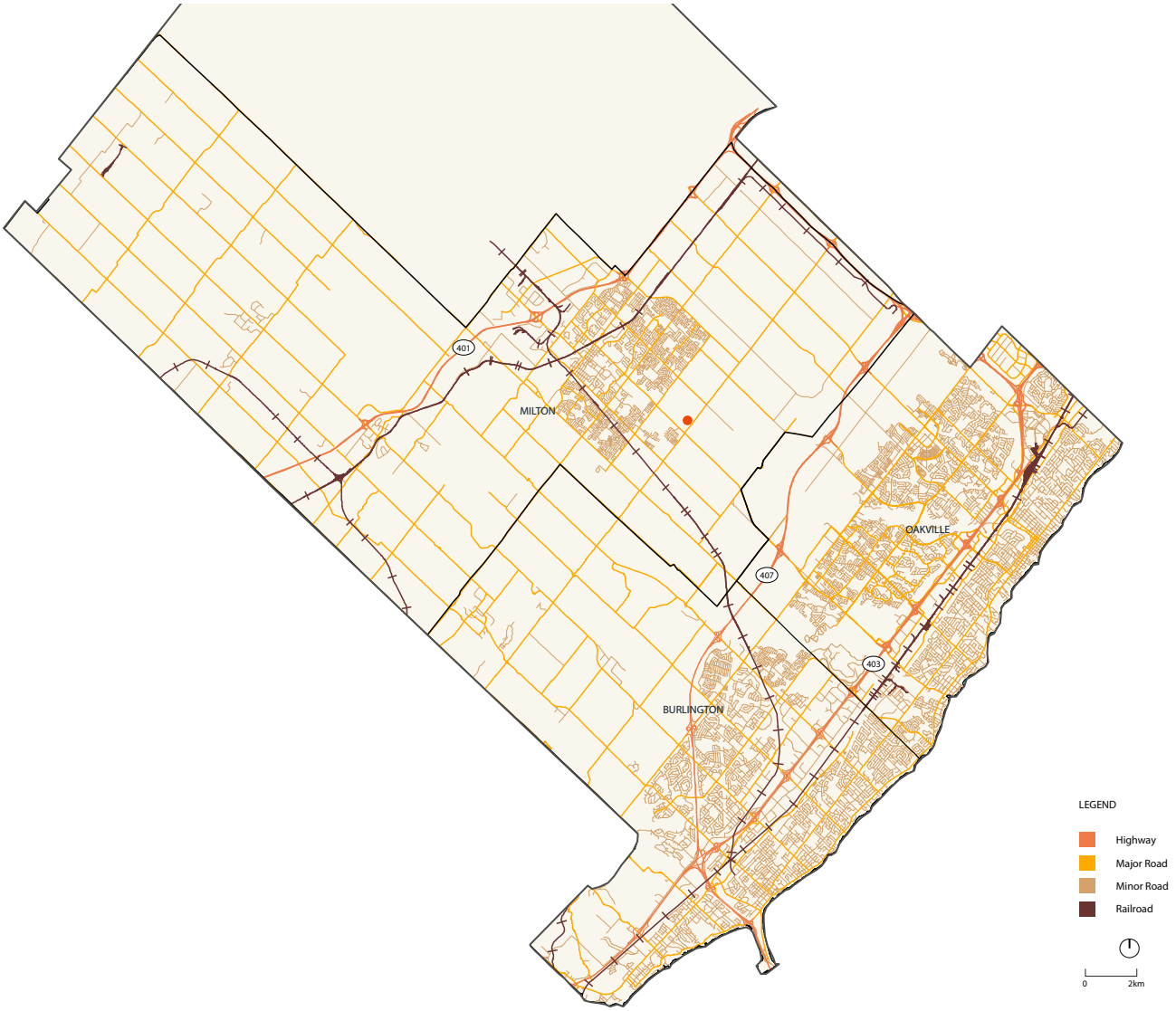


Figure A.37 - Transportation Networks, Halton Region.

CULTURAL:

Existing Farms and Agricultural Land Use - Halton

This map shows the location of farmland in the Halton Region. Agricultural land use is divided into 3 types depending on what kind of biotic material or service they sell. These 3 include: Produce Farms, Stables, and Greenhouses, Garden's and Nurseries. Most of the remaining farms are located in either an area with a rural or agricultural zoning, and thus concentrated on the outskirts of urban areas. Milton still has several operating produce farms, as well greenhouse/garden/nurseries. Meanwhile Oakville has no produce farms and only stables(horses) near its northern border.

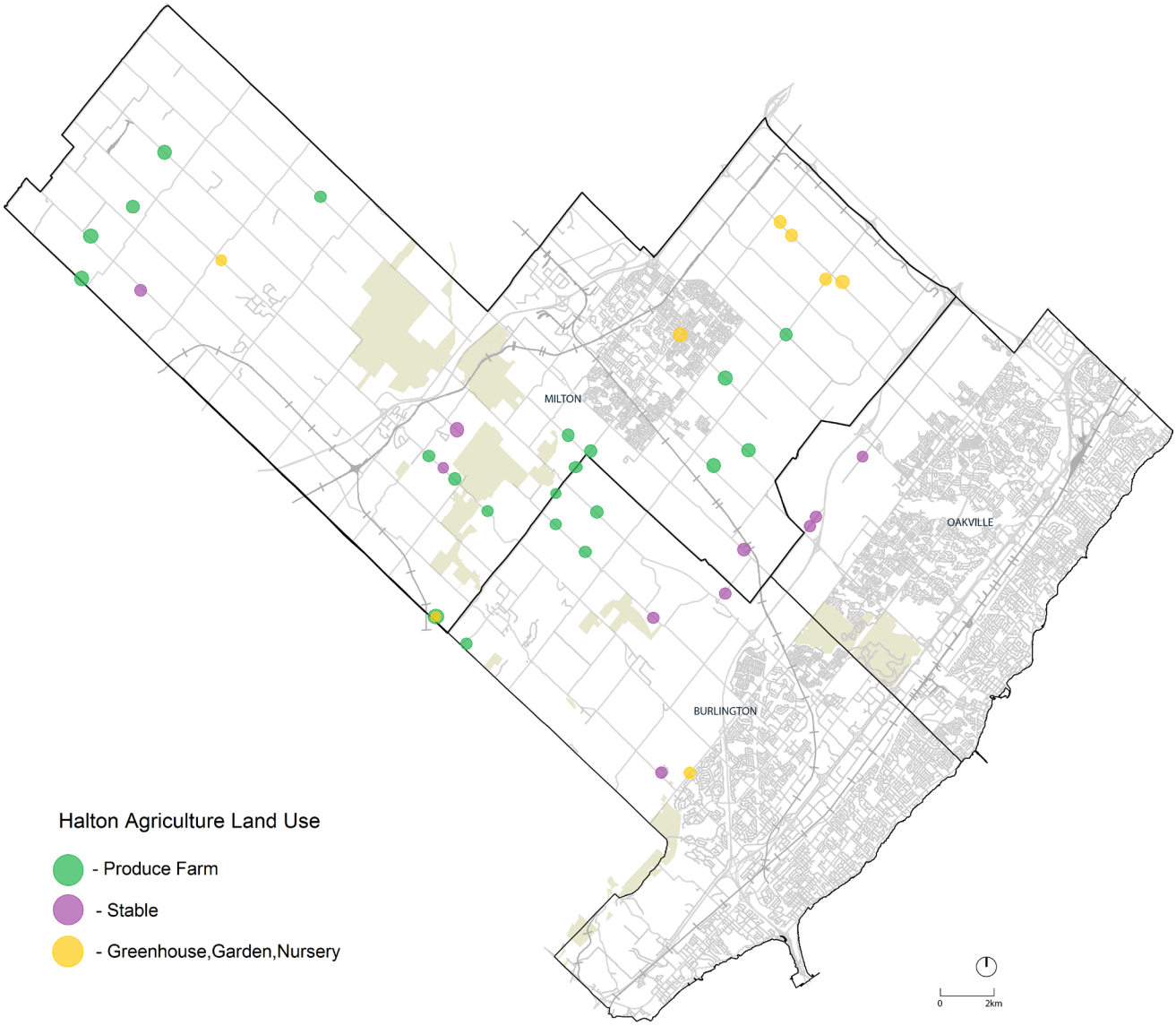


Figure A.38 - Existing Farms and Agricultural Land Use, Halton Region.

CULTURAL:

Outdoor Recreation and Conservation Areas - Milton

The landscape and unique natural features of the Niagara Escarpment are protected by Conservation Halton authorities from development through the formation of Conservation Areas. These areas are managed and maintained so that all of the Town's residents and visitors from other cities can enjoy them. The 4 major conservation areas in Milton are Hilton Falls, Kelso, Crawford Lake and Rattlesnake Point. Through all four of them contain trails that can be enjoyed on foot, biking, or by horse or snowshoeing. They also offer opportunities for recreational activities such as swimming, canoeing, as well as cultural learning opportunities. The close access to these green recreational spaces is a factor that draws people to live in Milton (or Halton).

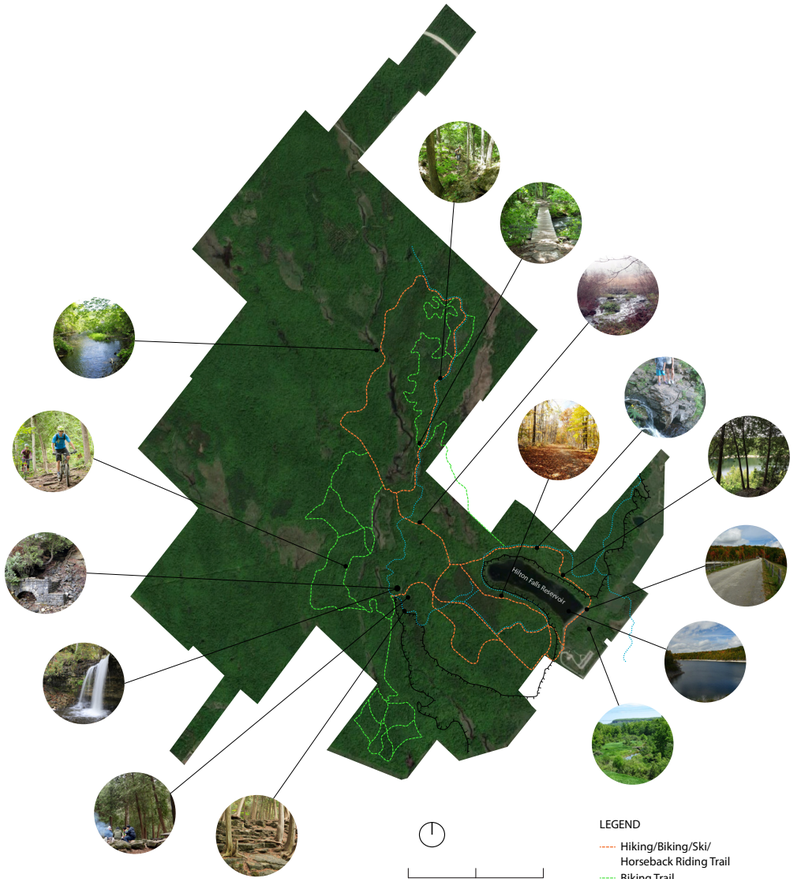


Figure A.39 - Hilton Falls Conservation Area, Milton, ON.

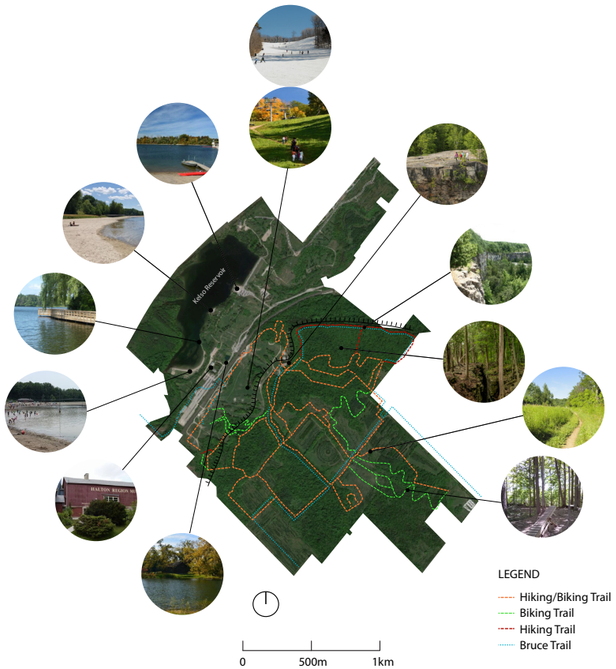


Figure A.40 - Kelso Conservation Area, Milton, ON.

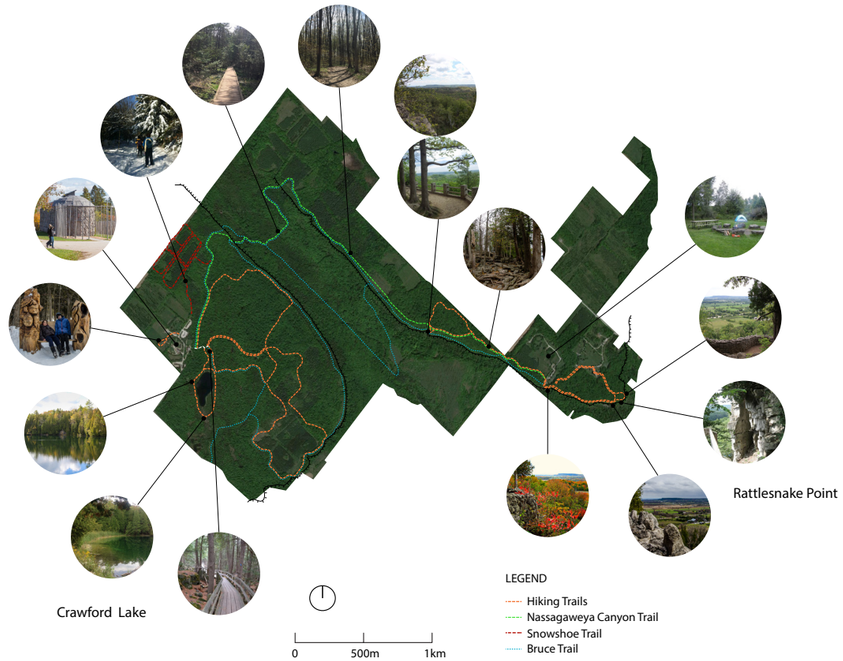


Figure A.41 - Crawford Lake and Rattlesnake Point Conservation Area, Milton, ON.

ENERGETICS:

The Effect of Urbanization and Urban Forests on Natural Cycles

Forests have many positive effects on flood management and in maintaining the water quality of creeks because of the filtration and absorption capacities of vegetation. However when buildings and pavement replaces forests as in the process of urbanization those functions being performed by the forest are no longer taking place. Asphalt and concrete replace the soil but they are impervious meaning they do not absorb the rainwater and so a large amount of precipitation in cites ends up as surface run-off that drains into the storm sewers. The catch basin carries the water to stream outside the city at a rate higher than a stream can handle causing flooding problems for the watercourse.

The planting of urban forests can help mitigate the problem of run-off in urban areas. Through evapotranspiration and by storing water in their roots they can help reduce surface run-off. Urban forests can provide other ecosystem services as well, such air filtration, releasing oxygen, regulating climates, providing habitats for wildlife, preventing erosion by stabilizing soils, reducing stress in humans and being aesthetically pleasing.

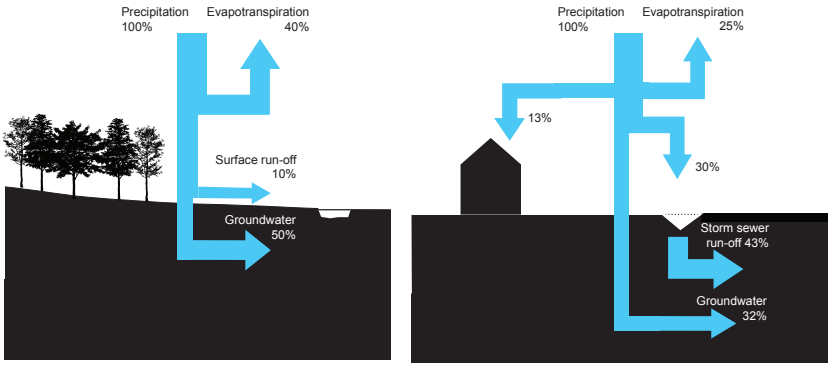


Figure A.42 - The effect of urbanization on the hydrology. From left: pre-urban; post-urban.

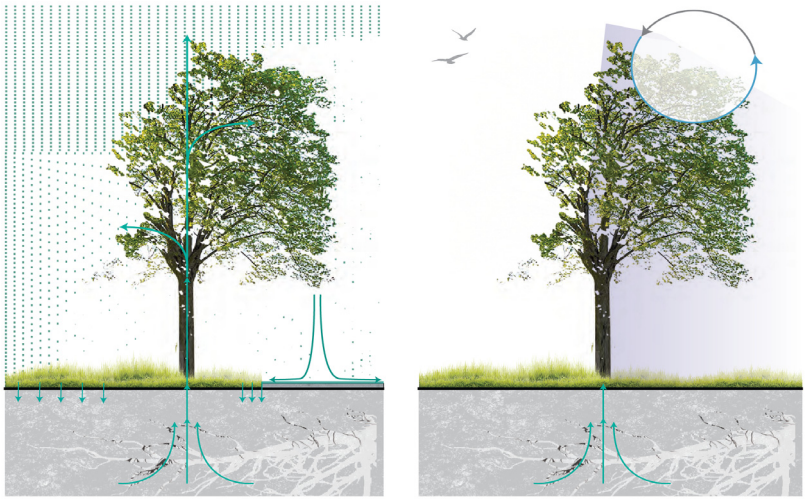
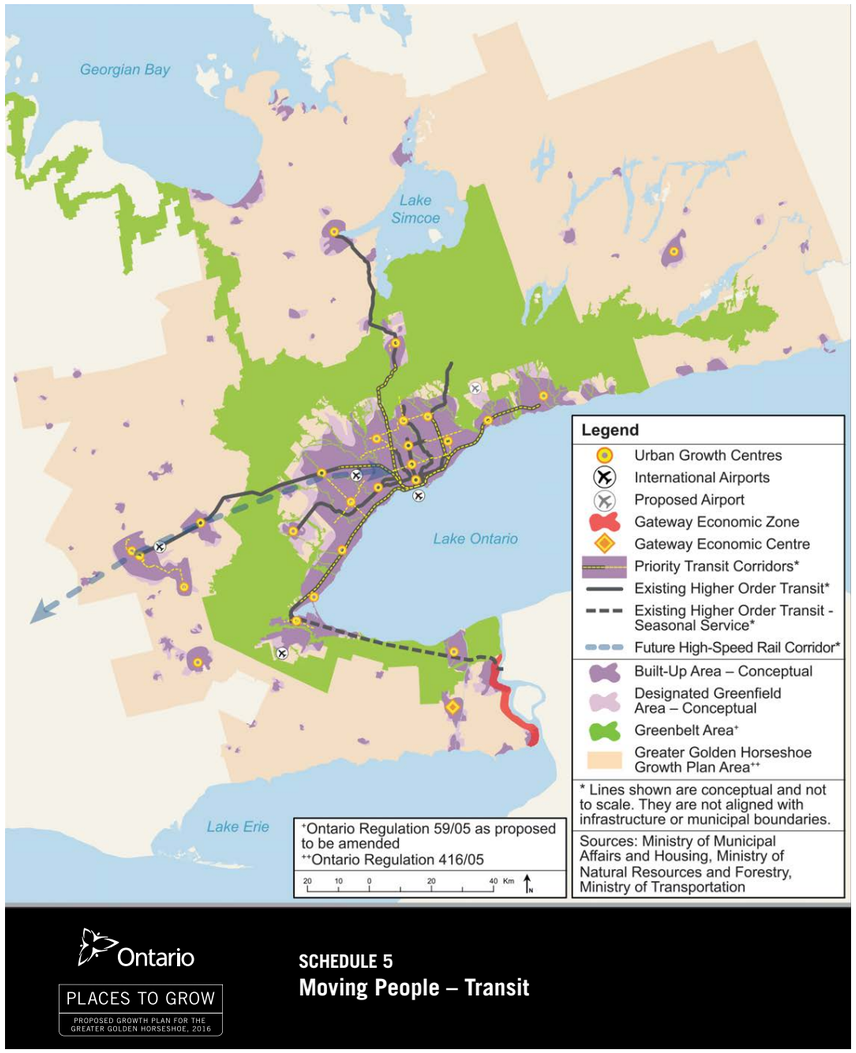


Figure A.43 - Diagram of the value of urban forests. Image Source: New Westminster

ENERGETICS:

Transportation Networks (People) - GGH

The extensive infrastructure network of roads and highways within the Greater Golden Horseshoe allows for a fast and effective flow of people and goods across the region. The GO Transit system makes it easier for people to live and work in different cities by providing a quick commuting service option to the region's urban centers. The highways and rail lines also support the economic flow within the region and between Canada and the U.S. Because of the high rate of population growth expected in the coming years in the GGH region, in order to prevent congestion on the existing infrastructure, the province will be building extensions of the provincial highway that service the areas at the edge if the Green belt, as well as the Kitchener-Waterloo LRT which will finally close the distance between the GTA and the Waterloo region that the boundaries of the Greenbelt have caused.



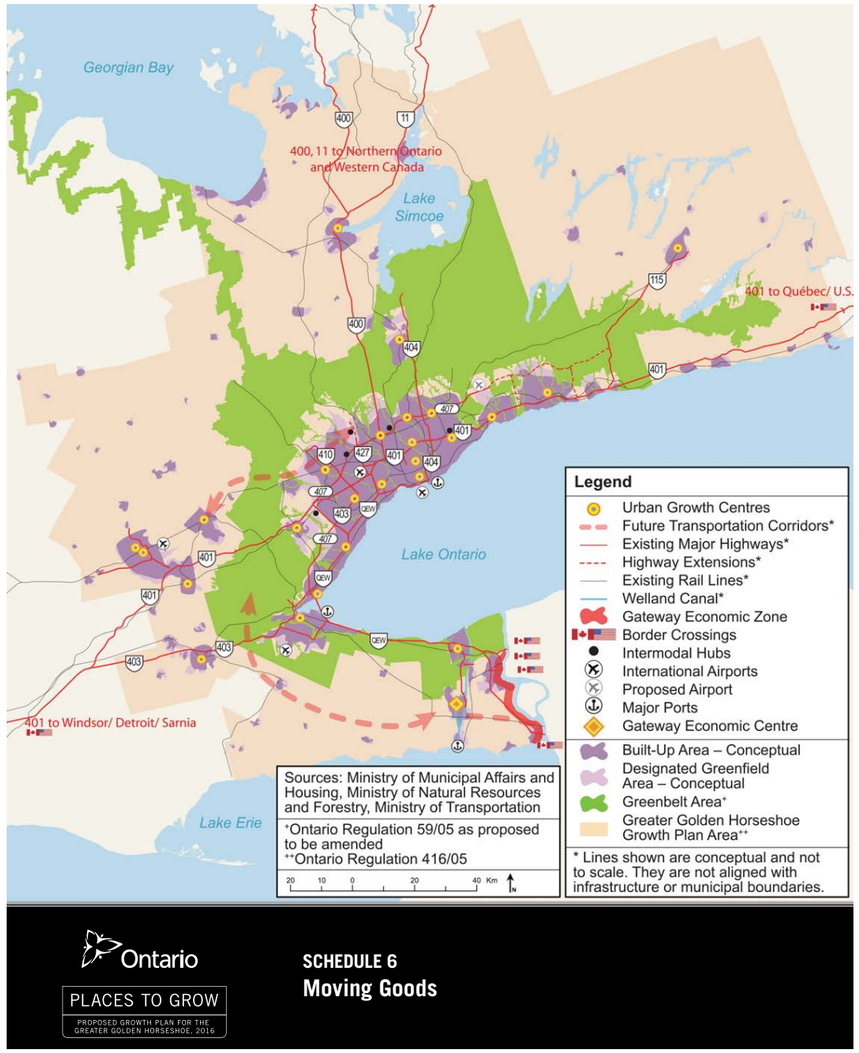


Figure A.44 - Proposed Growth Plan for the Greater Golden Horseshoe, 2016.

ATTRACTORS:

Milton Urban Growth

The factors that are contributing to the rapid population growth and increased rate of urban development:

AFFORDABILITY OF HOUSING

The rapidly rising house prices in Toronto and across the GTA make buying a house there unaffordable especially for younger generations. This is in part because of the lack of space in the city, which means no new single family homes are able to be built, and so lack of availability has driven the price up, as well as the somewhat easy process of getting a mortgage. The unaffordability of living in Toronto has caused people moving further away from the city to other nearby regions such as Milton where houses are less expensive.

YOUNG FAMILIES

A family-friendly lifestyle is more possible in Milton than in a large city such as Toronto. The desire to raise a family in a single-family home has not changed and is still as strong of a desire with the millenial generation as with past generations. A homeowner is able to get a better value on a house in Milton with more square-footage per dollar and a backyard. The small community feel of Milton is also an attractive quality, making it feel like a safer place to raise a family than a big city.

CONNECTEDNESS BETWEEN SUBURBS AND CITY

Nearly half of the employed residents living in Milton commute to a workplace outside of Milton. This is due to the relatively ease with which one can commute to work with due to the transportation infrastructure in the GTA. The Go Transit system and the provincial highways get people from Milton to Toronto in a short amount of time. The advantage of the connectedness between the cities within the GTA means people do not have to change work when they move municipalities. However, the fact that such a large portion of the residents spends most of their day outside the town of residence can negatively impact the level of community engagement.

ACCESS/PROXIMITY OF NATURE

One of the factors that makes Milton an appealing town to live in is the large amount of close by natural areas such as the Niagara Escarpment and the urban creek system. These natural areas provide many recreational opportunities for its residents and as well as those of nearby cities. The abundance of green space creates the perception that the town is a healthy place to live and raise a family.

DENSITY GOALS

Within the Greater Golden Horseshoe Plan the Province of Ontario has put forth density goals that each region is supposed to meet in order to accommodate the expected population growth of "11.5 million by 2031."[11] The 2005 Places to Grow Act required regions to grow within their existing boundaries at an annual rate of development of 40% in order to increase density in existing areas. Halton fell short of this goal and was at 33% rate of development. [12]

ACTORS AND MONITORING & GOVERNANCE

The many actors who govern land use planning and development that occurs in Ontario and in the Milton Municipality. The main actor is the government The public can become involved only to the extent of attending public meetings and review, joining an advisory committee or appealing a proposed plan through the Ontario Municipal Board.

Table A.5: Existing System of Governance of Land Use Planning and Development in Ontario.

Existing Actors		Systems of Monitoring and Governance		
Governance Body	**Actors**	**Legislation**	**Plans and Policies**	**By-Laws and Guidelines**
Federal Government	Canadian Environmental Assessment Agencies Environment and Climate Change Canada Fisheries and Oceans Canada	Canadian Environmental Assessment Act Migratory Birds Convention Act Species at Risk Act Fisheries Act Canada-U.S. Transboundary Air Quality Agreement	Environmental Emergency Regulations Migratory Birds Regulations	
Provincial Government: Ontario	Ministry of Municipal Affairs and Housing Ontario Ministry of Natural Resources Niagara Escarpment Commission Environmental and Land Tribunals Ontario Ontario Municipal Board Ministry of Transportation Conservation Ontario	Planning Act Greenbelt Act Places to Grow Act Niagara Escarpment Planning & Development Act Parkway Belt Planning & Development Act Municipal Act Environmental Protection Act Green Energy Act	Growth Plan for the Greater Golden Horseshoe Greenbelt Plan Oak Ridges Moraine Conservation Plan Niagara Escarpment Plan Places to Grow Plan Parkway Belt West Plan Provincial Policy Statement	Ministry of Ontario Design Guidelines Ministry of Environment Land Use Compatibility Guidelines (D-Series)
Regional Government: Halton Region	Halton Regional Council Conservation Halton Advisory Boards & Committees: Planning and Public Works Standing Committee Natural Heritage Advisory Committee (NHAC) Halton Agricultural Advisory Committee Halton Public Sector Smog Response Committee		Halton Region Official Plan Sustainable Halton Growth Management Plan Halton Region Strategic Action Plan 2015-2018 Clean Air Plan	
Municipal Government: Town of Milton	Milton Planning and Development Department Milton Council Heritage Milton Committee of Adjustment Town Administration - Services Department		Town of Milton Official Plan Strategic Action Plan - "Destiny Milton 3" 16 Mile Creek, Areas 2 and 7 Subwatershed Planning Study Secondary Plans: Boyne Secondary Survey Milton Education Village Secondary Plan Derry Green Corporate Business Park Secondary Plan	
Government Agency	Metrolinx	Metrolinx Act	Regional Transportation Plan (GTHA) - "The Big Move"	
Public Company	Canadian National Railway			
Public Organizations	Ontario Federation of Agriculture Carolinian Canada Universities & Colleges			
	Property Owners Developers Planners General Public			

ACTORS AND SYSTEM OF GOVERNANCE

The main actors in today's governance systems that determine and control how land is used in Ontario:

PLANNING ACT

- Governs land use planning in Ontario
- Allows/give power to the Province of Ontario to issue Provincial Policy Statements (PPS)

MINISTRY OF MUNICIPAL AFFAIRS & HOUSING (MMAH)

- The ministry that governs land use planning provincially
- Issues the PPS
- Lead ministry responsible for preparing provinicial plans
- Advises municipalities
- Acts as a approval authority

PROVINCE OF ONTARIO (OTHER MINISTRIES)

- Other ministries are also consulted and invited by MMAH to contribute to the draft the policies in the PPS, and to contribute to the preparation of provincial plans
- Not all ministries are involved in all planning; it depends on whether the plan involves their area of services and whether they are invited by the MMAH

PROVINCIAL POLICY STATEMENT (PPS)

- Guides land use planning in the province
- Provides a planning direction for land use, development and resource management
- "Reflect the priorities and values of the Ontario government" [1]
- Allows the province to have more control over the planning decisions of municipalities
- The Planning Act states that all planning and land-use decision made by the province, municipalites, the OMB, etc, must be in agreement with the PPS

MUNICIPALITY (e.g. TOWN OF MILTON)

- Based on the goals and policies set out by the province, the municipality "makes local planning decisions that will determine the future of (the) community" [2]
- Creates the Official Plan which determines the future land use within the municiplaity
- Creates Zoning By-Laws to control development

1 Environmental Commissioner of Ontario, "Land Use Planning in Ontario," January 2011, 5.

2 Environmental Commissioner of Ontario, "Land Use Planning in Ontario," January 2011, 5.

How these actors work in relationship to each other within the Ontario Land Use Planning System

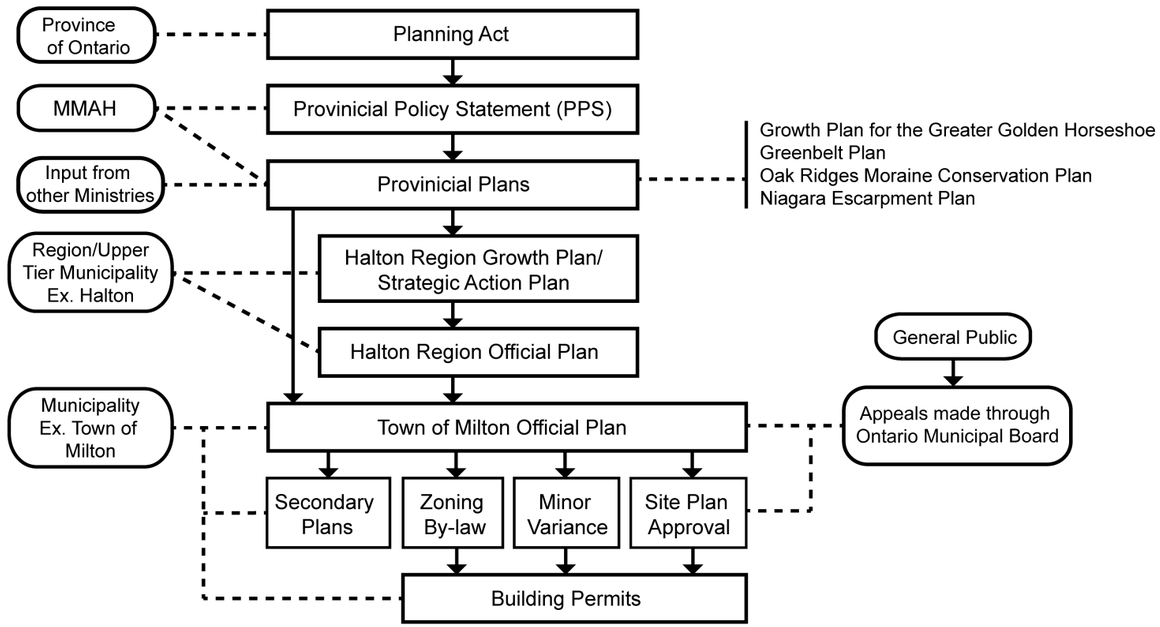


Figure A.45 - Land Use Planning System in Ontario: Actors

The Official Plan Process followed by Municipalities in Ontario

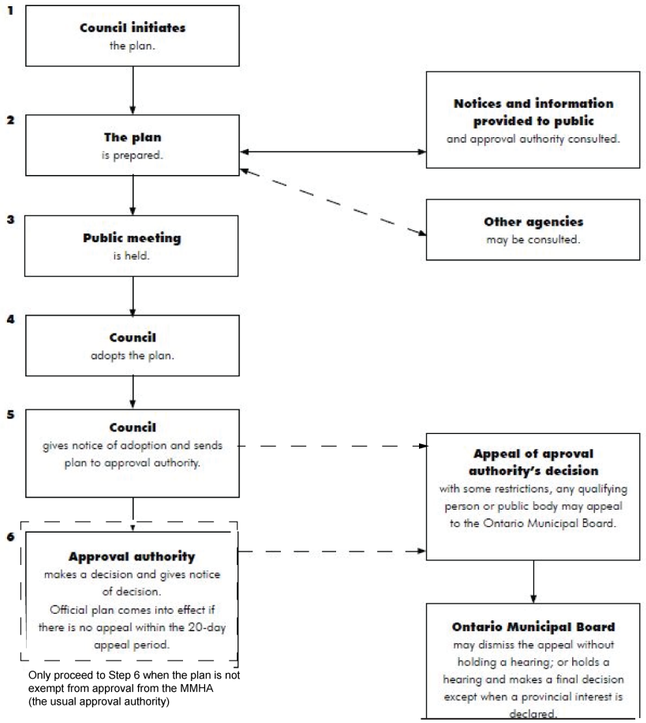


Figure A.46 - Land Use Planning System in Ontario: Process.

REARRANGED ACTORS

When it comes to land-use planning, the current relationship that exists between the actors gives most of the control to the government. When the government focuses on growth and providing buildings/ infrastructure to support the growth, the environment impact of the growth is often given minimal attention. The diagram on this page illustrates a rearranged actor relationship where the public and groups that represent the environment's interest have greater influence on land redevelopment than in the current model. Together these 4 actors collaborate to create an official plan that hopefully considers the impact of the development on the environment and ecosystems to a greater degree.

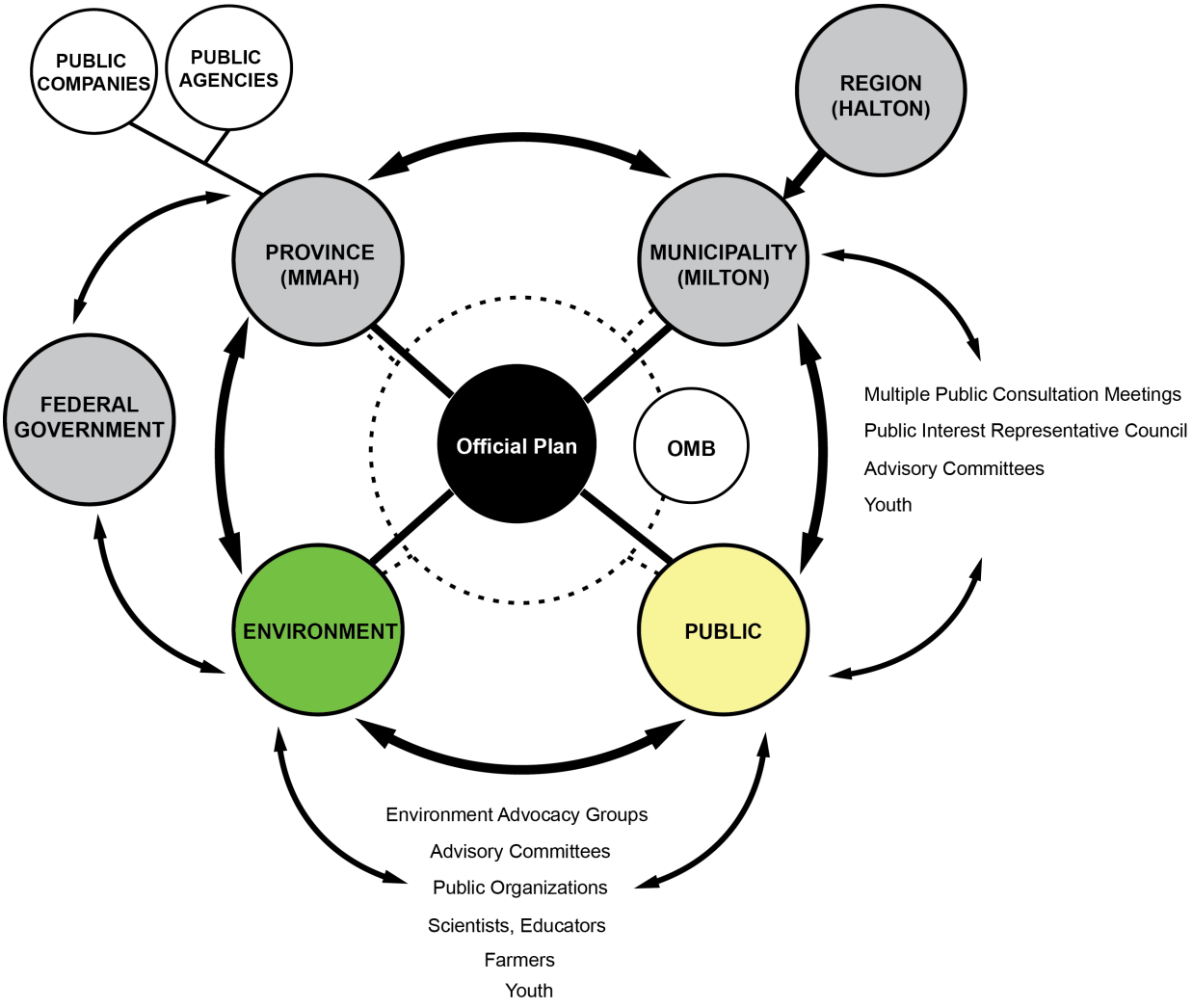


Figure A.47 - Proposed Rearrangement of Actors.

STRATEGIC INITIATIVES

Ecosystem Goals and Strategies

GOAL

The goal of this analysis is to understand the current ecosystem of the Town of Milton; and to apply this to the development an ecologically-based design for the community. Each strategy if implemented is intended to reduce the negative effects of urbanization on ecosystems, and to promote/maintain their health.

STRATEGIES

URBAN FOREST

Preserve and increase the extent of Milton's urban forest. The preservation of the urban forest is important in protecting the local watersheds. Urban forests help prevent flooding and control surface run-off which helps maintain the quality of the water. They form a habitat and for animals in urban areas, in addition to many other environmental benefits. This strategy can be achieved by setting up and then maintaining a target for urban canopy cover.

CORRIDOR/PATCH LINKAGES

Larger patches and corridors contain greater biodiversity of plants and animals - and a diverse ecosystem is a healthy one. The urban area in Milton has somewhat disconnected corridors: there are many long corridors in the north-south direction along the creek system, but lack of corridors in the east west direction. The strategy would be to create new corridors and patches along the E-W direction to ultimately connect them not only to the patches surrounding the creeks but also to the conservation areas west of the town. The creation of new urban forests would be part of this strategy.

CONNECTING HUMANS

Extend the existing trail system in the urban parks so that it connects to the conservations area and other natural areas of ecological significance, creating a linkage between the urban and rural.

BUFFER ZONES

Create buffer zones between the lands/creek systems that are protected by Conservation Halton and form the Natural Heritage System and the urban development. These buffer zones could be an extension of the urban forest system.

URBAN FARMING

Promote and develop new community gardens. There are currently three public community gardens where town residents can rent a garden space. Despite their proximity, the urban and rural are very distinct and seperate areas. Bringing a "rural" practice, farming, into the town would contribute to environmental awareness in the town by making visible a very important and life-sustaining natural process.

ENVIRONMENTAL EDUCATION

This strategy could also be implemented through the creation of a school whose central value is environmental education. In order to break the view "of the city as separated from the natural processes that support life"[13] environmental education should be localized. Children learn firstly about local and regional issues and interact with nature in their own neighbourhood.

Endnotes for Appendices

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