

ABSTRACT

Title of Thesis: **URBAN BEEING:
ENHANCING ECOLOGY THROUGH
THE CROSS-POLLINATION OF
ARCHITECTURE AND APICULTURE**

Trevor Wood, Masters of Architecture,
2019

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Architecture

Bees play an essential role in our ecosystems. The majority of all flowering plants on earth, both crop and wild, are pollinated by animals. With bees acting as the chief pollinators globally, they play an essential role in maintaining ecological diversity, promoting agricultural crop yields, and enhancing resiliency. Recent bee population declines across the globe have raised concerns from researchers and governments alike about the stability of our current environments and economies. This thesis aims to explore and reimagine post-industrial landscapes with remediating infrastructure that supports and is maintained through the natural processes associated with apiculture to enhance urban ecologies and resiliency.

Recasting the relationship that humans have with bees in urban environments will provide a new vision for ecological architecture and resilient landscape design. Various scales will connect apiaries with research and educational programmed architecture within a greater canal pollinator park network to activate community awareness and involvement in the process of promoting bee prosperity to achieve a new vision for ecological urbanism.

**URBAN BEEING: ENHANCING ECOLOGY THROUGH THE CROSS-
POLLINATION OF ARCHITECTURE AND APICULTURE**

by

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Table of Contents

Table of Contents	ii
List of Figures	iii
1. Situation	1
Bees in Decline	1
Concerning Factors	4
Consequences of Disappearance	6
Addressing the Threat	10
2. [Bee]havior	12
Phylogenesis	12
Pollination	13
Floral Relationship	14
Social Structures	15
Navigation and Communication	16
Architecture	17
3. Concept	22
Urban Apiaries	22
Urban Apiaries as a Catalyst for Enhanced Ecology and Resiliency	23
Bees Thrive in the City	24
Hive Architecture	25
Locating the Apiary	30
Beekeeping Tools and Equipment	33
Harvesting and Production	34
Data Tracking	37
Urban Resiliency	38
Green Infrastructure	39
Inland Stormwater Management	40
Resilient Edges	46
4. Vision	51
Site	51
Gowanus	53
Site History	55
Environmental Concerns	59
Gowanus After Industry	64
Program	69
Masterplan	69
Building	70
5. Realization	72
Gowanus Growlands	72
NYC Beekeepers Association Apiculture Center	77
Apiary Park – Hive as Urban Infrastructure	84
Bibliography	87

List of Figures

Figure 1.1: The United States has seen a loss of 1/3 of all commercial honeybee colonies since 2006. (Source: Author, 2019)	2
Figure 1.2: U.S. Average Winter Bee Colony Loss from 2009 to 2018. Normal Winter colony loss is 15%, however recent trends have noted losses from 22.3-34.4%. (Source: Author, 2019).....	3
Figure 1.3: 2017/18 Average Winter Loss Per Beekeeper by Operation Size in U.S. (Source: Author, 2019).....	4
Figure 1.4: Pollinators, flowering plants, and crops. Bee pollination of agricultural crops accounts for about one-third of our diets. Honeybees are the most economically valuable pollinators of agricultural crops worldwide and are the only bee species kept commercially in the United States. (Source: Author, 2019)	7
Figure 1.5: 75% of the nuts, fruits, and vegetables that Americans eat are pollinated by bees. (Source: Author, 2019).....	8
Figure 1.6: Proportion of crop pollinators that are bees. Bee pollination of agricultural crops accounts for about one-third of our diets. (Source: Author, 2019).....	9
Figure 2.1: Bees are the chief pollinators globally, providing a key ecological service that promotes biodiversity, agricultural crop yields, and resiliency. (Source: Author, 2019).....	12
Figure 2.2: Anatomy of Worker Bee. To carry pollen from flower sources to the hive worker bees have specialized Corbicula structures, or pollen baskets, which allow them to store the resource along their journey. (Source: Peace Corps, 1978)	14
Figure 2.3: Stages of Bee Development. (Source: The Bee: A Natural History, 2014).....	16
Figure 2.4: Honeybee Nest Section Within Hollow Tree (Source: Author, 2019)	19
Figure 2.5: Opposing Layers of a Honeycomb. (Source: Author, 2019)	20
Figure 2.6: Time Lapse of Honeycomb Construction in artificial hives. The bees build from the top down filling in as additional space is needed for honey storage. (Source: Chandler B. Beach, 1914)	21
Figure 3.1: Bees in the city. Promoting urban pollination through an architecture for apiculture. (Source: Author, 2019)	22
Figure 3.2 Through an architecture that creates place for formal and informal education, research, and on-site apiaries a cyclical process can be introduced into urban environments that enhances biodiversity, promotes resiliency, and reverses the declining bee population. (Source: Author, 2019).....	23
Figure 3.3 The architecture of apiculture. (Source: Author, 2019)	25
Figure 3.4 Leaf Hive, designed by Francois Huber. Revolutionizing beehives, this design used fully removable frames allowing for easy management. (Source: Francois Huber, 1789).....	26
Figure 3.5 Langstroth Hive, designed by Lorenzo Lorraine Langstroth in 1852. This hive implemented the concept of “bee space,” which improved spatial efficiency. The design also made adding additional space easy through the stacking organization. (Source: Author, 2019).....	27

Figure 3.6 Flow Hive Frame draining honey without needing to remove the frame from the hive. (Source: Author, 2019)	29
Figure 3.7 Flight path diagram. Good urban beekeeping practice is to alter the flight path of bees as the approach and depart the hive with a minimum 6-foot barrier, such as a fence or hedge. (Source: Author).....	32
Figure 3.8 Typical beekeeping equipment. (Source: Author, 2019).....	33
Figure 3.9 The process of uncapping wax with a knife and honey being extracted using a multi-frame electronic extractor. (Source: Joshua Hennig, 1954)	36
Figure 3.10 Sustainable Urban Drainage System (SUDS) model for stormwater management. (Source: Author)	41
Figure 3.11 Intensive vs. Extensive Green Roof. (Source: Author, 2019)	42
Figure 3.12 Rain garden cross section. (Source: Author, 2019).....	43
Figure 3.13 Bio-swale cross section. (Source: Author, 2019).....	45
Figure 3.14 Retention Basin cross-section showing inflow and outflow during storm surges. (Source: Author).....	46
Figure 3.15 Floodable Field Diagram. (Source: Author)	47
Figure 3.16 Marsh Riparian Buffer showing vegetation phases from subtidal to above tide elevations. (Source: Author).....	49
Figure 4.1 Site Selection Matrix comparing the Gowanus Canal and the Newtown Creek. (Source: Author, 2019).....	51
Figure 4.2 Map of New York City highlighting location of potential sites. (Source: Author, 2019).....	52
Figure 4.3 Gowanus is situated between the residential neighborhoods of Carroll Gardens, Park Slope, and Boerum Hill and is within 1 mile of Prospect Park. The Canal is accessible by the F-G and D-N-R subway lines. (Source: Author, 2019)	53
Figure 4.4 Scale of the Gowanus Canal compared to similar sized linear parks. (Source: Author, 2019).....	54
Figure 4.5 Pre-Settlement: The Gowanes Creek consisted of a tidal creek, marsh wetlands, and freshwater streams. (Source: Author, 2019)	55
Figure 4.6 1661- 1853: After the Dutch settled what is now Brooklyn, the Gowanes Creek was transformed for use as tidal mills, oyster fishing, and farming. (Source: Author, 2019).....	56
Figure 4.7 1853-1950: The Gowanus Canal became the primary commercial and maritime hub in Brooklyn until the mid-20 th century, but due to a lack of regulations it endured years of pollution, dumping, and sewer overflow. Gaining the nickname, “Lavender Lake,” the Gowanus Canal became the most contaminated waterway in the United States. (Source: Author, 2019)	57
Figure 4.8 Map of the middle portion of the Gowanus Canal from 3 rd Street to 13 th Street, 1880. (Source: G.M. Hopkins & Co., 1880)	58
Figure 4.9 Polluted water in the Gowanus Canal. (Source: Author, 2019).....	60
Figure 4.10 Contamination of land surrounding the canal. Resulting from poor environmental regulation, industrial activity from the mid-19 th century to present day has left the land contaminated with heavy metals, DNAPL, and LNAPL. (Source: Author, 2019).....	61

Figure 4.11 Canal Cleanup efforts as result of site being granted a superfund site by EPA. (Source: Author, 2019).....	62
Figure 4.12 Gowanus Canal superfund cleanup timeline. The dredging and capping of the canal will take place in three phases from 2017 to 2022. (Source: Author, 2019)	63
Figure 4.13 The fragmented urban fabric of Gowanus creates a stark divide between the tight neighborhood blocks of the surrounding residential neighborhoods. (Source: Author, 2019).....	64
Figure 4.14 Gowanus transforming as a result of the downturn in industrial activity. New commercial and creative land uses have begun to infiltrate the historically industrial fabric along the canal corridor. (Source: Author, 2019)	65
Figure 4.15 Current land use in Gowanus and the surrounding neighborhoods of Carroll Gardens and Park Slope. A distinct separation between the residential fabric and transforming industrial fabric along the Canal. (Source: Author, 2019)	66
Figure 4.16 The new 12-story mixed-use residential buildings developed by The Lightstone Group, completed in 2016. (Source: Author, 2019)	67
Figure 4.17 The character of the edges along the canal corridor are mostly inaccessible and offers limited public space. The majority of existing bulkheads are in need of replacement. The buildings lining the canal are primarily 1-2 story low-value post-industrial buildings, many of which are vacant. (Source: Author, 2019).....	68
Figure 4.18 Building program. (Source: Author, 2019).....	71
Figure 5.1 Tidal Marsh Pond. Wrapping the new softened edge of the Gowanus Canal, a public esplanade and path network mediates the urban fabric and the canal pollinator park. (Source: Author, 2019).....	72
Figure 5.2 The Gowanus Canal is transformed through the removal of existing bulkheads at locations along the canal corridor to create a new varied edge condition. The new edge includes a stepped edge, intertidal terracing, and a soft edge to compliment the high bulkhead condition as it exists now. (Source: Author, 2019)	73
Figure 5.4 Master Plan Exploded Axon. (Source: Author, 2019).....	74
Figure 5.3 Site Plan. (Source: Author, 2019).....	75
Figure 5.5 Meadow along the canal. Urban orchard and pollinator meadow line the public esplanade in the mid-canal. (Source: Author, 2019)	76
Figure 5.6 Canal Section cutting through a terraced edge condition along the mid-canal portion of the canal corridor. (Source: Author, 2019)	77
Figure 5.8 Site Response Diagrams. (Source: Author, 2019).....	78
Figure 5.7 Perspective of the honey room cantilevering over the pollinator garden below. (Source: Author, 2019).....	79
Figure 5.9 Building program articulated into stacked cellular volumes referencing the architecture of hives. (Source: Author, 2019)	80
Figure 5.10 Building Sections. (Source: Author, 2019)	80
Figure 5.11 Honey room, providing honey tasting and offering views up the canal. The materiality of the room creates the sense of being encapsulated in honey. (Source: Author, 2019).....	81

Figure 5.12 Observation hive room, acting as an exhibit for visitors and a bee sanctuary from which new beekeepers can buy a starter colony to begin their hive. (Source: Author, 2019).....	82
Figure 5.13 Plans. (Source: Author, 2019).....	83
Figure 5.14 Observation hive, concealed and deployed. Supported by a steel frame, the backside of the hive is set within a track, while a pulley system allows the hive to be raised and lowered for viewing and maintenance. The totemic nature of the hive elevates 22' above the ground creating a flight path out of the void in the top of the hive frame that is well above the human occupied zone on the ground. (Source: Author, 2019).....	84
Figure 5.15 Apiary Park. (Source: Author, 2019).....	85
Figure 5.16 Observation Hive. The bright golden character of the wooden top-bar hive is concealed behind the waxy translucent shell of the larger infrastructure allowing each hive to glow. The bottom side of the hive is glazed with orange-tinted laminated glass, providing a viewing portal into the hive, allowing park goers to observe the bees as they work. (Source: Author, 2019).....	86

1. Situation

Bees in Decline

In recent years the dramatic decline in bee populations has created dire uncertainty for the future of our agricultural production and ecological diversity. The global dependence on natural pollinators for increasing or even just maintaining plant diversity is of paramount concern as we see significant losses in bee colonies across the globe. This disappearance has already caused environmental and economic impacts that have prompted new research agendas and institutional actions into the causes and potential solutions to this growing issue. It is clear that a continued bee decline will have grave consequences on our ability to produce sustainable levels of food and will devastate our ecological systems.

Since no international monitoring research programs currently exist, it is difficult to determine the severity and extent of bee population decline at a global scale.¹ However, national and regional data has provided insight into localized concerns about declining populations and bee colony losses. A global tracking program measuring fluctuations in pollinators is urgently needed to protect ourselves from the financial and environmental crisis that would ensue with rapid pollination loss.

¹ Lebuhn, Gretchen, Sam Droege, Edward F. Connor, Barbara Gemmill-Herren, Simon G. Potts, Robert L. Minckley, Terry Griswold, Robert Jean, Emanuel Kula, David W. Roubik, Jim Cane, Karen W. Wright, Gordon Frankie, and Frank Parker. "Detecting Insect Pollinator Declines on Regional and Global Scales." *Conservation Biology* 27, no. 1 (2012): 113-20.



1/3 LOSS

Figure 1.1: The United States has seen a loss of 1/3 of all commercial honeybee colonies since 2006. (Source: Author, 2019)

Regional data has noted that the case in North America and Europe has been more severe than its counterparts elsewhere. In particular, the United States has lost around one-third of commercial honeybee colonies since 2006.² In Europe, it is estimated that 25% of honeybee colonies have been lost from 1985 to 2010, with

² Lebuhn, "Detecting Insect Pollinator Declines on Regional and Global Scales," 113-20.

even more significant losses in the United Kingdom, which has seen a reduction of roughly 54% in this timeframe.³ These losses are particularly concerning due to the high levels of agricultural production that these regions generate.

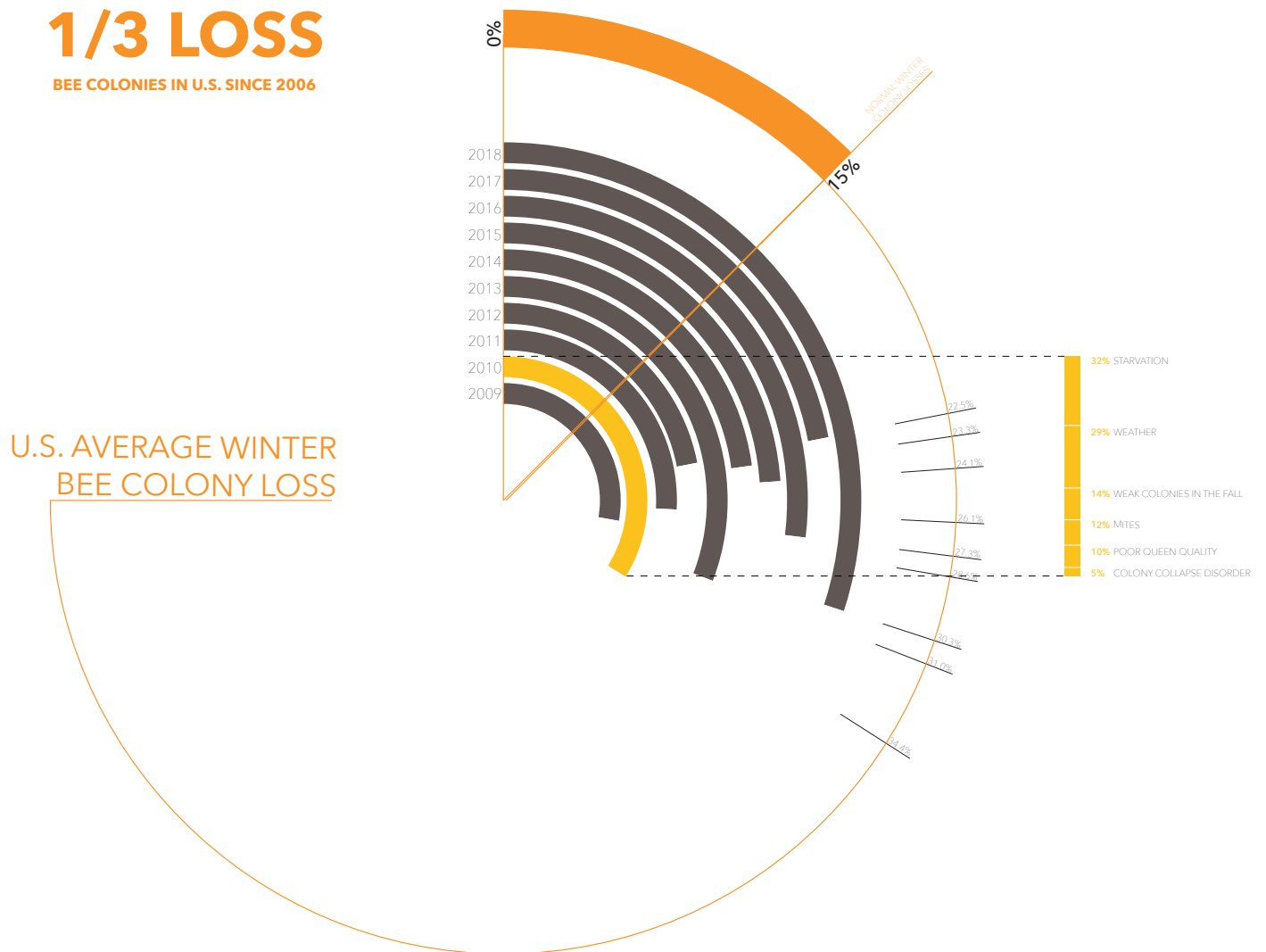


Figure 1.2: U.S. Average Winter Bee Colony Loss from 2009 to 2018. Normal Winter colony loss is 15%, however recent trends have noted losses from 22.3-34.4%. (Source: Author, 2019)

³ Potts, Simon G., Jacobus C. Biesmeijer, Claire Kremen, Peter Neumann, Oliver Schweiger, and William E. Kunin. "Global Pollinator Declines: Trends, Impacts and Drivers." *Trends in Ecology & Evolution* 25, no. 6 (2010): 345-53.

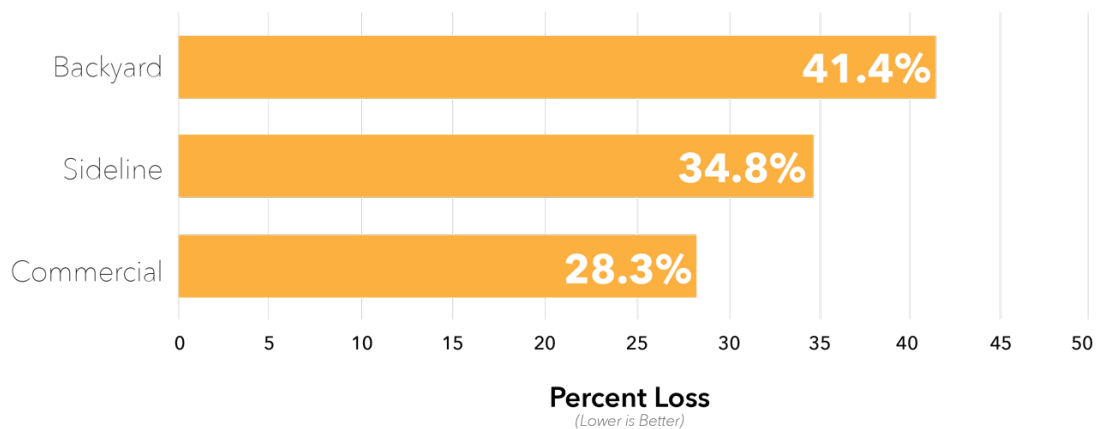


Figure 1.3: 2017/18 Average Winter Loss Per Beekeeper by Operation Size in U.S.
(Source: Author, 2019)

Concerning Factors

A variety of factors have played a role in the recent bee population decline. Although increases in diseases, parasites, and chemical use in agricultural processes are leading causes, no single factor is solely to blame. Their decline is most likely a result of multiple factors acting in concert with one another, with some reasons likely still unknown.

Colony collapse disorder, a condition characterized by the disappearance of worker bees, is one of the major contributors to declining bee populations. In the United States, this syndrome accounted for the loss of 30-40% of commercial honeybee colonies from 2006 to 2013.⁴ This can largely be attributed to the increasing application of pesticides in agricultural practices, which have a disorienting effect on bees leaving them unable to find their way back to the hive. With the loss of worker bees, the colony is left with a queen, the brood, and an

⁴ Lebuhn, "Detecting Insect Pollinator Declines on Regional and Global Scales," 113-20.

abundance of nectar and honey reserves. However, without worker bees, the colony soon becomes unsustainable in the long-term and is likely to collapse during the winter season.

The use of pesticides, insecticides, and other chemicals in industrial agriculture has many harmful effects on bee health. Neonicotinoids, a standard class of insecticides derived from nicotine, is particularly detrimental. Contact with the chemical poses risks not only to the worker bees but also lower the queen bee's ability to reproduce. Although this does not immediately kill off the colony, the lower reproductive rates slowly kill off the colony over time. To make matters worse, the combination of pesticides with other herbicides and fungicides often increase the toxicity of the pesticides making them an even more significant threat to colony survival.⁵

Another threat to bee populations is increasing cases of diseases and parasites. Varroa mites, an external invasive parasitic insect, which originated in Asia, have spread across the globe posing new risks to apiculture. These pinhead-sized mites spread from hive to hive feeding off of the blood of bees, leaving them in a weakened state. In addition, they also spread viral diseases and harmful bacteria, often leading to a total colony collapse within a three-year timeframe.⁶

Nosema, a harmful honeybee pathogen, also poses a severe risk to bees globally. Although most prevalent in European countries, Nosema has been found worldwide. The risk associated with Nosema does not directly affect the queen bee,

⁵ Dengler, Roni. "Neonicotinoid Pesticides Are Slowly Killing Bees." PBS. June 29, 2017. Accessed March 29, 2019. <https://www.pbs.org/newshour/science/neonicotinoid-pesticides-slowly-killing-bees>.

⁶ UNEP, UNEP Emerging Issues: Global Honeybee Colony Disorder and Other Threats to Insect Pollinators. United nations Environment Program, (2010).

but instead leads to high levels of mortality for the foragers, a key propionate of the colony's division of labor, which in time weakens the colony as a whole.⁷

Climate change has also affected the health of bees. Increased rainfall, rising temperatures, and the increase of extreme weather events add yet another level of stress to the health of bees. Although the effects of climate change on bee populations is harder to track, it undoubtedly has added further levels of stress to bees across the globe.

Consequences of Disappearance

The loss of bees would create severe inefficiencies in agricultural production and lead to diminishing ecosystem conditions. Beyond the implicit ecological and social concerns, this catastrophe would also have significant economic implications. There is a substantial economic value associated with the role that bees play as pollinators. Both the food we eat and the environments that we live heavily rely on bees, and pollinating animals in general.

Our current wild plant ecosystems and agricultural systems are dependent on the pollination from bees. An estimated 87.5% of flowering plants, both crop and wild, are pollinated by animals.⁸ In terms of agriculture, pollination from animals increases fruit and seed yields in three-quarters of the world's top food crops.⁹ With

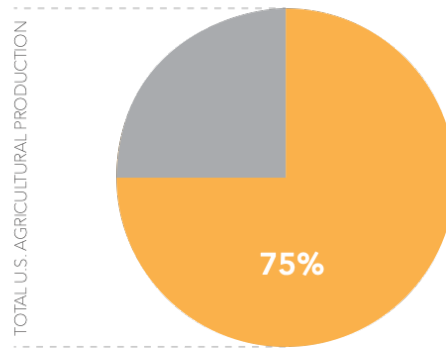
⁷ Higes, Mariano, Aránzazu Meana, Carolina Bartolomé, Cristina Botías, and Raquel Martín-Hernández. "Nosema Ceranae(Microsporidia), a Controversial 21st Century Honey Bee Pathogen." *Environmental Microbiology Reports* 5, no. 1 (2013): 17-29.

⁸ Ollerton, Jeff, Rachael Winfree, and Sam Tarrant. "How Many Flowering Plants Are Pollinated by Animals?" *Oikos* 120, no. 3 (2011): 321-26.

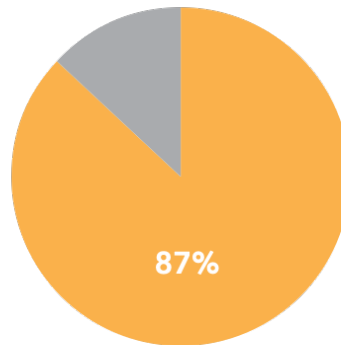
⁹ Klein, Vaissière A-M, BE Cane, JH Steffan-Dewenter, and I. Cunningham. "Importance of Pollinators in Changing Landscapes for World Crops." *Proceedings of the Royal Society B: Biological Sciences* 274 (2007): 303-13.

bees acting as the chief global pollinator it is easy to understand how vastly important they are in maintaining diverse ecologies and food production levels.

U.S. POLLINATOR DEPENDENT CROPS



FLOWERING PLANTS POLLINATED BY ANIMALS



\$15 BILLION
ESTIMATED U.S. ANNUAL ECONOMIC VALUE

Figure 1.4: Pollinators, flowering plants, and crops. Bee pollination of agricultural crops accounts for about one-third of our diets. Honeybees are the most economically valuable pollinators of agricultural crops worldwide and are the only bee species kept commercially in the United States. (Source: Author, 2019)



Figure 1.5: 75% of the nuts, fruits, and vegetables that Americans eat are pollinated by bees. (Source: Author, 2019)

"The Food and Agriculture Organization of the United Nations (FAO) estimates that out of some 100 crop species which provide 90% of food worldwide, 71 of these are bee-pollinated."¹⁰ Without bees, agricultural pollination would have to be done manually, dramatically lower efficiencies in productivity, making pollination an impossible task. As a result of this reality, it has been estimated that the global economic benefit of pollination totals over \$349Bn.¹¹

Wild plant diversity also plays a vital role in the larger ecosystem. Animal pollination is crucial in maintaining diverse plant options, which serve as food for mammals, birds, and insects. With a continued decline in bee population, a collapse in the animal food chain would occur, creating an immeasurable economic downturn.

¹⁰ UNEP, UNEP Emerging Issues: Global Honey Bee Colony Disorder and Other Threats to Insect Pollinators. United nations Environment Program, (2010).

¹¹ Lautenbach, Sven, Ralf Seppelt, Juliane Liebscher, and Carsten F. Dormann. "Spatial and Temporal Trends of Global Pollination Benefit." *PLoS ONE* 7, no. 4 (2012).

Bee pollination is also paramount in maintaining biodiversity, which helps keep sufficient vegetation coverage. Thus, bees provide a critical ecosystem service in terms of aiding flood protection, water purification, carbon sequestration, erosion control, and nitrogen fixation.¹² Without bees to maintain this plant diversity the economic toll of human-made infrastructural systems and human maintenance would be unsustainable.

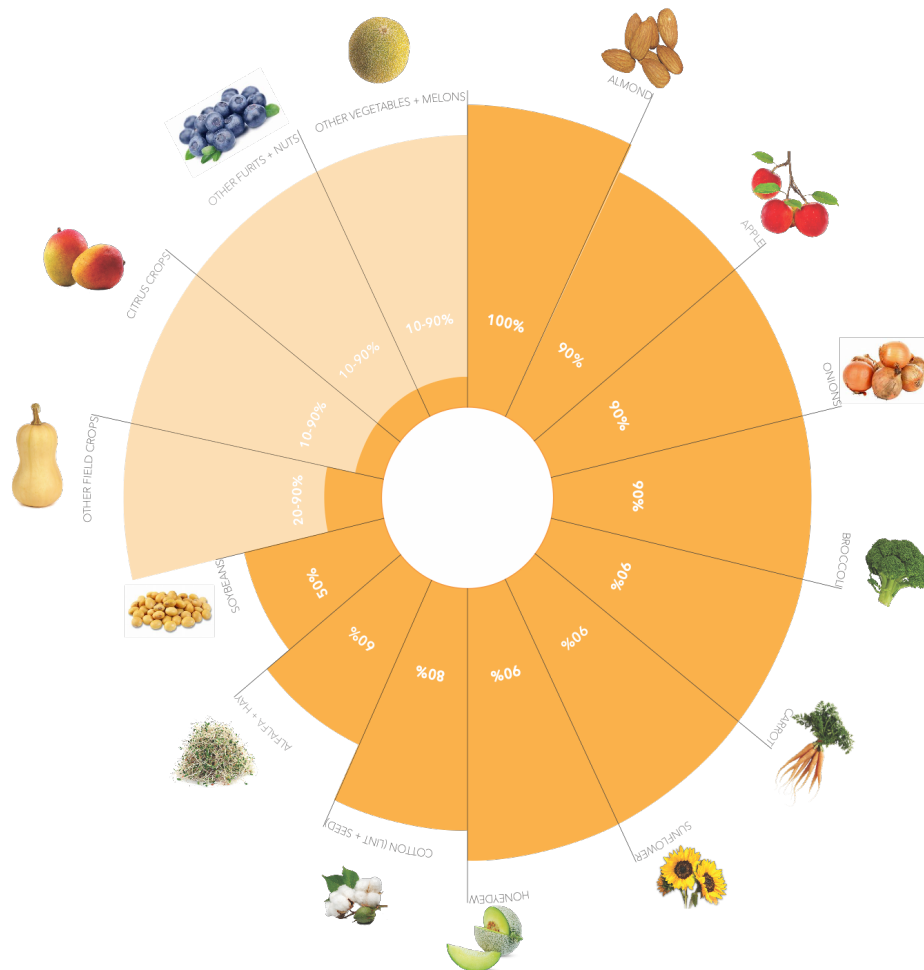


Figure 1.6: Proportion of crop pollinators that are bees. Bee pollination of agricultural crops accounts for about one-third of our diets. (Source: Author, 2019)

¹² Kremen, Claire, and Albie Miles. "Ecosystem Services in Biologically Diversified versus Conventional Farming Systems: Benefits, Externalities, and Trade-Offs." *Ecology and Society* 17, no. 4 (2012).

Addressing the Threat

The environmental service that bees provide through pollination is a crucial factor in sustaining and potentially improving human wellbeing. Although not always visible, the value of bees is too high to ignore. Moving forward, actions are needed to protect the health of bees to avoid the threat of ecological and agricultural catastrophes.

In response to the rising concerns associated with declining bee populations, activists and researchers have lobbied for government and institutional action. In the United States, some measures have been made in recent years to help reverse the declining bee populations. The U.S. Department of Agriculture (USDA) has provided significant incentives through the Conservation Reserve Program (CRP) for farmers who establish new habitats for honeybees in five of the states with the largest agricultural production. The USDA is also pursuing other potential solutions through research laboratories dedicated to bee genetics, biology, physiology, and breeding.¹³

Although government acknowledgment of the concerns associated with declining bee populations is an important start, the measures that have been taken have proven to be insufficient in improving bee health. Moving forward attention needs to focus on the current industrial chemical-intensive farming model, which is a leading cause in bee decline.

To address the issue in the short-term policymakers should aim to ban harmful pesticides and chemicals currently used in agricultural practices. Incentives should also be made to farmers who comply with agricultural practices that promote

¹³ United States Department of Agriculture. "USDA Provides \$8 Million to Help Boost Declining Honey Bee Population." News release, June 20, 2014. Accessed March 28, 2019. <https://www.usda.gov/media/press-releases/2014/06/20/usda-provides-8-million-help-boost-declining-honey-bee-population>.

the health of pollinators, such as crop rotation, organic farming, and ecological focus areas. Finally, improvements need to be made in areas around agricultural land that promote the conservation of natural and semi-natural habitats of bees.

2. [Bee]havior

Phylogenesis

Within seven families there are over 16,000 bee species throughout the world. With the shared trait of working as pollinators in our ecosystems, the different species encompass a broad variety of traits and characteristics relating to diet, social behavior, nesting structures, and communication techniques. These sophisticated properties of bees allow them to function as the primary pollinators in our ecosystems.

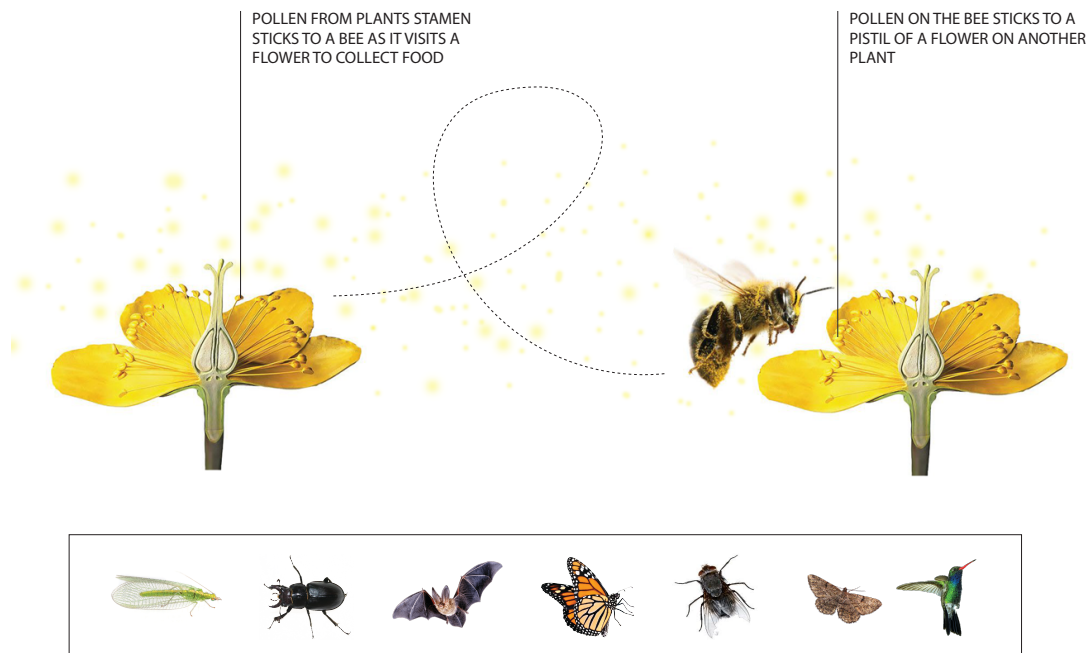


Figure 2.1: Bees are the chief pollinators globally, providing a key ecological service that promotes biodiversity, agricultural crop yields, and resiliency. (Source: Author, 2019)

Pollination

The principal contribution of bees to our ecosystems is their ability to pollinate. They are the leading pollinators across the globe, helping to maintain diverse ecologies that benefit both flora and fauna. Pollination is a process in which pollen is transferred from the male reproductive organ of a plant, stamen, to the receptive female part, pistil. Typically, pollination occurs between two of the same plant species; however, when pollination occurs between two different species it can result in hybrid offspring. Since fruiting relies on fertilization, plant diversity and agriculture are both dependent on pollination.

There are two types of pollination, Biotic and abiotic. Biotic pollination relies on animal pollinators, while abiotic depends on wind and water to transfer pollen from plant to plant. Biotic pollination accounts for 80% of total pollination processes, making animal pollinators a vital aspect of plant biodiversity.¹⁴

Bees are the most recognized and successful pollinators. A major reason for the effectiveness of bees is due to the fuzzy hair on their exteriors combined with their electrostatic charge. These properties give them an advantage as sticky pollen easily adheres to their bodies as they move from plant to plant. Since bees collect pollen that they use as a food source for their young, they are also equipped with specialized pollen-carrying structures. In honeybees and bumblebees, this takes the form of a corbicula, located on their hind legs, which act as a pollen basket. In most other bees, pollen is carried in the scopa, which can also be located on the hind legs,

¹⁴ Ackerman, Josef Daniel. "Abiotic Pollen and Pollination: Ecological, Functional, and Evolutionary Perspectives." *Pollen and Pollination*, 2000, 167-85.

or the lower abdomen.¹⁵ As bees collect pollen to bring back to the hive, some of the pollen is inadvertently lost from flower to flower resulting in pollination.

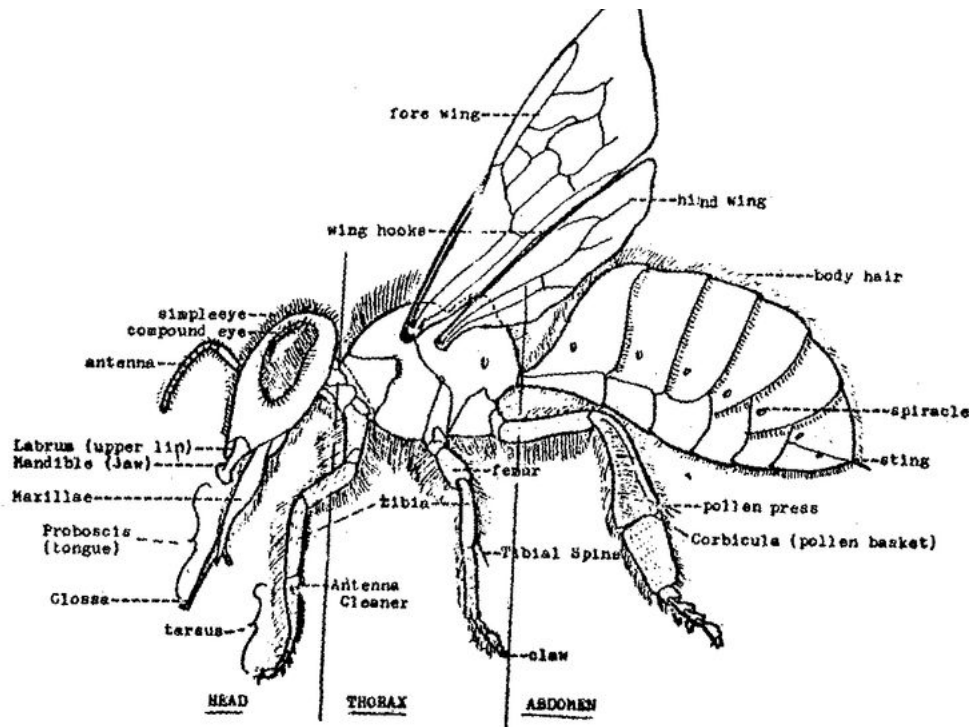


Figure 2.2: Anatomy of Worker Bee. To carry pollen from flower sources to the hive worker bees have specialized Corbicula structures, or pollen baskets, which allow them to store the resource along their journey. (Source: Peace Corps, 1978)

Floral Relationship

Bees role in ecologic diversity is dependent on the types of plants that they pollinate. The majority of bees are polylectic, meaning they gather pollen from an assortment of flower sources, while some are oligoleges, and prefer pollen from only one or a small number of closely related flower species.¹⁶ Bees are capable of

¹⁵ Westbrook, Fred E., Paul Bergman, and Robert Wearne. *Pollination and the Honey Bee*. Washington, D.C.: U.S. Government Printing Office, 1975.

¹⁶ Ollerton, Jeff, and Nickolas Merritt Waser. *Plant-pollinator Interactions: From Specialization to Generalization*. Chicago: Univ. of Chicago Press, 2007.

determining a pollens desirability from different flower types in multiple ways. Typically, bees will use their senses to acknowledge different pollen sources, either visually looking for ultraviolet patterning on flowers or through the scent of floral odors. In some cases, electromagnetic fields can even help determine pollen preferences. Once the bee has landed on the flower, it can determine its preference for the pollen source based on taste and nectar quality.¹⁷

Social Structures

Although some bees live in solitary, many species live in a variety of complex community structures. The most advanced bees live in eusociality, which is the highest level of social organization found in a variety of insects, crustaceans, and mammals. Eusociality is characterized by divisions of labor, overlapping and layering of generations with a colonies social group, and cooperative care for its offspring.¹⁸

Honeybees and stingless bees are examples that exhibit highly eusocial behavior. Stingless bees live in perennial colonies and practice mass provisioning, in which mothers prepare for their offspring by stockpiling enough food to sustain them before she lays eggs. Both Honeybees and stingless bees have a complex division of labor where from young ages the bees begin a regimented and evolving series of tasks that supplement the reproductive functions of the single queen bee.

The most immature bees are typically tasked with the menial work of cleaning out cells. As they grow, they are tasked with more complex jobs, the next of which is

¹⁷ Dafni, Amots, Michael Hesse, and Ettore Paccini. *Pollen and Pollination*. Place of Publication Not Identified: Springer, 2013.

¹⁸ Wilson, Edward O. *The Insect Societies*. Cambridge, Mass.: Belknap Press, 1992.

to help feed the queen and larvae. Once the beeswax glands have matured, a majority of their attention is turned towards building both living and storage structures for the colony. The next job of mature bees is to begin the process of unloading and stowing away pollen and nectar brought back to the hive by foragers. Eventually, adult bees are tasked with guarding the hive entrance and foraging for food sources to supplement the colony. Foraging, a dangerous job, is generally the last task of a worker bee, and generally is continued until the bee dies from old age, after roughly three to five weeks.¹⁹

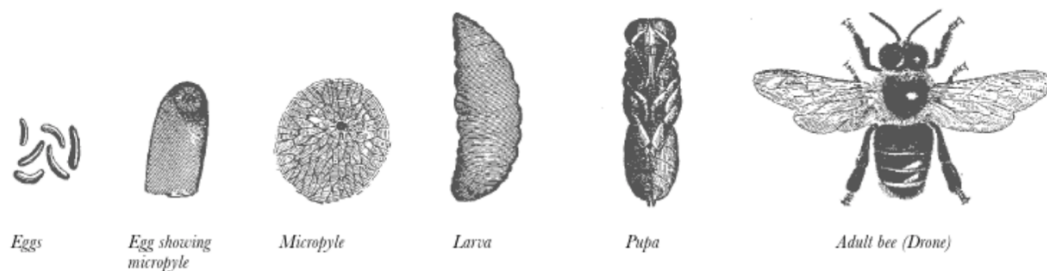


Figure 2.3: *Stages of Bee Development.* (Source: *The Bee: A Natural History*, 2014)

Navigation and Communication

The act of foraging relies on sophisticated navigation and communication techniques that allow them to find food sources and safely return to the hive. Ethologist Karl von Frisch studied the various navigation techniques used by bees and discovered a means of communication that is achieved through dance, termed the waggle dance, which communicates the location of known pollen and nectar sources to fellow workers within the hive. Primarily using the sun as a compass, the

¹⁹ Gould, James L., and Carol Grant. Gould. *Animal Architects: Building and the Evolution of Intelligence*. New York: Basic Books, 2012.

bee's dance points in the direction of the food source providing a path for the unemployed worker bees in the hive to fly towards.²⁰ The duration of the dance indicates to the bees watching the distance the source is from the hive.

Stingless bees use scent as a communication device to signal found food sources. When a forager returns to the hive after finding a rich pollen or nectar source, it will fly throughout the hive buzzing. The scent of the flower source on the bee's waxy hairs will excite the unemployed worker bees who will subsequently set out to search for the same smell. Like honeybees, the search for the odor comes easily as they can detect and recognize the distinct odors of different locations. Another technique that some stingless bees use is a sophisticated mapping system created by a forager returning to the hive upon finding an abundant food source. This forager will make short stops every few yards leaving a distinct scent marker along the way. Upon returning to the hive, the waiting worker bees are then able to follow these scent markers to the food source.²¹

Architecture

There is an inherent and profound architecture associated with bees. Their building abilities are perhaps the greatest among all other insects. Although construction methods and techniques vary from species to species, the defining traits that characterize bee construction include the use of highly efficient structural

²⁰ Frisch, Karl Von. *The Dancing Bees An Account of the Life and Senses of the Honey Bee*. London: Methuen, 1966.

²¹ Gould, *Animal Architects: Building and the Evolution of Intelligence*, 2012.

geometric systems, sophisticated material applications, and complex spatial program organizations.

Elegant use of building materials allows bees to incorporate environmental protection into their designs. The development of waterproofing elements provides elements of environmental protection and insulation from unfavorable conditions. Some species collect plant resins and tree sap, which they mix with either pulp or mud, to create a waterproofing material, called batumen. To make this even more efficient, bees often add wax, which they produce in special glands. Beeswax performs well in higher temperatures, retaining structural integrity well over 100o F, making the waterproofing mixture a long-term sustainable material. Other species of bees use wax as a thin waterproofing varnish, which they apply around cells and tunnels to create an environmental shield.²²

Bees also employ defensive structures through material resourcefulness. Stingless bees typically use Batumen as a protective membrane, which can range from one to three inches in depth. This batumen layer protects against attacks from both above and below the nest if located in a hollow tree trunk. Some bees also use a mixture of plant resin, sap, and wax, known as cerumen, as a defensive membrane. Instead of being applied as a solid membrane like batumen, cerumen is applied into multilayer insulating sheets to provide protection.

Storage of both pollen and honey are essential to sustain a bee colony. Stingless bees use cerumen to construct storage pots within their nest to stockpile their feeding supplies. Honeybees use a different method for storage. Rather than building specialized storage pots, they store pollen and honey directly in the

²² Gould, *Animal Architects: Building and the Evolution of Intelligence*, 2012.

hexagonal honeycomb cells for which they also keep their brood. For honey bees, these cells are constructed entirely of beeswax.²³

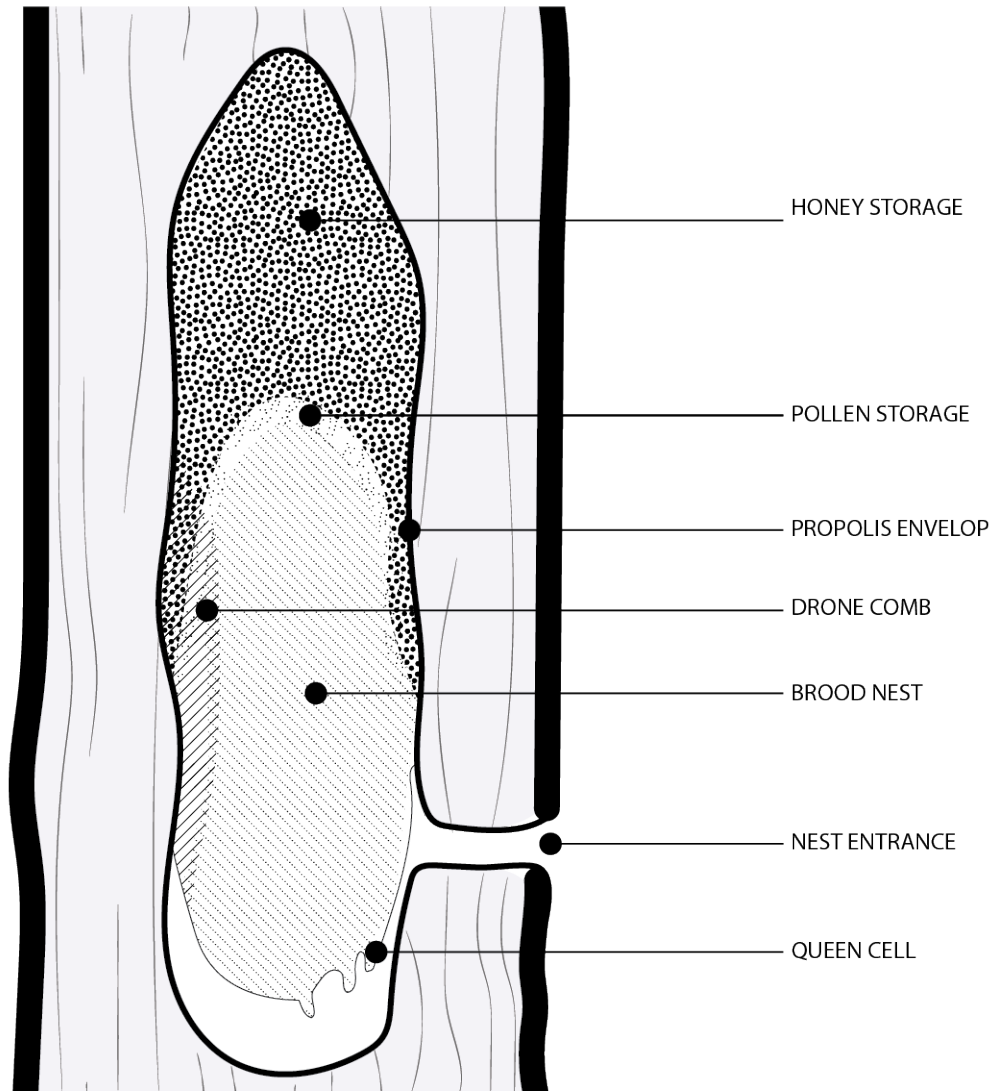


Figure 2.4: Honeybee Nest Section Within Hollow Tree (Source: Author, 2019)

²³ Gould, *Animal Architects: Building and the Evolution of Intelligence*, 2012.

Honeycomb structures used by honeybees develop through an additive process. As additional space is needed new hexagonal cells are added vertically from the top down. Cells are built out horizontally and attached back to back creating a double-sided layer. The geometric properties of this structural organization are incredibly efficient. One ounce of wax derived honeycomb can sustain a load of two pounds of honey, pollen, larvae, and pupae.²⁴

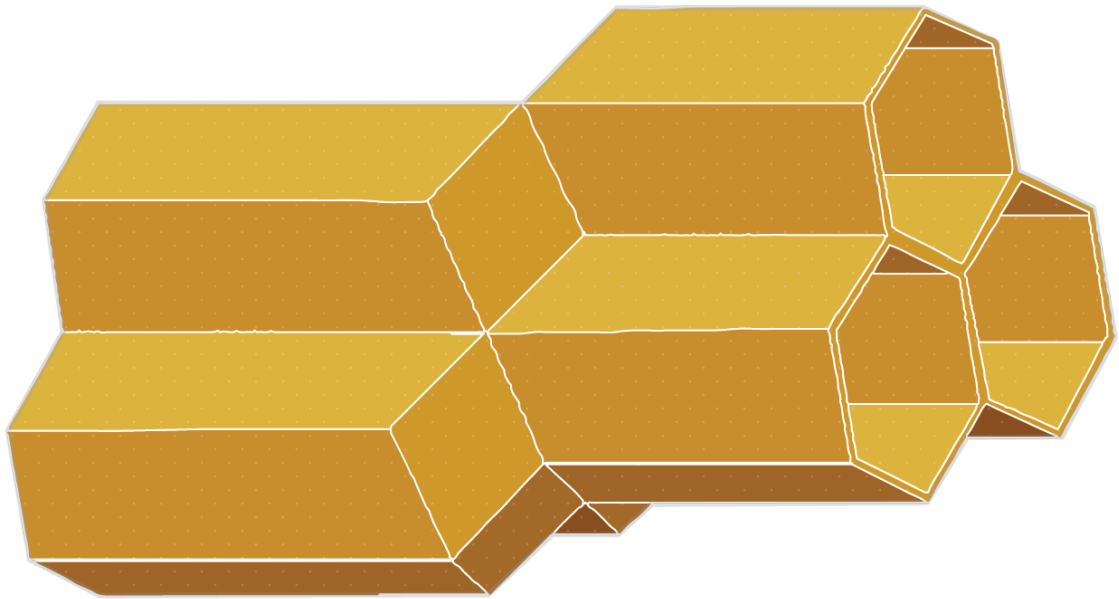


Figure 2.5: *Opposing Layers of a Honeycomb.* (Source: Author, 2019)

²⁴ Gould, *Animal Architects: Building and the Evolution of Intelligence*, 2012.

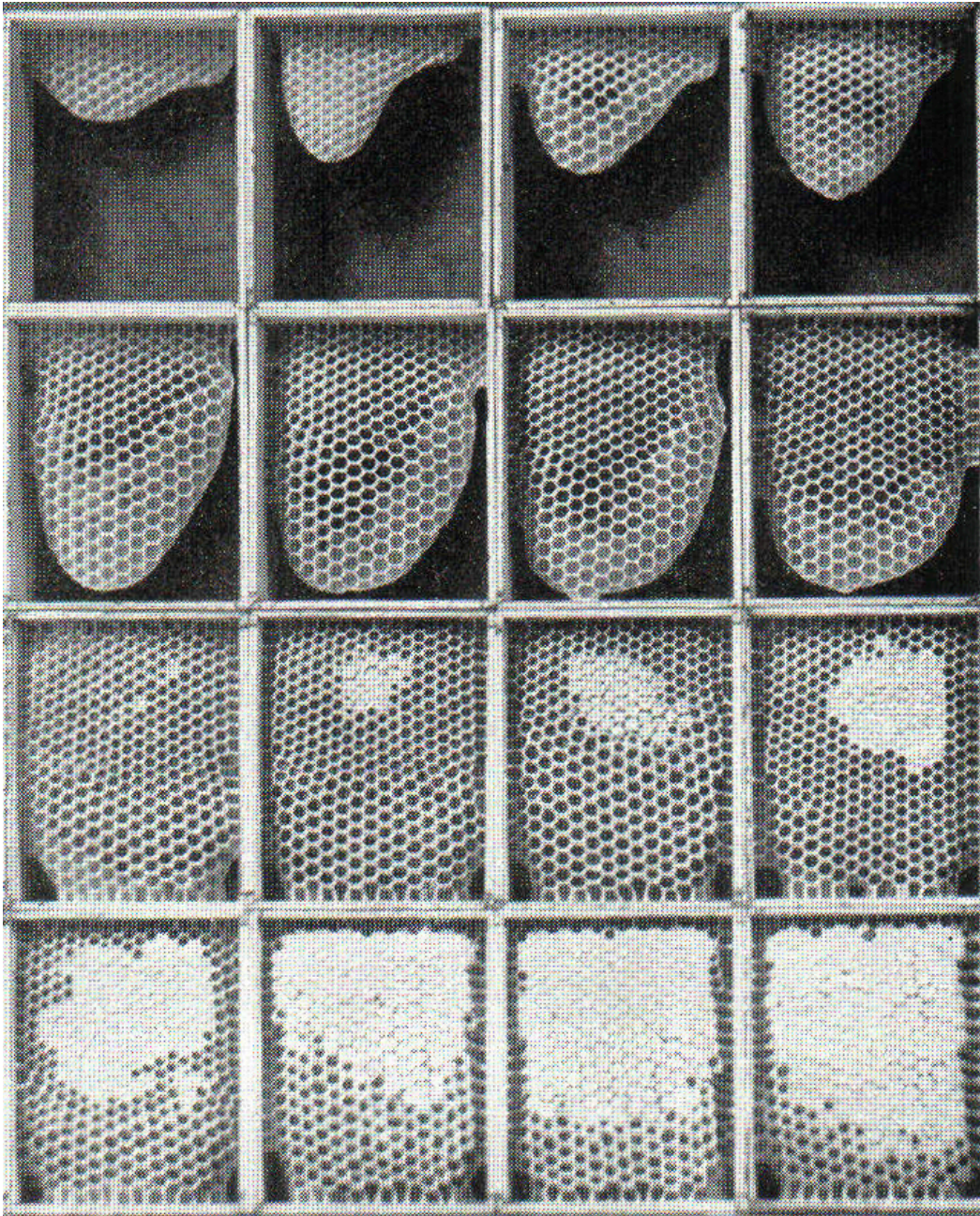


Figure 2.6: Time Lapse of Honeycomb Construction in artificial hives. The bees build from the top down filling in as additional space is needed for honey storage. (Source: Chandler B. Beach, 1914)

3. Concept

Urban Apiaries

Our relationship with bees goes beyond our reliance on them for commercial pollination. For centuries, Apiarists have worked to collect and produce the natural resources generated by bees. Honey, wax, propolis, and venom are typically harvested by beekeepers for use as food, alternative natural medicine, candles, lotions, balms, polishes, among other things. This thesis looks to add a new by-product of urban beekeeping to this list: the enhancement of water resiliency as a result of the improved surrounding ecologies that bees will foster.



Figure 3.1: *Bees in the city. Promoting urban pollination through an architecture for apiculture. (Source: Author, 2019)*

Urban Apiaries as a Catalyst for Enhanced Ecology and Resiliency

In addition to creating a rewarding new hobby for city dwellers, urban apiaries are mutually beneficial for the surrounding ecology and improving the declining bee population. Through the process of pollination, urban bees can transform the landscape of cities into rich and resilient ecosystems. With the rising risks of urban flooding, the addition of apiaries can foster green infrastructure capable of reinvigorating the natural cycles that were lost with industrial development. This new infrastructure can limit the damages associated with rising sea levels and climate change and mitigate flood risks with a natural alternative to costly grey infrastructure.

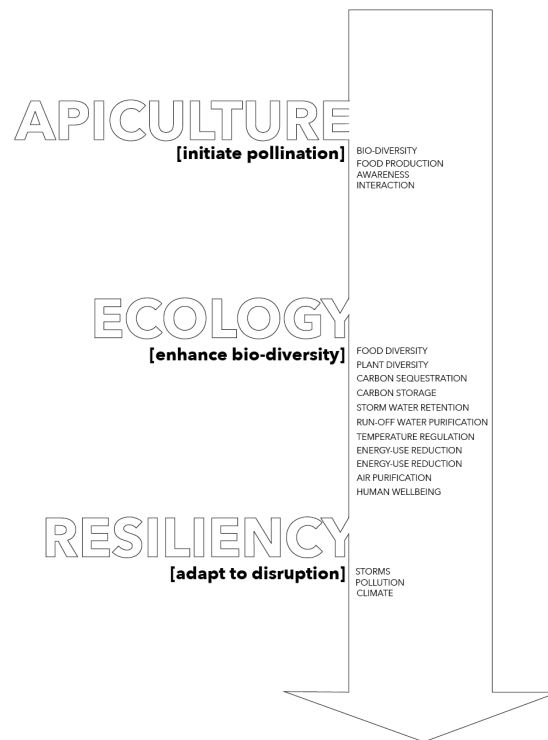


Figure 3.2 Through an architecture that creates place for formal and informal education, research, and on-site apiaries a cyclical process can be introduced into urban environments that enhances biodiversity, promotes resiliency, and reverses the declining bee population. (Source: Author, 2019)

Bees Thrive in the City

Bees have shown to thrive in urban settings, above that of rural and suburban areas. Higher honey yields and bee survival rates have been reported in cities when compared with the countryside. These improved metrics are primarily due to warmer climates, as a result of the urban heat island effect, and less contact with pesticides than on agricultural land. Urban environments also provide a better diet for bees offering more flowers and a varied diet from community gardens. Bee health is improved in the city as the diverse pollen sources improve bee immune function and the proximity of these pollen sources to the hive limits the energy that bees must expend on foraging, lowering their overall stress levels. An example of the higher prosperity and production of urban bees has been witnessed in Boston. From 2010 to 2013, the 200-honeybee hives spread throughout eastern Massachusetts were tracked and the highest honey producing hives each year were consistently either in the urban areas of Boston and Cambridge.²⁵

Legal issues have traditionally limited urban beekeeping due to the fallacy of danger associated with bees. Improved awareness of the benefits of urban bees, an increasing interest in urban beekeeping, and the local food movement have motivated municipalities across the globe to reassess their relationship with bees. Until March 2010, it was illegal to keep bees in New

²⁵ Wilson-Rich, Noah, Kelly Allin, Norman L. Carreck, and Andrea Quigley. *The Bee: A Natural History*. Princeton, NJ: Princeton University Press, 2018.

York City, and by 2016 there were over 300 registered hives throughout the city.

Hive Architecture

Apiary technology has dramatically advanced through time. Early beekeepers in Egypt and Central America traditionally used simple containers that mimicked bee's natural habitat in tree hollows. Made of a combination of natural materials, such as hollow logs, sticks, bamboo, straw, and stone, these hives were challenging to manipulate and often resulted in ruining the hive during harvesting. During the Middle Ages, fixed-comb designs were implemented as natural and inexpensive solutions to beekeeping. In the form of Logs, skeps, and box hives these habitats were still inefficient and inconvenient. Due to the fixed nature of their combs, the hives could not be thoroughly inspected for disease and pests, and the harvesting of honey and wax was a destructive procedure that resulted in the loss of the hive, which either killed the bees or left them homeless.



Figure 3.3 *The architecture of apiculture. (Source: Author, 2019)*

In 1789, the invention of movable combs by Swiss naturalist Francois Huber revolutionized beehives. His Leaf Hives used frames that opened up like pages of a book allowing for the removal of frames without disrupting the hive. This invention then inspired what has become the standard of beehives, the Langstroth Hive, which was patented in 1852. Lorenzo Lorraine Langstroth noticed that honeybees add wax comb to spaces that are wider than $\frac{3}{8}$ ", leading to his introduction of the concept of "bee space," the minimum measurement of $\frac{3}{8}$ " from which bees can comfortably move through.²⁶

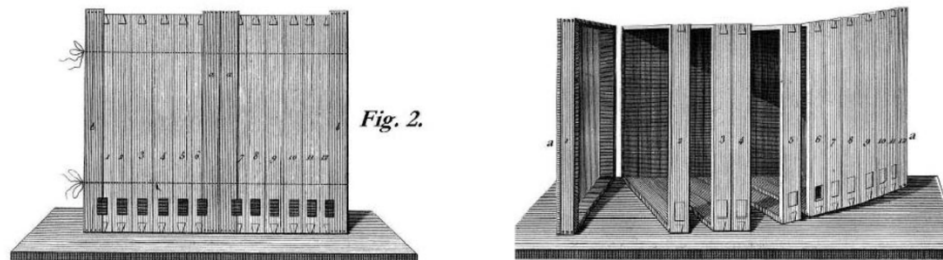


Figure 3.4 Leaf Hive, designed by Francois Huber. Revolutionizing beehives, this design used fully removable frames allowing for easy management. (Source: Francois Huber, 1789)

The Langstroth Hive implemented fully removable frames. These frames were set on two interior ledges, called runners, which support the top bars of the wooden frames. The frames hang freely with their wax comb at a

²⁶ Wilson-Rich, *The Bee: A Natural History*, 2018.

3/8" distance from the hive walls to prevent comb or propolis generation, thus ensuring that the frames remain free to remove from the hive. The hive box rests on a bottom board that has a raised edge to allow for ventilation through a small hive entrance on the front. In response to colony expansion and to prevent overcrowding in the hive, the Langstroth design allows for additional boxes, called supers, to be stacked on top.²⁷

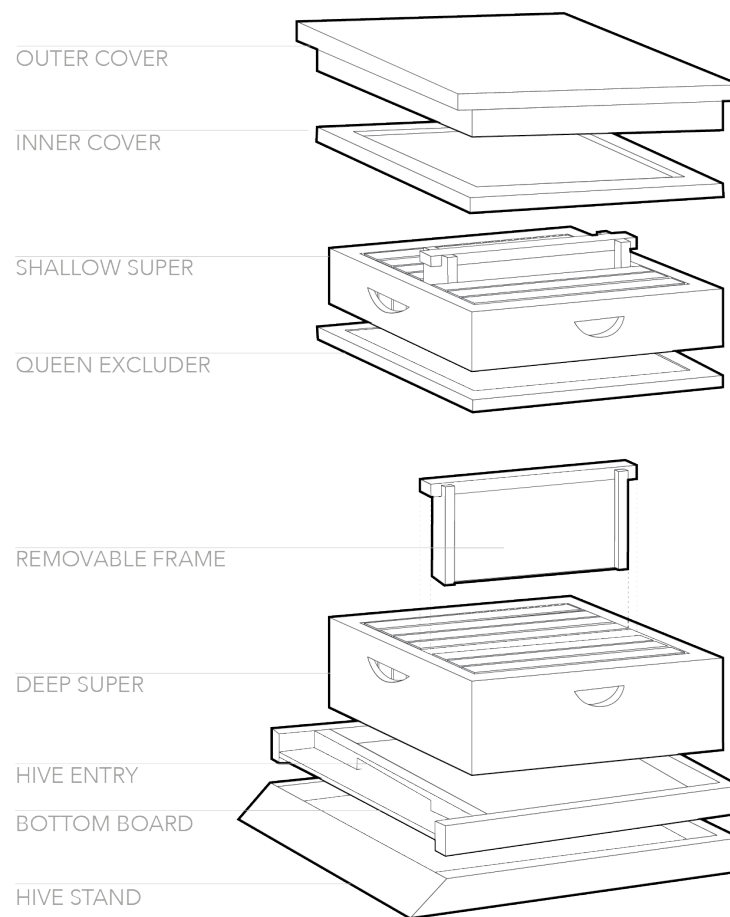


Figure 3.5 Langstroth Hive, designed by Lorenzo Lorraine Langstroth in 1852. This hive implemented the concept of “bee space,” which improved spatial efficiency. The design also made adding additional space easy through the stacking organization. (Source: Author, 2019)

²⁷ Wilson-Rich, *The Bee: A Natural History*, 2018.

Along with the Langstroth hive, the Warre hive and Top Bar Hive are among the most used hives today. Although Warre hives are similar to Langstroth hives in terms of their vertical orientation, they in that they do not use box frames. Instead, top bars are used, which are affixed to each box provide the structure for bees to draw down their comb. A quilting layer is used in the uppermost box that provides insulation for the hive, with a roof enclosure located on the top and entrance to the hive at the bottom. The Top Bar Hive has a horizontal organization while using top bar frames, similar to that of the Warre hive. The horizontal design of the top bar hive makes working with the hive easy, especially for those with physical limitations. Both the Warre hive and the top bar hive are cheap alternatives to the more expensive Langstroth Hive.

Since the 17th century, observation hives have been used for research and educational purposes. These hives use transparent glass walls, which showcase the day-to-day activities of the bees inside the hive. Although not typically used for commercial hives, observation hives can support sustained honey production at similar rates as traditional hives.

As a result of growing concerns of bee population decline and the advancement of modern technology in the 21st century new innovative solutions for apiaries have created a renaissance of apiculture practices. 3D printing technology has enabled new possibilities for hive designs. The Flow Hive, designed by Australians Stuart and Cedar Anderson, uses 3D printed frames that fit into standard Langstroth Hives. These frames are unique in

that they consist of partly formed honeycomb cells which the bees then complete with wax, and subsequently fill with honey. When the frame is ready for harvesting, a key is inserted into the hive that splits the 3D printed honeycomb from the wax portion releasing the honey, which drips to the bottom of the hive and flows out of a tap to be jarred. Once the honey is emptied, the frames can be reset for a new cycle of honey production. This process does not require smoking of the hive as the bees can remain in place during the process without any fatalities.²⁸

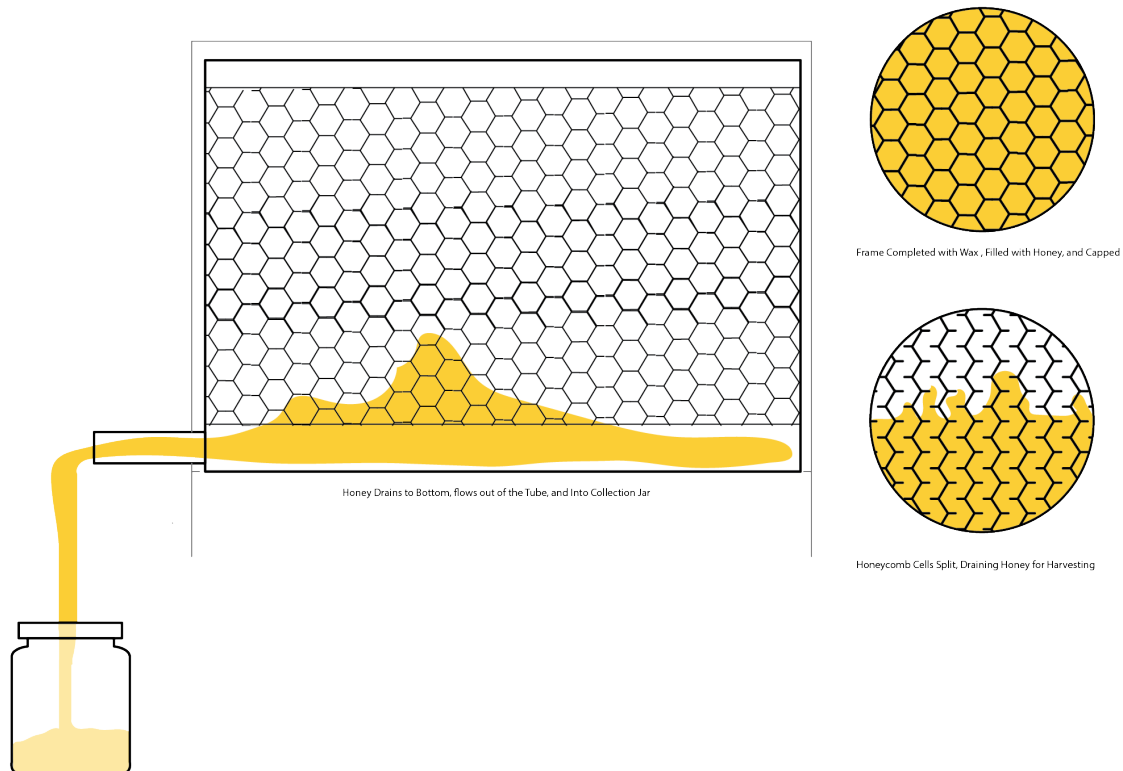


Figure 3.6 Flow Hive Frame draining honey without needing to remove the frame from the hive. (Source: Author, 2019)

²⁸ "Flow Frame." How Flow Works - Flow Hive. Accessed April 25, 2019. <https://www.honeyflow.com/about/about-flow/how-flow-works/p/62>.

A new Italian startup, Beeing, has introduced a patented hive that is specifically designed for urban beekeeping. The design allows apiarists to extract honey without coming into contact with bees by separating the spaces where the bees live and where they store honey. The hive also uses a chimney that raises above the head height of people on the ground allowing the bees to depart and arrive the hive above the pedestrian elevation level. Glass is used for the honeycombs allowing for observation of honey production. Materials include cork, which helps maintain a suitable standard temperature for the bees and waterproofing materials that protect the hive from the elements. These design strategies enable new measures of convenience and safety for urban beekeeping.²⁹

Locating the Apiary

Apiaries can improve the surrounding environment, however locating them requires careful considerations for both success and public safety. Urban apiaries have traditionally found successful homes atop of the bounty of rooftops available in cities. Rooftops reduce many of the risks posed to pedestrians by being raised above the public domain. However, rooftop apiaries have drawbacks in terms of access and maintenance due to the requirement of having to climb stairs in order to reach the hives, which can become a hassle when carrying the equipment associated with beekeeping.

²⁹ "B-hive Your Bees Your Honey. Produce Honey by Yourself." Beeing. Accessed April 25, 2019. <https://beeing.it/en/b-hive-yours-urban-beehive/>.

Backyard apiaries offer convenience of access and visibility. However, traditional hives do little to keep bees from flying at the pedestrian level when departing or approaching the hive. This issue requires landscaping interventions that can dictate the bees fly path. Trees and shrubs placed near the entrance of the hive can force bees to fly above them when coming to and leaving the hive, thus setting their flight path above the pedestrian elevation. Modern hives that implement a raised chimney hive entrance bypass this issue.

When locating apiaries on the ground it is important to consider adjacent pedestrian paths, streets, and neighboring buildings. Although many cities, such as NYC, do not require setbacks it is good practice to be respectful to surrounding environments. The Long Island Beekeepers Club suggests that hives be kept at a minimum of 10 feet from neighboring property lines.³⁰ Good urban beekeeping practices also suggest the use of barriers with heights at a minimum of 6 feet, such as hedges and fences, to be used as a way to deter the flight path of bees up and away from the pedestrian realm.³¹

³⁰ "Long Island Beekeepers Club." LIBC Beeline News. Accessed April 25, 2019. <http://www.longislandbeekeepers.org/>.

³¹ Wilson-Rich, *The Bee: A Natural History*, 2018.

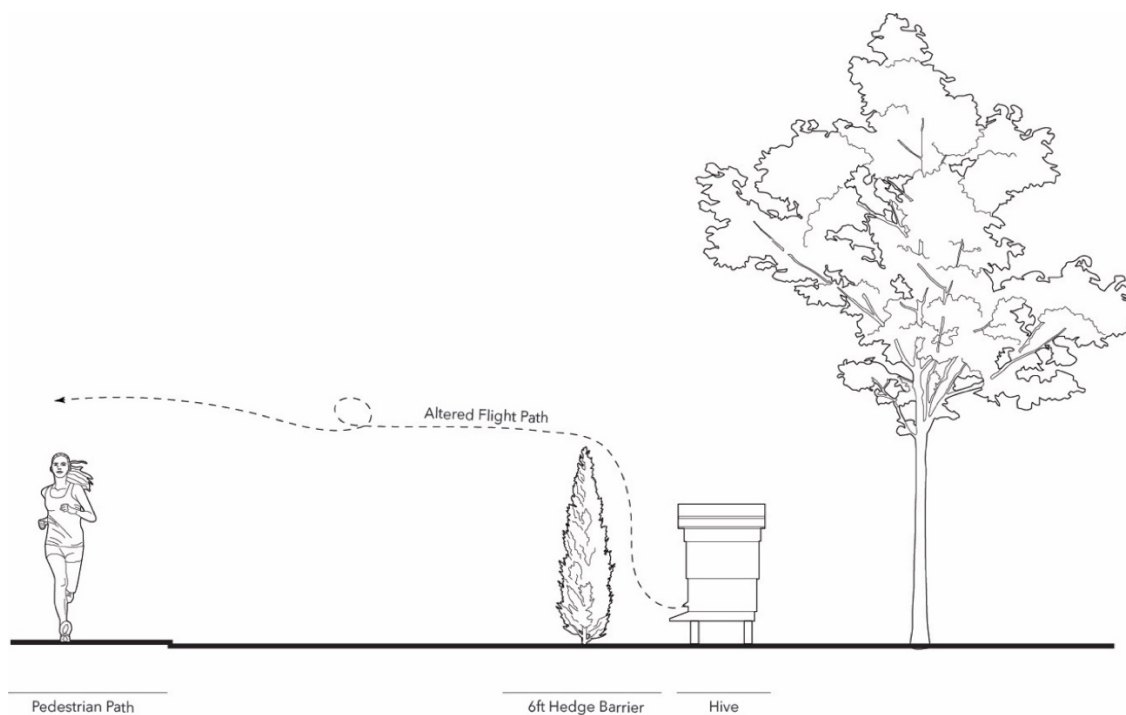


Figure 3.7 *Flight path diagram. Good urban beekeeping practice is to alter the flight path of bees as the approach and depart the hive with a minimum 6-foot barrier, such as a fence or hedge. (Source: Author)*

The number of apiaries and the distance from one another depends mainly on the surrounding ecological environment. Bees can travel up to five miles foraging for pollen sources, but the longer the distance, the more stress is put on the bee, which can limit their lifespan. Apiarists can choose to locate successive hives adjacent to one other, separated by a minimum of 2", or can choose to spread them out further. This decision is primarily based on preference as both are viable options. However, choosing to spread hives further away from each other can limit disease and the potential for drift between hives.

Other considerations for urban apiary setup include access to water and shading. Bees require nearby water sources for survival. Making sure

that this need is met can be as simple as providing localized fountains or locating the hives next to waterways. In the summer season, hives can get extremely hot, which increases the stress of the colony. During the hot mid-day hours offering shading will promote a healthier bee. However, providing morning and evening sun can be of benefit as well.

Beekeeping Tools and Equipment

When tending the hives, beekeepers must be prepared with the proper equipment and protective attire. While working with bees using traditional hives, apiarists generally wore a beekeeper suit for safety and protection. A typical suit can come in the form of a jacket or entire bodysuit, gloves, and a veil. This uniform will offer ventilation and provide appropriate visibility, while also protecting against potential bee stings.



Figure 3.8 Typical beekeeping equipment. (Source: Author, 2019)

On top of the outfit, when working with a traditional hive, beekeepers should also be equipped with a smoker, bee brush, and a multi-purpose hive tool for extracting the frames from the hive. Before removing frames from the hive, a smoker is used to trigger a feeding instinct, which makes the bees less aggressive, while simultaneously obscuring the pheromones that bees use in communicating with one another. A hive tool helps in the process of removing the frame from the hive without killing any bees. Once the frames are removed from the hive, a bee brush can be used to remove any bees still on the frame, before transporting the frame to a safe area to extract the honey.

Modern hives, such as the Flow Hive and Beeing Hive, limit the need for traditional equipment. The Flow Hive does not require the frames to be removed during honey extraction limiting the need for a smoker or bee tools. The Beeing Hive separates the bees living space from the honey storage area ultimately limiting the need for any traditional bee equipment during the extraction process.

Harvesting and Production

Harvesting honey is one of the most rewarding aspects of working with bees. Honey requires no additives or processing of any kind after extraction making it edible as soon as it is removed from the honeycombs. The extraction process can be achieved using equipment or manually depending on the number of frames being harvested.

Once a bee has filled a cell with honey, they close the cell with a wax capping. The first step in extracting the honey is to scrape off the wax cappings from the top of each honeycomb cell allowing the honey to flow out. This process is typically achieved by using a knife to scrape away the wax cap.³²

Once the wax cap is removed, the honey is ready for the extractor, either manually or using an extractor. The manual process of extraction involves scooping or pressing the honeycomb into a bowl and then filtering the honey into a jar through a cheesecloth. The more efficient way to remove honey is by using a honey extractor. This machine removes the honey with little human effort by spinning the frames within the cylindrical container. The centrifugal force of the rotation flings the honey out of the open honeycomb cell onto the side wall of the extractor, which eventually pools down at the bottom and is pumped out into jars for storage. Honey extractors can vary in size from holding a couple of frames up to 60 frames to fit the needs of both small-scale and commercial operations. Smaller extractors can typically be powered manually, while commercial extractors utilize an electric motor for efficiency.

³² Wilson-Rich, *The Bee: A Natural History*, 2018.



Figure 3.9 *The process of uncapping wax with a knife and honey being extracted using a multi-frame electronic extractor. (Source: Joshua Hennig, 1954)*

Another bee product that can be extracted for use is wax. Beeswax has many applications for use, such as for candles, preservatives, polishes, coatings, lotions, and balms among other things. Wax accumulates as a by-product of honey harvesting and can also be extracted from the honeycombs themselves. Wax typically includes impurities, such as dirt and pollen, and requires some filtering and processing before being usable. Purifying wax can be done by melting down the extracted solid wax in a pot of boiling water and then pouring the hot liquid through a strainer into a clean pot. During the cooling process, the wax will rise to the top above the water and harden. The hardened wax can be removed and is then ready for storage or to be used.³³

Bees also produce substances that can be used for natural alternative medicines. Propolis is a sticky material derived from the mixture of beeswax and tree resins creating a substance that has antimicrobial properties. Bees

³³ Wilson-Rich, *The Bee: A Natural History*, 2018.

use propolis as a sealant for unwanted open space inside the hive, that reduces bacteria growth and has thermal insulating properties. Propolis can be chipped off the interior of the hive for use in creams and tinctures that aid in healing wounds.

Data Tracking

Tracking and recording data on bees has always been good practice for beekeepers. With the rising health risks that bees face data tracking is more important now than ever. When working with bees, it is essential to track productivity, bee health, and potential for swarming. Traditionally, these metrics have been tracked manually; however new technology has made this more manageable with the introduction of “smart hives,” which are app-based tracking services that provide real-time reports on trends and risks.

When looking at bee productivity, apiarists should track honey and pollen levels. This data can provide insight into the health of the queen bee. Health checks should examine the colony for disease, pests, and population, which can help to reduce the risks associated with Colony Collapse Disorder. The size of the colony, along with the number of queen cells present in the hive, is critical data that can inform the risk of a potential swarm. Reducing the risk of swarming is crucial, especially for urban beekeepers, as this is the most significant risk posed to the general population near the apiary.³⁴

³⁴ Wilson-Rich, *The Bee: A Natural History*, 2018.

Smart hives significantly reduce the labor of manual data tracking making it an ideal application for urban beekeepers and novice beginners. Pollenity, a new startup that aims to save the declining bee populations, offers in hive data trackers that provide data to help beekeepers make informed decisions in response to their colony's health and productivity. Smart hives are gaining popularity among aspiring new apiarists, as it eases the risk of a failing hive by handling the technical and more advanced aspects of beekeeping.³⁵

Urban Resiliency

Climate change has caused rising sea levels and increased both the frequency and strength of superstorms. Water has become a paramount environmental issue that affects both urban and rural areas worldwide. Natural disasters, such as Hurricane Sandy, have brought attention to the issue, prompting research and investments in resilient solutions. Studies have shown that green infrastructure is both an economically and environmentally beneficial solution when compared with its grey infrastructure counterpart. This thesis aims to explore how the enhanced ecologies that result from increased pollination efforts of apiary installments in urban areas can promote resilient green infrastructure that protects critical flood areas from natural disasters.

³⁵ "Innovative Beehive Monitoring System by Pollenity." Pollenity. Accessed April 25, 2019. <https://pollenity.com/>.

Green Infrastructure

The risk of flooding depends on several factors including the amount of rainfall, topography characteristics, river-flow, drainage systems, and tidal-surge. Plants play a crucial role in successful green infrastructure that helps mitigate these flood risks. Green infrastructure relies on the implementation of plants and permeable areas in a decentralized and integrated network that aims to reduce storm-water runoff in a way that mimics the pre-development water cycle. Developed areas can also apply green infrastructural solutions by way of green roofs and greywater recycling and reuse initiatives, which collect stormwater for use or to be held and slowly released into the water system after a storm has subsided.

The introduction of bluebelt masterplans in watershed areas has proven to be an efficient and cost-effective solution to manage flood risks. In Staten Island, NY an award-winning bluebelt program was initiated in the early 1990s serving as green infrastructure for 12,000 acres focused on a watershed area at the southern end of the island. Using a series of carefully placed natural drainage corridors made up of streams, ponds, and other wetland areas the Bluebelt provides both open community space and performs the function of storing, conveying and filtering polluted stormwater. New York City saved roughly \$300 million to construct the bluebelt system, compared to a grey water infrastructure system alternative.³⁶

³⁶ "A Natural Solution to Stormwater Management." The Bluebelt Program. Accessed April 25, 2019. <https://www1.nyc.gov/html/dep/html/stormwater/bluebelt.shtml>.

Plants play a crucial role in green infrastructure flood mitigation efforts. Whether used along shore edge wetlands or inland systems for retention and drainage the ecological service of plants is essential for water resiliency. Plants are capable of both limiting stormwater accumulation on land and cleansing polluted rainwater before it is directed back into larger bodies of water.

Inland Stormwater Management

Green infrastructure stormwater management works to mitigate flooding risks by either retaining or effectively draining water. Urban flooding typically occurs when rainwater accumulates on the overabundance of impervious surfaces in cities, such as paved streets, quickly overpowering grey infrastructure drainage systems. Using green infrastructure interventions can help reduce this load of combined sewer systems by collecting, storing, and slowly draining water at peak flow periods. This is achieved by transforming drainage systems to be more compatible with the elements of the natural water cycle, such as bio-filtration and soil percolation.

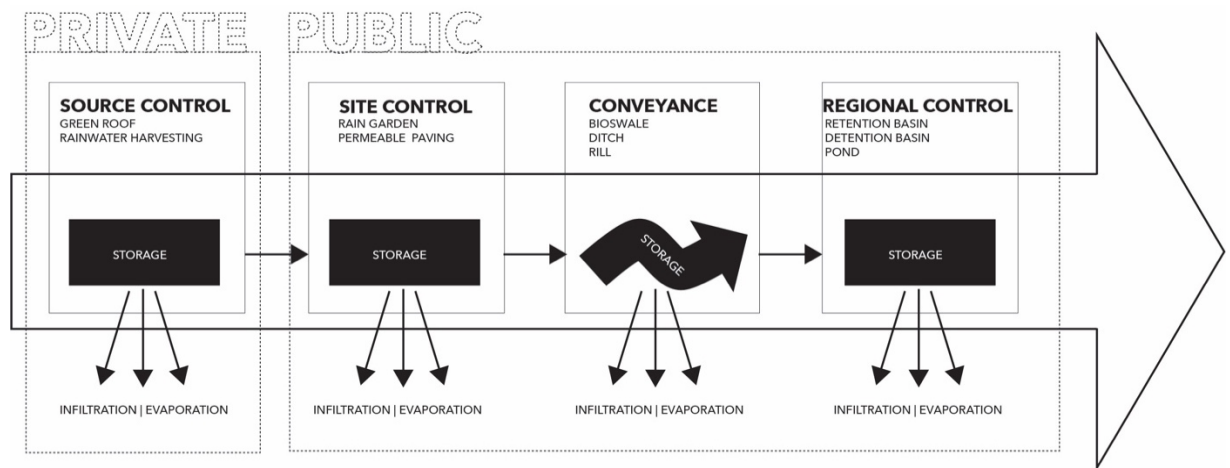


Figure 3.10 Sustainable Urban Drainage System (SUDS) model for stormwater management. (Source: Author)

The Sustainable Urban Drainage Systems (SUDS) model looks at four distinct areas for managing rainwater. The first is controlling the water at the source, which typically occurs in the private realm. Source control efforts include green roof applications and rainwater harvesting efforts by buildings. Green roofs are classified as a roof that is partially or entirely covered with vegetation, using either intensive or extensive designs. The benefits of rooftop vegetation include the ability to reduce stormwater runoff by initially storing rainwater in the substrate, which is then taken up by the plants and returned to the atmosphere through the process of evaporation and transpiration. Evidence shows that extensive green roofs with 4 inches of substrate intercept 70 - 80% of rainfall events.³⁷ Excess water that is not

³⁷ Stovin, Virginia, Gianni Vesuviano, and Hartini Kasmin. "The Hydrological Performance of a Green Roof Test Bed under UK Climatic Conditions." *Journal of Hydrology* 414-415 (2012): 148-61.

absorbed by the green roof is delayed by the filtration process, increasing the time at which runoff occurs, thus limiting the stress of stormwater on the ground and grey water drainage systems. Buildings can also reduce rainwater runoff by incorporating rain barrels and cisterns that collect the water on site to be recycled for use in the building later on.³⁸

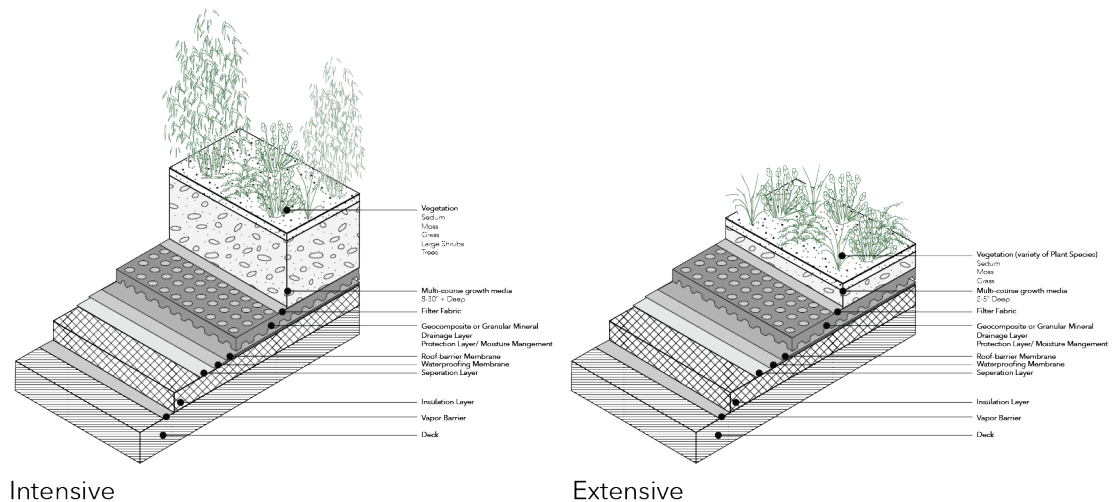


Figure 3.11 Intensive vs. Extensive Green Roof. (Source: Author, 2019)

Site control can be used to limit the rainwater runoff from buildings and surrounding impervious surfaces. Efforts for site control can include rain gardens, permeable surfaces, and tree plantings. Once the water has left the roof, it can be sent to a rain garden, which is a shallow basin for holding and draining rainwater. Rain gardens are typically 6" deep or less, filled with free-draining and absorbent soil, such as coarse sand and organic material. Plants are included to help with the drainage process and need to be capable of

³⁸ Grant, Gary. *The Water Sensitive City*. Chichester, West Sussex, United Kingdom: John Wiley & Sons, 2016.

surviving in both dry and wet conditions. Capable of flooding for one or two hours, the plants and organic substrates in these gardens can also help cleanse water as it filters downward. In heavy rain conditions, rain gardens can be designed to overflow into larger bio-swales, conventional drains, or other green infrastructure drainage sources.³⁹ The effectiveness of rain gardens can be seen in Portland, Oregon, which was subject to a 25-year short-duration, high-intensity storm in 2003. As a result of the Glencoe Rain Garden, peak flows were reduced by 80% and delayed by 28 minutes.⁴⁰

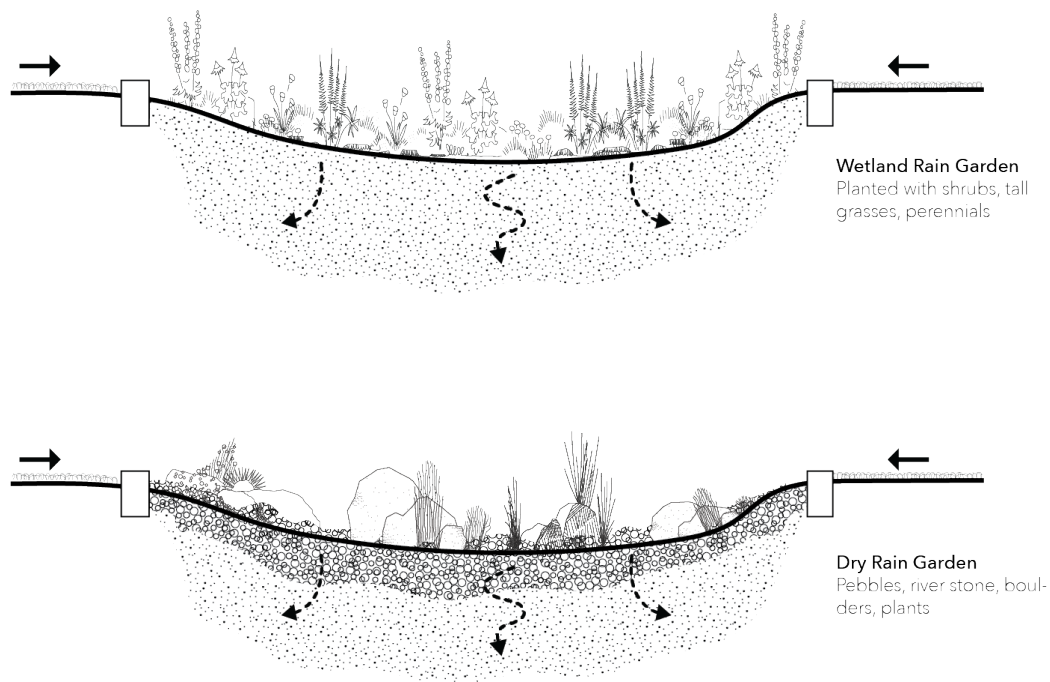


Figure 3.12 Rain garden cross section. (Source: Author, 2019)

³⁹ Grant, *The Water Sensitive City*, 2016.

⁴⁰ PortlandOregon.gov | The City of Portland, Oregon. Accessed April 25, 2019. <https://www.portlandoregon.gov/bes/article/63096>.

Once rainwater has been absorbed through site source green infrastructure, overflow can be handled through the process of conveyance with bio-swales, ditches, and rills. Although similar to rain gardens in appearance, bio-swales differ in that they are sloped to a particular destination as a way to move water, while simultaneously allowing it to be filtered and absorbed. Four main types of bio-swales can be deployed depending on the needs of the location. Low grass bio-swales offer ease of maintenance, as they can be cared for similar to a typical yard but are less effective in treating and collecting stormwater runoff. Vegetated bio-swales use taller growing plants and shrubs, ornamental vegetation, and even trees. Rocks are typically also used to slow down stormwater runoff and to increase collection time for pollutant cleansing. Low water bio-swales are designed for dry and hot climates, and typically only hold stormwater runoff only after storms, remaining dry for the rest of the time. Similar to wetlands, wet bio-swales are designed to collect and retain water for extended periods, allowing for the majority of stormwater to be infiltrated rather with overflow discharged into conventional storm drains built into the swale or at the end of the swale.⁴¹

⁴¹ Caflisch, Mary, and Katie Callahan. "An Introduction to Bioswales." Home & Garden Information Center | Clemson University, South Carolina. May 25, 2015. Accessed April 25, 2019. <https://hgic.clemson.edu/factsheet/an-introduction-to-bioswales/>.

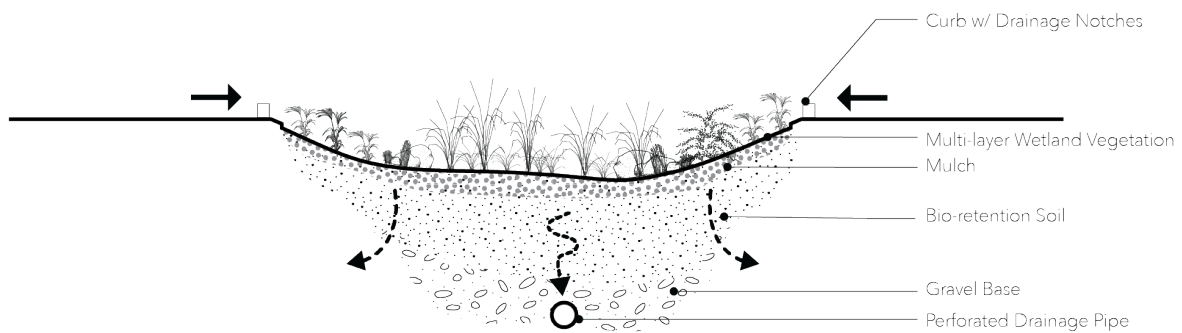


Figure 3.13 Bio-swale cross section. (Source: Author, 2019)

With large storm surges, regional water control measures can act as the final step to protect against flood events. At this scale, large ponds and detention/retention basins provide additional attenuation, storage, and cleaning of stormwater runoff. Detention basins are depressed open spaces, often covered with grass/vegetation, that can be filled with overflow water during flooding events. Typically, these basins include a throttled outlet, which can slow and control outflows. In dry conditions, detention basins can act as informal recreation spaces. Typically, attenuation ponds remain in a wet state and are designed with extra depth to accept an influx of water during storms. Ponds can include wetland vegetation helping to maximize the ponds ability to filter and decontaminate polluted runoff water.⁴²

⁴² Grant, *The Water Sensitive City*, 2016.

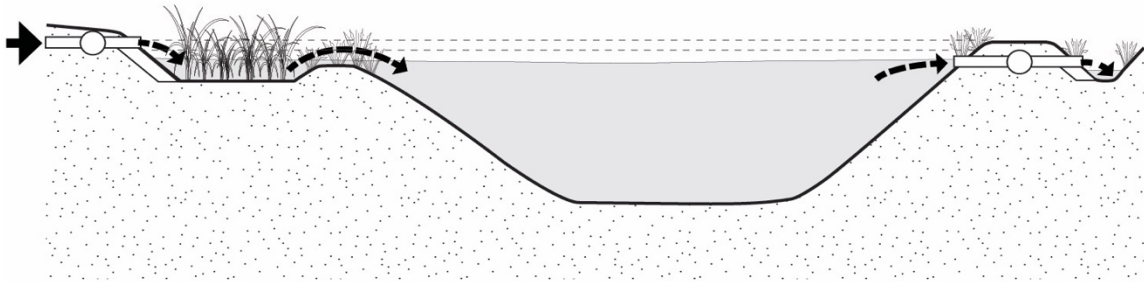


Figure 3.14 Retention Basin cross-section showing inflow and outflow during storm surges. (Source: Author)

Resilient Edges

Rising water levels resulting from climate change and superstorms are increasing threats to flood mitigation. Edge conditions in urban areas play a critical role in deterring flood risks. The traditional approach to edge protection is to replace sloping vegetated banks with vertical, armored walls as a response to the industrial requirements for ships and vessels to be berthed, loaded, and unloaded. This approach, although historically beneficial for industry, has proven to be damaging to wetland biodiversity, which previously had provided natural resiliency services. The removal of wetland vegetation along river edges has also been a significant contributor to declines in water quality.

Resilient edges also on riparian buffers and floodable fields that allow periodic inundation to reduce inland flooding. Floodable fields allow water to spill out of river channels onto an area with natural land cover providing a

place for temporary flooding, which reduces the pressure on levees and more sensitive areas downstream during times of peak flow. The lightly vegetated floodplain allows water to infiltrate to the subsurface when temporarily flooded while offering a public recreational space when dry.⁴³

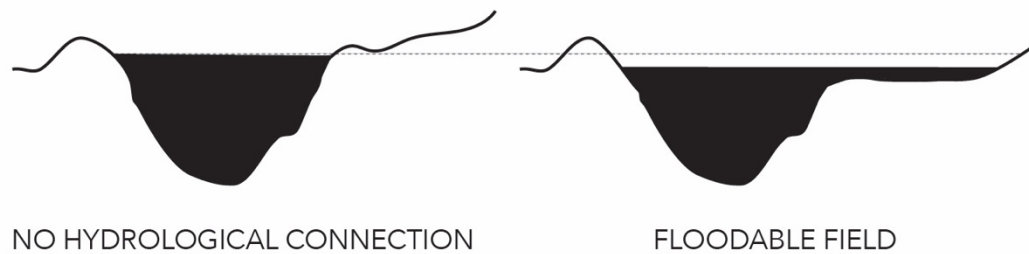


Figure 3.15 Floodable Field Diagram. (Source: Author)

Riparian zones act as natural shoreline buffers in the interstitial zone between land and water. Including a combination of wetlands, grasslands, and woodlands riparian buffers service a plethora of environmental services including filtering pollutants as water moves from land to water, providing storage for floodwaters, creating diverse habitats for wildlife, providing erosion stability through root mass, and allowing water to meander naturally. Typically ranging from 20 to 250 feet, these buffers are often broken up into terraced zones that reflect the environmental changes which mediate the change from wet to dry landscapes.⁴⁴

⁴³ McDonald, Robert Ian. *Conservation for Cities: How to Plan and Build Natural Infrastructure*. Washington, DC: Island Press, 2015.

⁴⁴ NYC Department of Environmental Protection. *Innovated and Integrated Stormwater Management Report*. New York, NY: Water Research Foundation, 2017.

Wetlands are one of the most biologically diverse ecosystems that support the life of a diverse range of plant and animal life. The ecological benefits of healthy wetlands include water storage, groundwater replenishment, shoreline stabilization, water purification, biodiversity, and climate change adaptation.⁴⁵ Wetland plants play an essential role in flood mitigation primarily through shoreline stabilization, wave attenuation and water storage. For example, marshes ecologies are effective in erosion control due to their plant roots ability to hold and bind sediment together. Wetland plants also slow down water as it moves through them encouraging sediment deposition that can maintain and even help raise marsh elevations over time. Wave attenuation is also achieved due to the friction of the wetland vegetation causing wave energy to dissipate.⁴⁶

⁴⁵ Grant, *The Water Sensitive City*, 2016.

⁴⁶ McDonald, Robert Ian. *Conservation for Cities: How to Plan and Build Natural Infrastructure*. Washington, DC: Island Press, 2015.

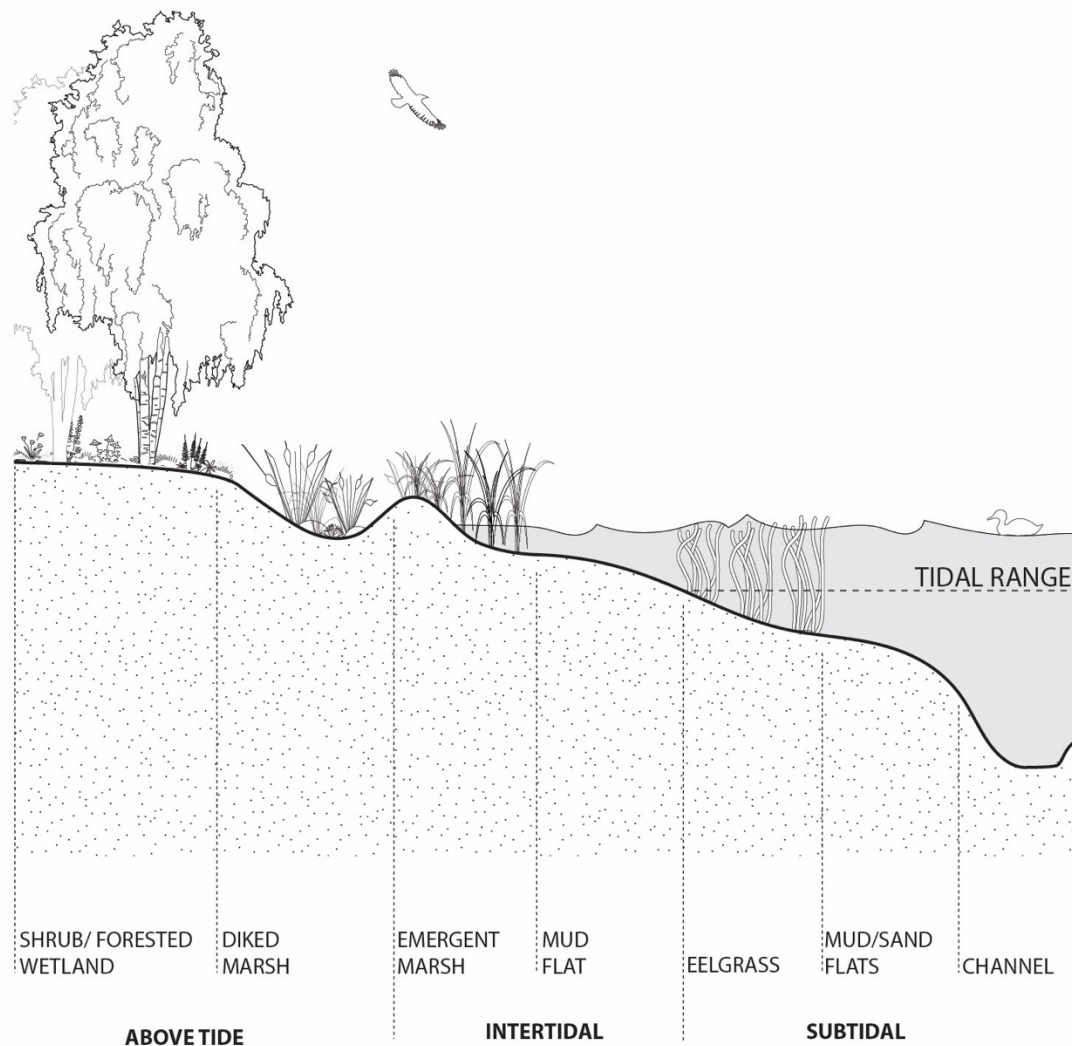


Figure 3.16 Marsh Riparian Buffer showing vegetation phases from subtidal to above tide elevations. (Source: Author)

Floating wetlands are a form of constructed wetlands that can be added when traditional wetlands are not possible due to marginal area as a result of adjacent development to the water's edge. In the form of rafts that are vegetated with wetland plants, these floating wetlands fluctuate as water levels rise and fall. The benefits of floating wetlands are similar to natural wetlands, while also supporting the formation of biofilms, such as algae and

microbes, on the roots of the plants. Additional services of floating wetlands are the creation of useful refuges for aquatic life below, as well as nesting and feeding spaces on top for waterfowl.⁴⁷

⁴⁷ Grant, *The Water Sensitive City*, 2016.

4. Vision

Site

Intending to enhance urban ecologies and improve flood resiliency, siting this thesis required areas that have been highly polluted, are at an increasing risk of flooding, have limited green space, and poor ecological diversity. Selecting a site for this thesis explored post-industrial urban brownfield areas that are amid flux as a result of slowed industrial activity. The selection process was narrowed down to two industrial canals in New York City, Newtown Creek and the Gowanus Canal.

	Gowanus Canal	Newtown Creek
Adjacencies	Proximity to Schools High Schools and Colleges near or Adjacent to Site	2 1
	Proximity to Institutions Museums, Zoos, and Gardens near or adjacent to Site	2 2
	Near Park Distance from Open Green Spaces	3 3
	Proximity to Public Transportation Near Subway or Bus Stops	3 1
	Proximity to Residential Near or Adjacent to Residential Buildings with Roof Access	3 3
Site Characteristics	Walkability Walkable streets adjacent to site	2 1
	Canal Width Connectivity across Canal	3 (120ft) 2 (240ft)
	Post-Industrial Site Demand for Site Remediation	3 3
Environmental	Urban Ecology Demand for Improved Ecological Diversity	10 8
	Flood Risk Demand for Improved Resiliency	9 8
Total		40 32

Figure 4.1 Site Selection Matrix comparing the Gowanus Canal and the Newtown Creek. (Source: Author, 2019)

Both sites were compared looking at metrics concerned with site adjacencies, site characteristics, and environmental concerns. Using a weighted ranking system that privileged environmental characteristics highest, the two sites both showed to have promising potential. Ultimately, the Gowanus Canal was selected as a result of having both the higher flood risk and weaker urban ecology.



Figure 4.2 Map of New York City highlighting location of potential sites. (Source: Author, 2019)

Gowanus

Gowanus is situated in South Brooklyn between the residential neighborhoods of Carroll Gardens to the west, Boerum Hill to the North, and Park Slope to the East. The neighborhood is accessible by the F, G, D, N, and R subway lines and the Gowanus-Maspeth and Downtown Brooklyn bus lines. Gowanus is currently zoned as M1, manufacturing land use, and M2, industrial land use. Gowanus' location and elevation make it an at-risk neighborhood for flooding and is currently marked as an AE flood zone, an area subject to inundation by a 1-percent-annual-chance flood event.

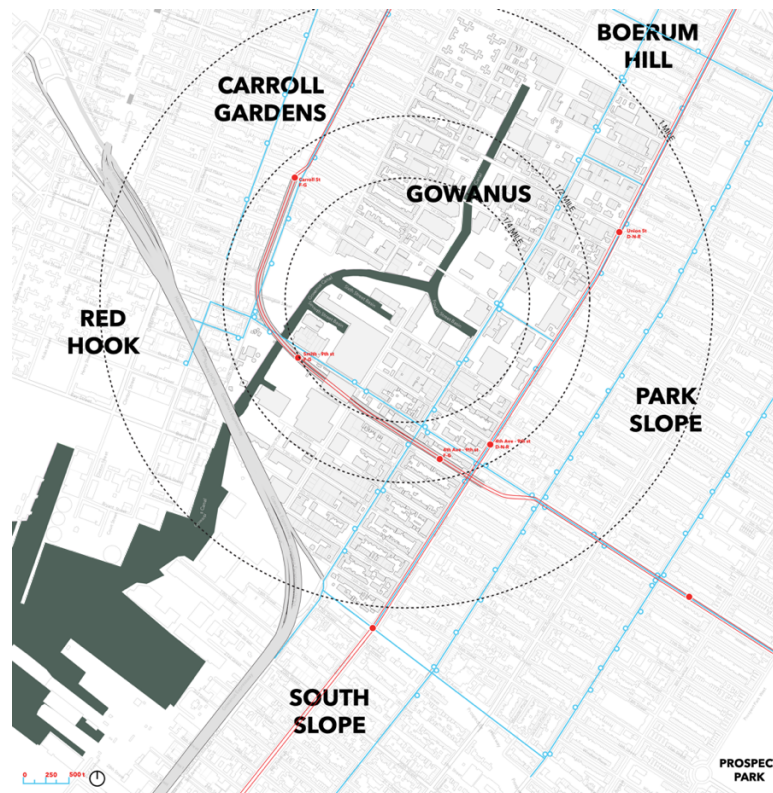


Figure 4.3 Gowanus is situated between the residential neighborhoods of Carroll Gardens, Park Slope, and Boerum Hill and is within 1 mile of Prospect Park. The Canal is accessible by the F-G and D-N-R subway lines. (Source: Author, 2019)

The character of Gowanus derives mostly from the Gowanus Canal, which has traditionally been used for industrial activity. The zoning of Gowanus has led the area to become a hub for industry and manufacturing, peaking in activity during the early 20th century. As a result of mass industrial pollution, the canal has become one of the most polluted bodies of water in the world. This thesis aims to transform the Gowanus Canal from an industrial and sewage wasteland into an ecologically vibrant and resilient neighborhood.

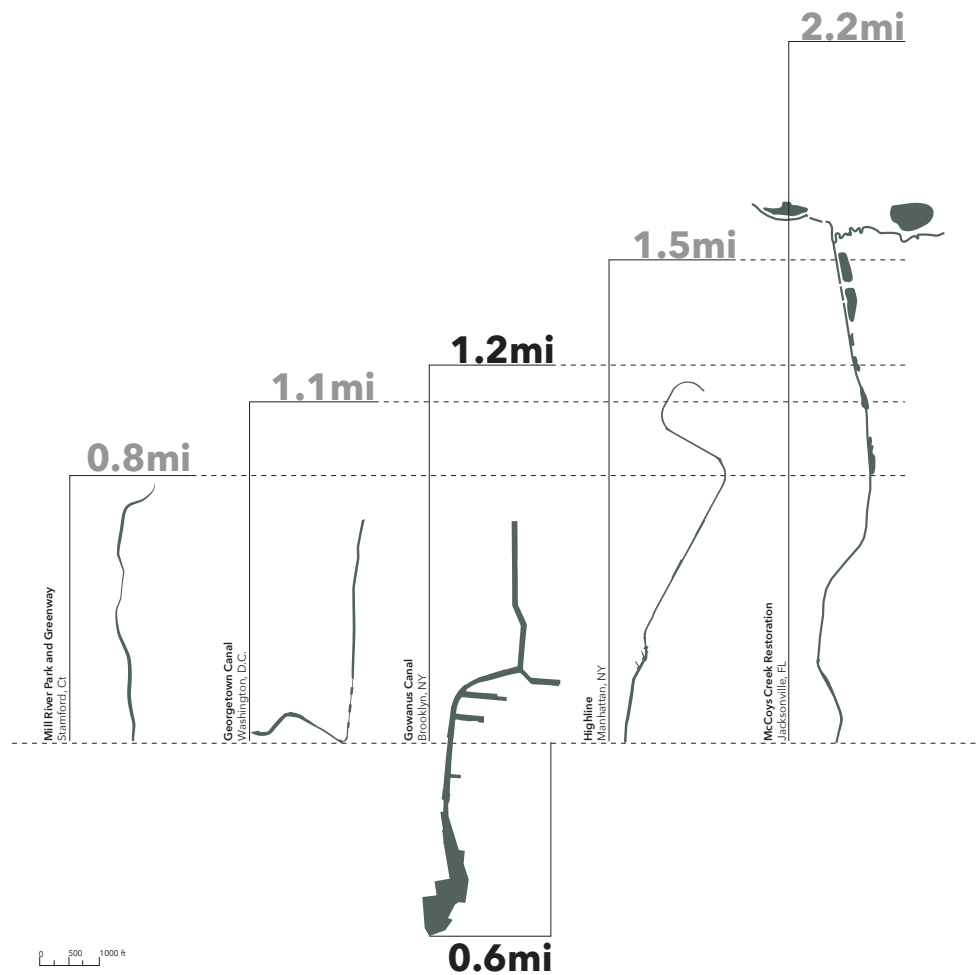


Figure 4.4 Scale of the Gowanus Canal compared to similar sized linear parks.
(Source: Author, 2019)

Site History

Prior to Dutch settlement, the Gowanus Bay was a tidal estuary comprised of creeks and saltwater marshes that were fed by freshwater streams within a 6 square mile watershed. Formerly Gowanus was occupied by the tribe of Native American Canarsees, who lived and farmed along its rich shorelines.

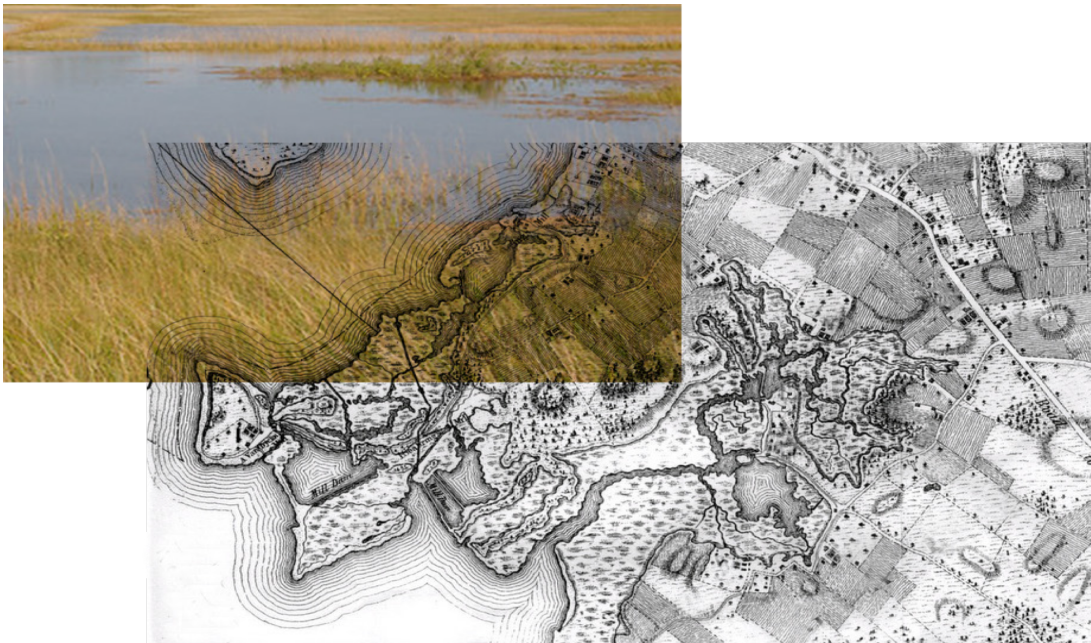


Figure 4.5 Pre-Settlement: The Gowanes Creek consisted of a tidal creek, marsh wetlands, and freshwater streams. (Source: Author, 2019)

The area around the Gowanus Creek was the site of the first Dutch settlement in what is now Brooklyn, and in 1636 made an initial purchase for land.⁴⁸ These early settlers named the estuary “Gowanes Creek,” after chief

⁴⁸ Stiles, Henry Reed. *A History of the City of Brooklyn: Including the Old Town and Village of Brooklyn, the Town of Bushwick, and the Village and City of Williamsburgh*. Salem, MA: Higginson Book, 2016.

Gowanes, a leader in the Canarsees tribe. The Dutch used the fertile land for farming and fishing along the banks of the Creek. Home to abundant wild and marine life, the settlers originally caught and shipped barrels of oysters back to Europe, making it Brooklyn's first export.⁴⁹



Figure 4.6 1661- 1853: After the Dutch settled what is now Brooklyn, the Gowanes Creek was transformed for use as tidal mills, oyster fishing, and farming. (Source: Author, 2019)

By 1661, new tidal mills were being constructed along the Gowanus Creek. During the 18th century, the land began to transform as the population grew. In 1704, the Gowanus Road was constructed connecting New Utrecht to the tidal mills along the creek. By 1836, three tidal mills were operating

⁴⁹ "Gowanus Canal History." Gowanus Dredgers. October 24, 2018. Accessed May 23, 2019. <https://gowanuscanal.org/gowanus-canal-history>.

along the creek, but would soon close as a result of the Erie Canal development.⁵⁰

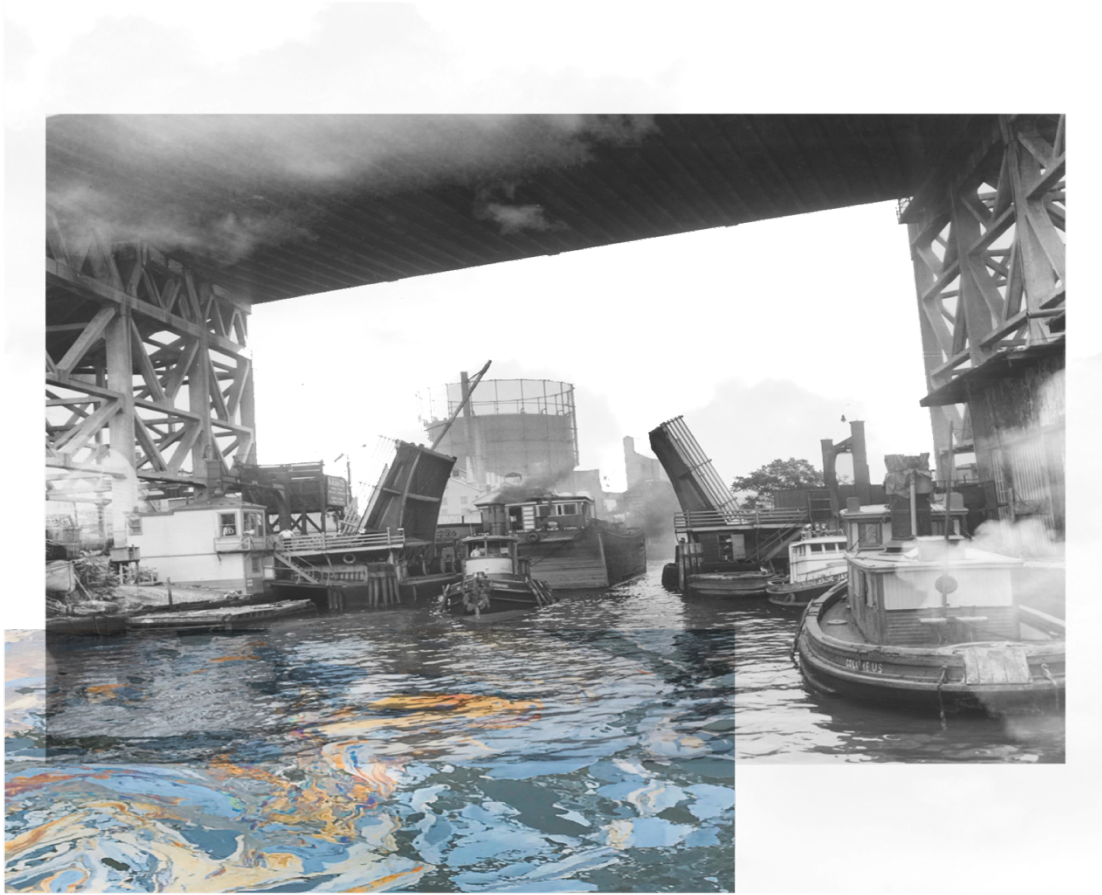


Figure 4.7 1853-1950: The Gowanus Canal became the primary commercial and maritime hub in Brooklyn until the mid-20th century, but due to a lack of regulations it endured years of pollution, dumping, and sewer overflow. Gaining the nickname, “Lavender Lake,” the Gowanus Canal became the most contaminated waterway in the United States. (Source: Author, 2019)

⁵⁰ Alexiou, Joseph. *Gowanus: Brooklyn's Curious Canal*. New York: New York University Press, 2015.

In 1837, growing pressures for navigational and docking facilities in the port of New York prompted the first proposal to improve the Gowanus Creek for navigation. The first plan for the Gowanus Canal arrived in 1847, which called for a 5,400-foot-long, 100-foot-wide, and 14-foot-deep channel contained by bulkheads set 4 feet above sea level. Two years later, in 1849, the New York State Legislature approved the construction for the new canal. As a result, the area surrounding the canal attracted new factories and residential communities, while the canal soon became a commercial and maritime hub in Brooklyn.⁵¹

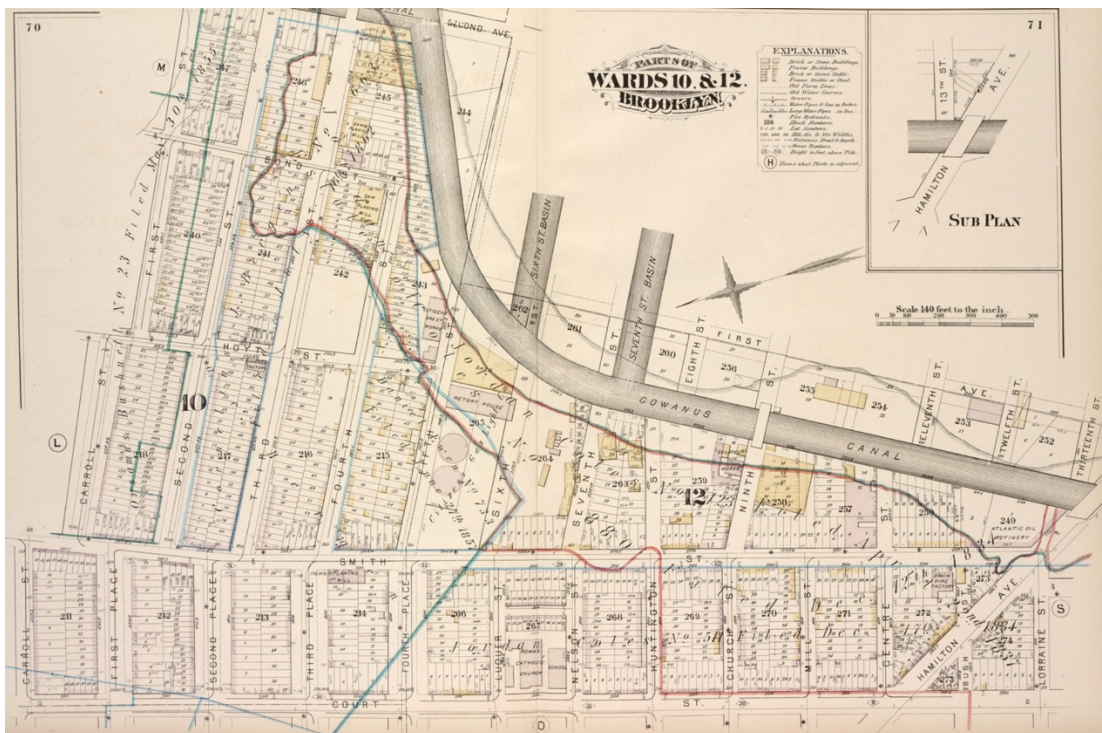


Figure 4.8 Map of the middle portion of the Gowanus Canal from 3rd Street to 13th Street, 1880. (Source: G.M. Hopkins & Co., 1880)

⁵¹ "Gowanus Canal History." Gowanus Dredgers. October 24, 2018. Accessed May 23, 2019. <https://gowanuscanal.org/gowanus-canal-history>.

By 1869, the canal completed constructed, and the surrounding areas had been fully urbanized.⁵² Industrial activity grew, with 31 firms operating by 1880, handling firewood, coal, lumber, oil, hay, grain, fertilizers, and building materials along the canal. From 1900 to 1932, activity along the Gowanus Canal peaked with 50-60 businesses in operation. During this time 70% of the vessels using the canal were for bulk cargo. Industrial decline, resulting from highway construction and the rise of truck distribution in the 1950s, began to transform Gowanus once again. By the late 1970s over 50% of the once active properties in Gowanus were either vacant or derelict, and by 2000 only five businesses still used the canal to transport oil, stone, and building materials.⁵³

Environmental Concerns

As Gowanus transformed from a vibrant wetland ecosystem to an industrialized canal, the effect on the environment was catastrophic. As was typical during the industrial revolution, there was little environmental regulation, and untreated waste from industry was generally discharged directly in nearby waterbodies. Such was the case for the Gowanus Canal, which became contaminated with a variety of industrial pollutants, including

⁵² "Gowanus Canal." Gowanus Canal – History. Accessed May 23, 2019.

https://www1.nyc.gov/html/dep/html/harborwater/gowanus_canal_history.shtml.

⁵³ Olsen, Kevin. "Gowanus Canal Historical Timeline." Montclair State University. Accessed May 23, 2019. https://msuweb.montclair.edu/~olsenk/Gowanus_timeline.htm.

heavy metals, dense non-aqueous phase liquids (DNAPL), and light non-aqueous phase liquids (LNAPL).



Figure 4.9 Polluted water in the Gowanus Canal. (Source: Author, 2019)



Figure 4.10 Contamination of land surrounding the canal. Resulting from poor environmental regulation, industrial activity from the mid-19th century to present day has left the land contaminated with heavy metals, DNAPL, and LNAPL. (Source: Author, 2019)

Making matters worse, the increased residential development in the nearby neighborhoods of Park Slope, Carroll Gardens, and Boerum Hill required the construction of nine combined sewer overflow (CSO) release points are located along the 1.8-mile long canal. During storm surges, wastewater and stormwater are released together into the canal when nearby sewer treatment plants are overwhelmed. An average of one million gallons of sewage is released into the canal daily. As early as 1900, this combination of industrial pollution and the newly developed sewage system resulted in rampant odors, with residents quickly nicknaming the Gowanus Canal, “Lavender Lake.”⁵⁴



Figure 4.11 Canal Cleanup efforts as result of site being granted a superfund site by EPA. (Source: Author, 2019)

⁵⁴ "Gowanus Canal." Gowanus Canal – History. Accessed May 23, 2019.
https://www1.nyc.gov/html/dep/html/harborwater/gowanus_canal_history.shtml.

Recent attention has been given to the environmental concerns of the Gowanus Canal. With rising interest to redevelop the area, in 2010, the Environmental Protection Agency designated the Gowanus Canal a Superfund site, allocating \$506 million for cleanup efforts. A remedial design was developed from 2014 to 2017, and the EPA released a final cleanup plan in 2018. The plan calls for three phases of cleanup, set to be completed in 2022. The plan involves dredging the polluted canal and recapping the bottom to isolate any remaining contaminants.



Figure 4.12 Gowanus Canal superfund cleanup timeline. The dredging and capping of the canal will take place in three phases from 2017 to 2022. (Source: Author, 2019)

Gowanus After Industry

Gowanus is once again in a transformational state as the slowed industrial activity has left a handful of vacant buildings along the canal corridor. With the Superfund cleanup effort underway, new land uses have begun to occupy vacant industrial buildings that had been left vacant and a renewed interest from developers have put pressures on defining what the future of Gowanus should look like.

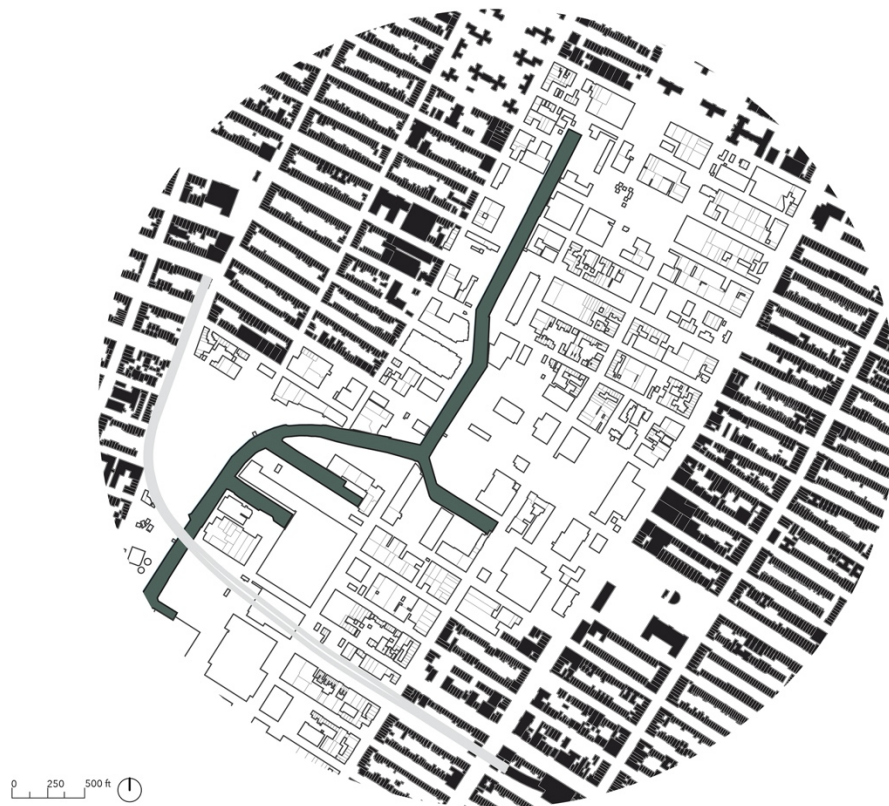


Figure 4.13 The fragmented urban fabric of Gowanus creates a stark divide between the tight neighborhood blocks of the surrounding residential neighborhoods. (Source: Author, 2019)

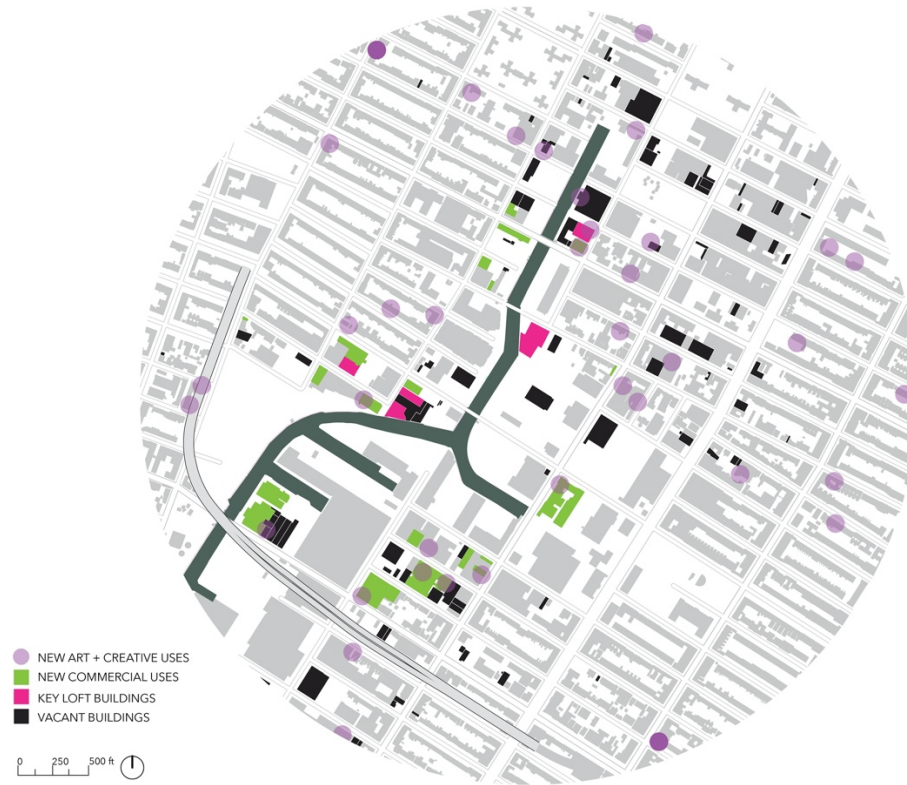


Figure 4.14 Gowanus transforming as a result of the downturn in industrial activity. New commercial and creative land uses have begun to infiltrate the historically industrial fabric along the canal corridor. (Source: Author, 2019)

Rising rents throughout New York City has increased the demand for affordable housing, bringing pressure to the Gowanus area for development. The shifting paradigm for how people work has also added pressures for flexible co-working spaces in the area. A handful of the vacant industrial loft buildings have recently been transformed for new commercial and creative use. Artist's studios and commercial entities, such as co-working spaces, have successfully found homes in retrofitted industrial buildings. Consumptive dining and retail uses have also begun to transform the industrial fabric within Gowanus.



Figure 4.15 Current land use in Gowanus and the surrounding neighborhoods of Carroll Gardens and Park Slope. A distinct separation between the residential fabric and transforming industrial fabric along the Canal. (Source: Author, 2019)

In 2013, the first Whole Foods in Brooklyn was built adjacent to the Canal above 3rd street. Finishing construction in 2016, two new mixed-used residential buildings were also built adjacent to the Canal on Bond Street. Developed by The Lightstone Group, the new 12-story buildings offer the area 700 market-rate apartments, while also adding a new promenade along the Canal's edge.⁵⁵

⁵⁵ "NYC Residential Development." Lightstone. Accessed May 23, 2019. <https://www.lightstonegroup.com/business/nyc-residential-development/>.

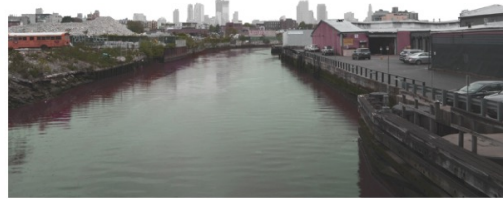


Figure 4.16 The new 12-story mixed-use residential buildings developed by The Lightstone Group, completed in 2016. (Source: Author, 2019)

However, even with these new additions, much of the vacant area around the canal corridor has still been untouched. With the increasing pressures for developing Gowanus, the NYC Department of City Planning (DCP) initiated a Gowanus neighborhood planning study in 2016. The outcome of this study, which involved community outreach to all of the concerning stakeholders, was a draft zoning proposal for the area. Released by the DCP in early 2019, Gowanus: A Framework for a Sustainable, Inclusive, Mixed-use Neighborhood, set forward recommendations for increased mixed-use density, open space, infrastructure, and transportation improvements.⁵⁶

⁵⁶ "Gowanus Neighborhood Planning Study." Gowanus Framework - DCP. Accessed May 23, 2019. <https://www1.nyc.gov/site/planning/plans/gowanus/gowanus-framework.page>.

A



B



C



D

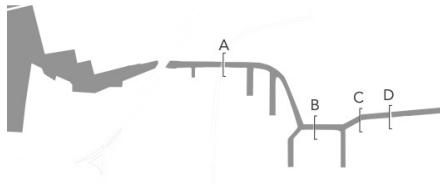


Figure 4.17 The character of the edges along the canal corridor are mostly inaccessible and offers limited public space. The majority of existing bulkheads are in need of replacement. The buildings lining the canal are primarily 1-2 story low-value post-industrial buildings, many of which are vacant. (Source: Author, 2019)

Program

Masterplan

Supported by the addition of public spaces, five new districts will be implemented along the Gowanus Canal corridor. A cultural and commercial zone to the south of 3rd Street will promote job creation and support a large number of local artists and creatives. The lower canal basins will maintain non-residential productive uses. The increased demand for flexible workspaces will be met with coworking spaces and commercial offices. The retention and reuse of critical industrial loft buildings will provide space for art galleries, artist's studios, and other creative professionals.

Situated between the 4th and 6th Street Basins will be an educational and community resources district. With the proposed addition of housing, the increased population will require new community resources. A new school, a boathouse for the Gowanus Canoe Club, and a pollinator center will provide ample community space to support the new Gowanus neighborhood.

Above 3rd Street, two mixed-use residential districts will stitch the divided residential fabric of Carroll Gardens and Park Slope together around the Gowanus Canal. From 3rd to Carroll Street, a live/work district will be cultivated. Targeting young professionals, this district will offer a mixture of consumptive, productive, and dwelling spaces. From Carroll Street to the end of the Canal, a live/consume district will cater to families supported by consumptive and dwelling spaces.

Building

Acting as a catalyst for the enhanced urban ecology of the Gowanus Canal is the Pollinator Center and Apiary. The program for this center will focus on education, both informal and formal, and research. An on-site apiary will be supported by processing equipment and by products will be sold in house.

Helping to support bee health and rejuvenate a post-industrial landscape, an education and research component will be essential to increase awareness and knowledge of the importance that bees play in our urban ecosystems. The educational program will engage and educate the local community about beekeeping processes, enabling a new generation of urban apiarists, providing apprenticeship opportunities and inform exhibit education. Research programs will continue critical explorations into bee health and their role in urban ecologies.

An on-site apiary park will help enhance the local ecology and produce natural products for consumption. A visitor center and exhibition hall will support public engagement with these processes by welcoming and educating the public that comes to enjoy the park.

Harvesting the yields of the apiary will be supported by a processing and production facility. The natural products that are generated will be sold in the retail component of the program.

	Area (SF)	Count	Total Area (SF)
Visitor Center			
Exhibit	15000	1	15000
Information / Reception	400	1	400
Tasting/samples + Sm Retail	1500	1	1500
			16900
Research + Education			
Labs	1600	3	4800
Classrooms	1400	2	2800
Auditorium	10000	1	10000
Offices	120	4	480
Apiary Equipment Storage	500	2	1000
Processing + Packaging	10000	1	10000
			29080
Services			
Mechanical	1000	1	1000
Bathrooms	250	4	1000
Storage	1000	1	1000
			3000
Circulation	0.25		12245
			61225

Figure 4.18 Building program. (Source: Author, 2019)

5. Realization

Gowanus Growlands

The history of the canal is the product of dynamic overlaps in ecologies, technologies, and complex urban systems. The development of the Gowanus Growlands plan was constructed as a palimpsest of its rich past and bountiful future. By looking at opportunity areas and utilizing a basic set of parameters, the process of expanding and contracting the canal edges created a layering of systems, which allowed for both a growth in density and biodiversity.



Figure 5.1 *Tidal Marsh Pond. Wrapping the new softened edge of the Gowanus Canal, a public esplanade and path network mediates the urban fabric and the canal pollinator park. (Source: Author, 2019)*

At the heart of the transformative master plan for the Gowanus Canal is the Growlands canal park. By softening portions of the existing canal edge, public green space is opened up to the community, while simultaneously offering a biologically diverse planting scheme that benefits pollinators and promotes water resiliency.

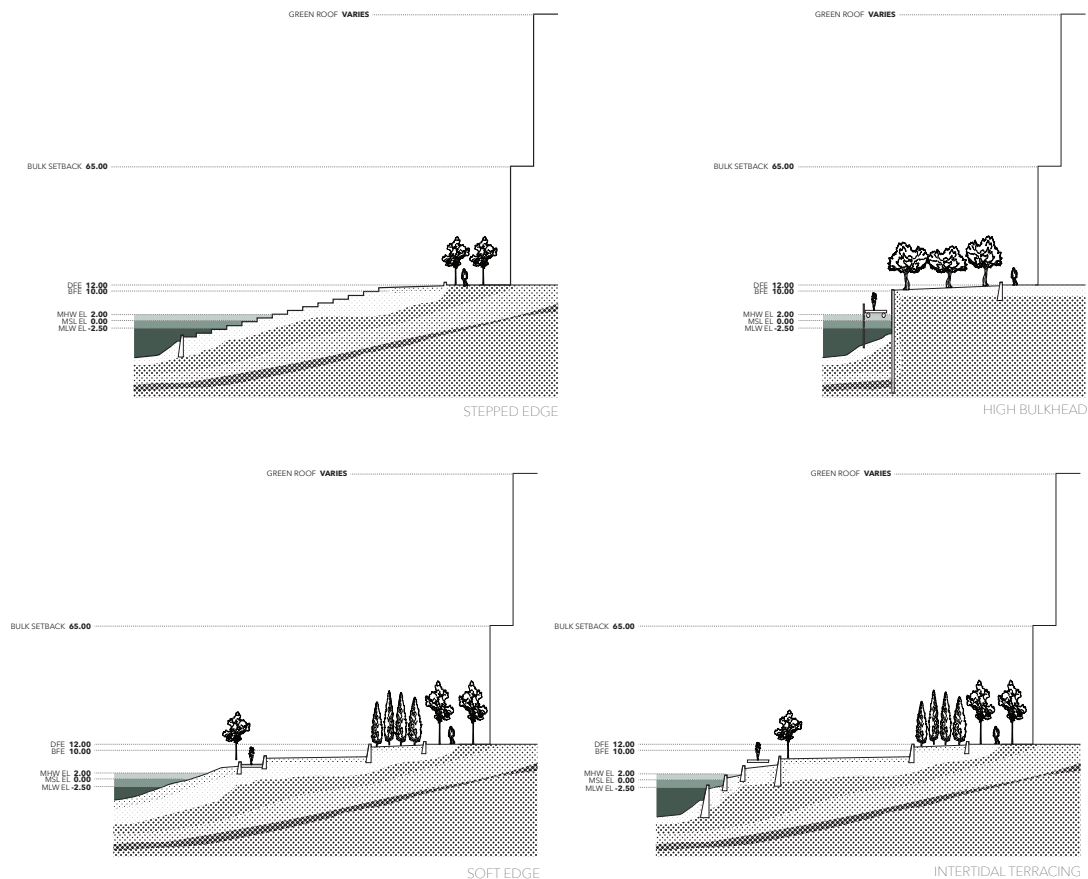


Figure 5.2 The Gowanus Canal is transformed through the removal of existing bulkheads at locations along the canal corridor to create a new varied edge condition. The new edge includes a stepped edge, intertidal terracing, and a soft edge to compliment the high bulkhead condition as it exists now. (Source: Author, 2019)

New developments line the Growlands Park, creating four new districts along the Gowanus Canal corridor. In the upper canal a mixed-use residential neighborhood mends the divide between the surrounding residential neighborhoods

of Carroll Gardens and Park Slope. The Lower-Canal remains a commercial district repurposing existing loft buildings to provide office space and studio space for artists, makers, and creatives. The mid-canal region offers a community and educational core and a live-work district mediating the upper and lower canal districts.

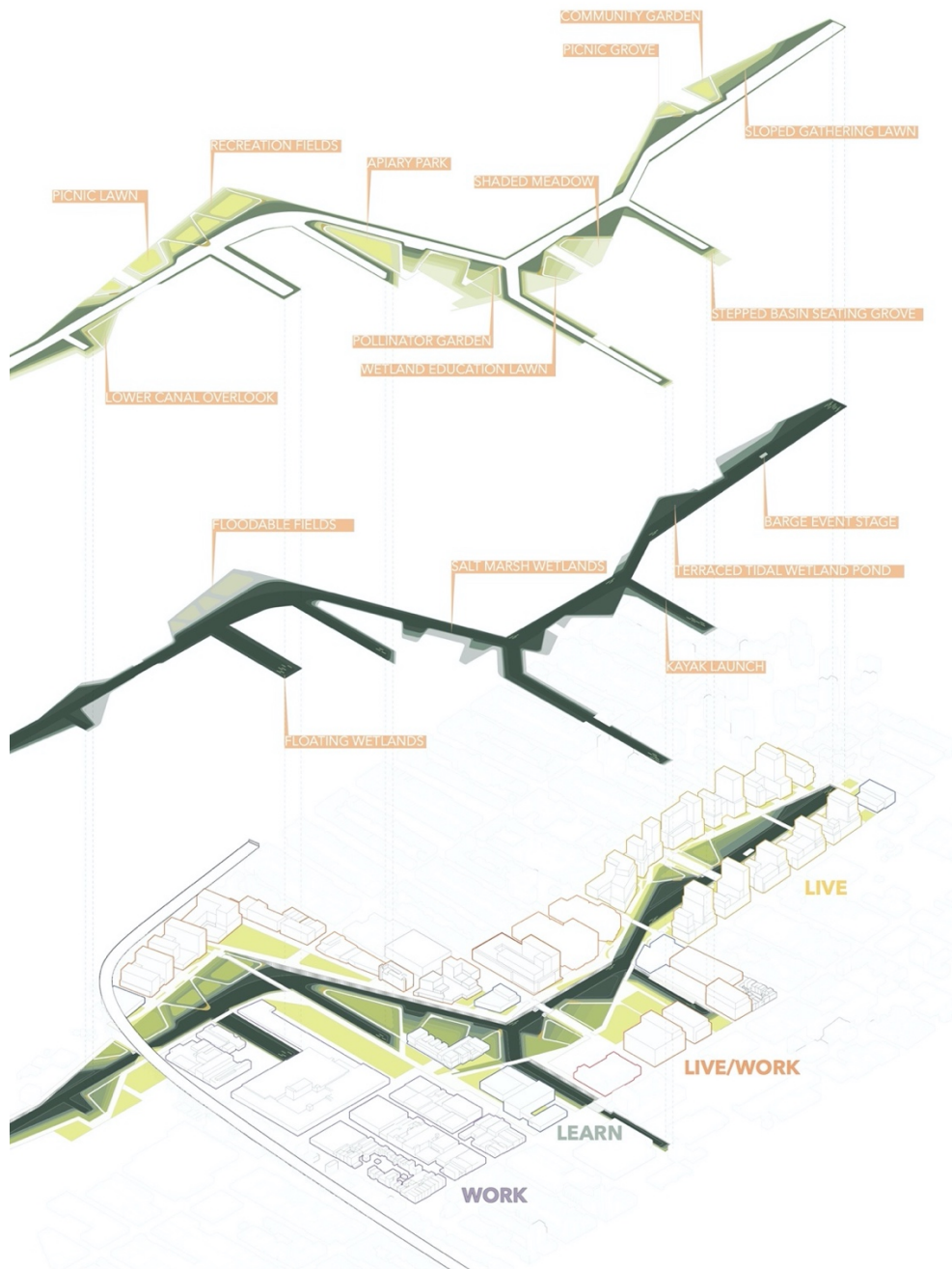


Figure 5.4 Master Plan Exploded Axon. (Source: Author, 2019)

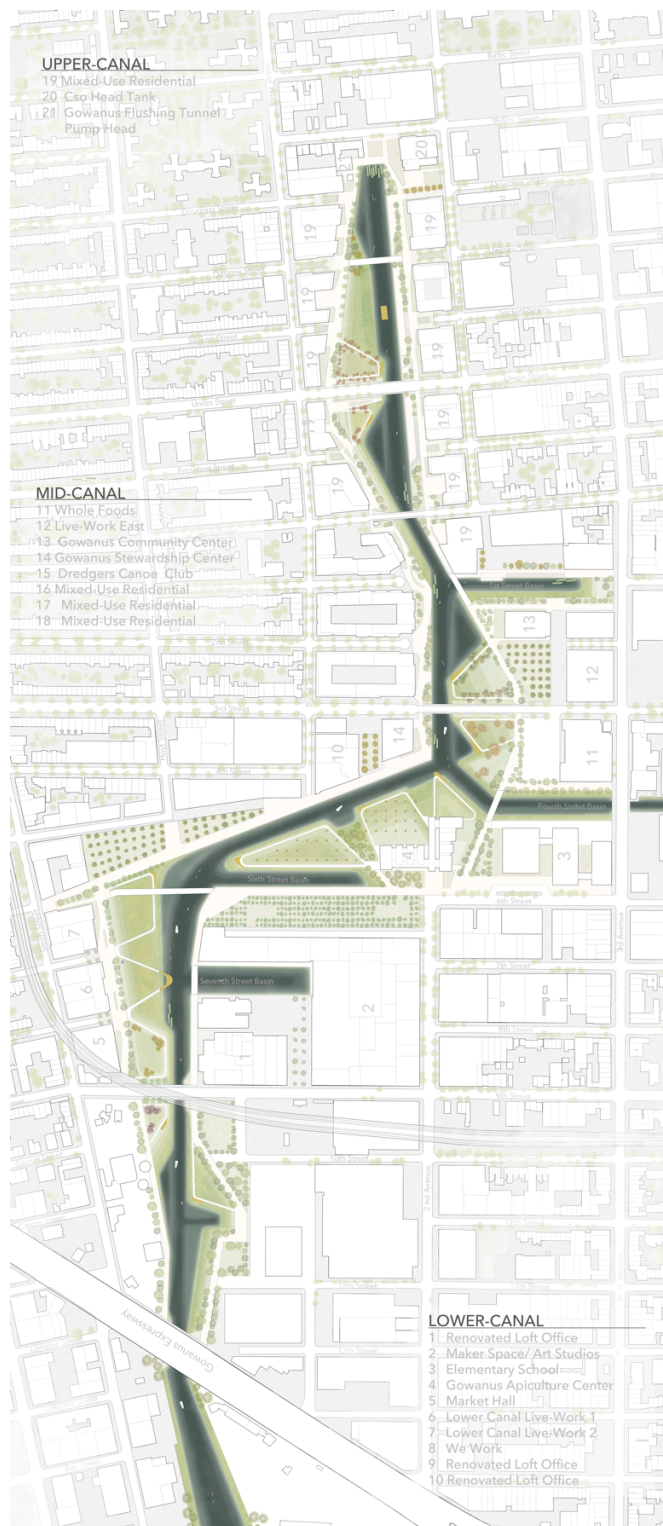


Figure 5.3 Site Plan. (Source: Author, 2019)



Figure 5.5 Meadow along the canal. Urban orchard and pollinator meadow line the public esplanade in the mid-canal. (Source: Author, 2019)

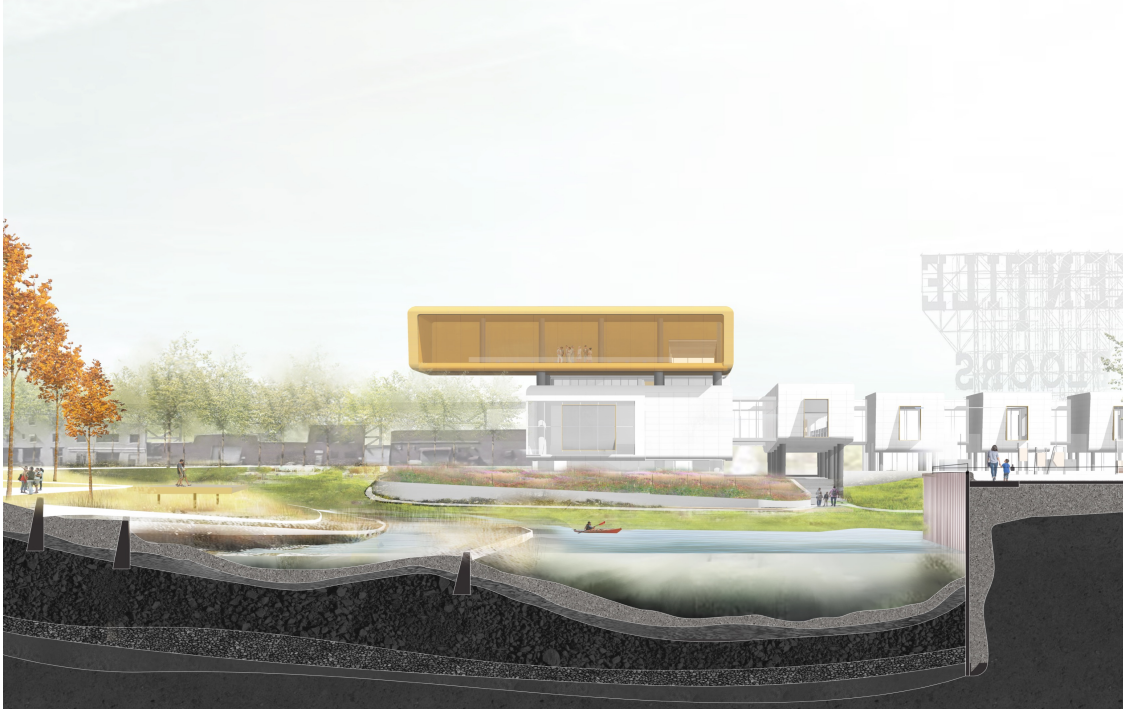


Figure 5.6 Canal Section cutting through a terraced edge condition along the mid-canal portion of the canal corridor. (Source: Author, 2019)

NYC Beekeepers Association Apiculture Center

The existing Salt Lot site, located at the fulcrum point of the canal between the 4th and 6th street basin offers a central location along the canal for the NYC Beekeepers Association Apiculture Center. Utilizing the L-building typology allows the center to hold the urban edge, while reaching out to the apiary park to the west and the canal to the north. Split on the ground level between a formal education and research building and an informal education and exhibit building, the campus is connected on the second level with a floating linear volume that creates a threshold that draws people from the urban fabric and into the park landscape that lines the canal. The building programs were sculpted and articulated to read as cellular volumes that reference the architecture of hives. The materiality of the building takes

inspiration from the unique character of honey and wax. Translucent polycarbonate façade systems create a waxy exterior, while a bright interior palette glow from within. Orange-tinted laminated glazing mimics the rich, glossy nature of honey.

The Apiculture Center utilizes the 3-dimensional nature of stacked ecologies in order to provide a direct relationship between interior and exterior spaces with roof apiaries and roof pollinator gardens supporting interior programs. Apiculture Research and educational programs rely on tangible exterior field apiaries adjacent to controlled interior environments, utilizing inhabitable walls as controlled threshold between the two. A sequence of informal educational exhibits invites visitors to engage and interact with apicultural processes, sparking a conscious new generation of potential beekeepers.

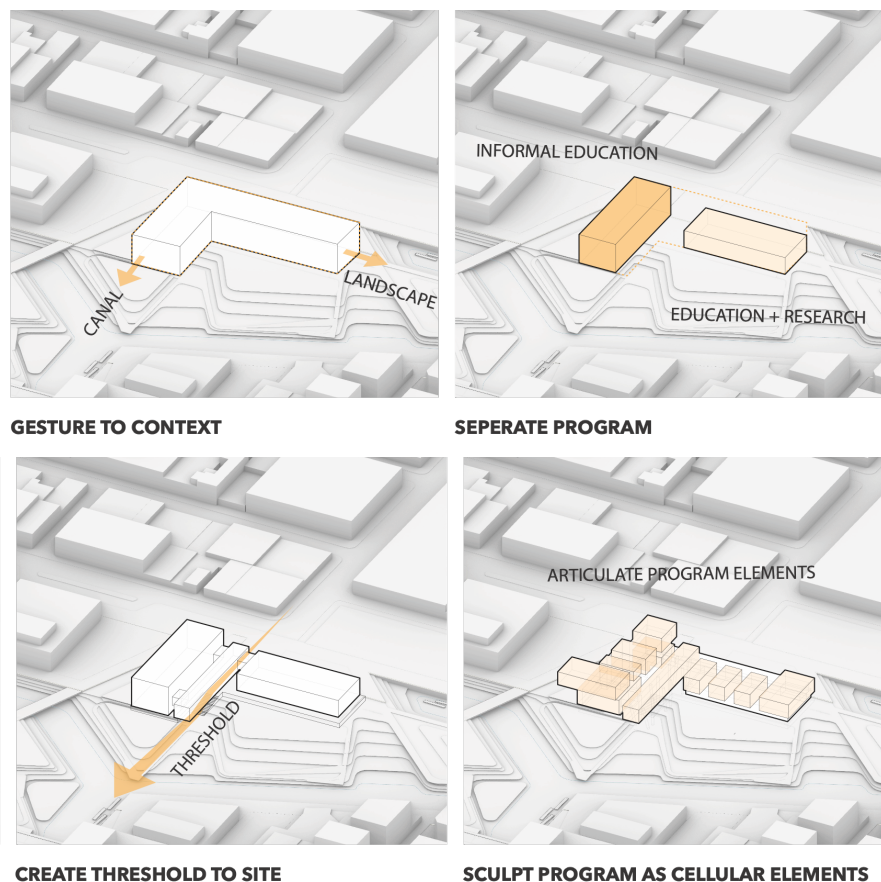


Figure 5.8 Site Response Diagrams. (Source: Author, 2019)



Figure 5.7 Perspective of the honey room cantilevering over the pollinator garden below. (Source: Author, 2019)

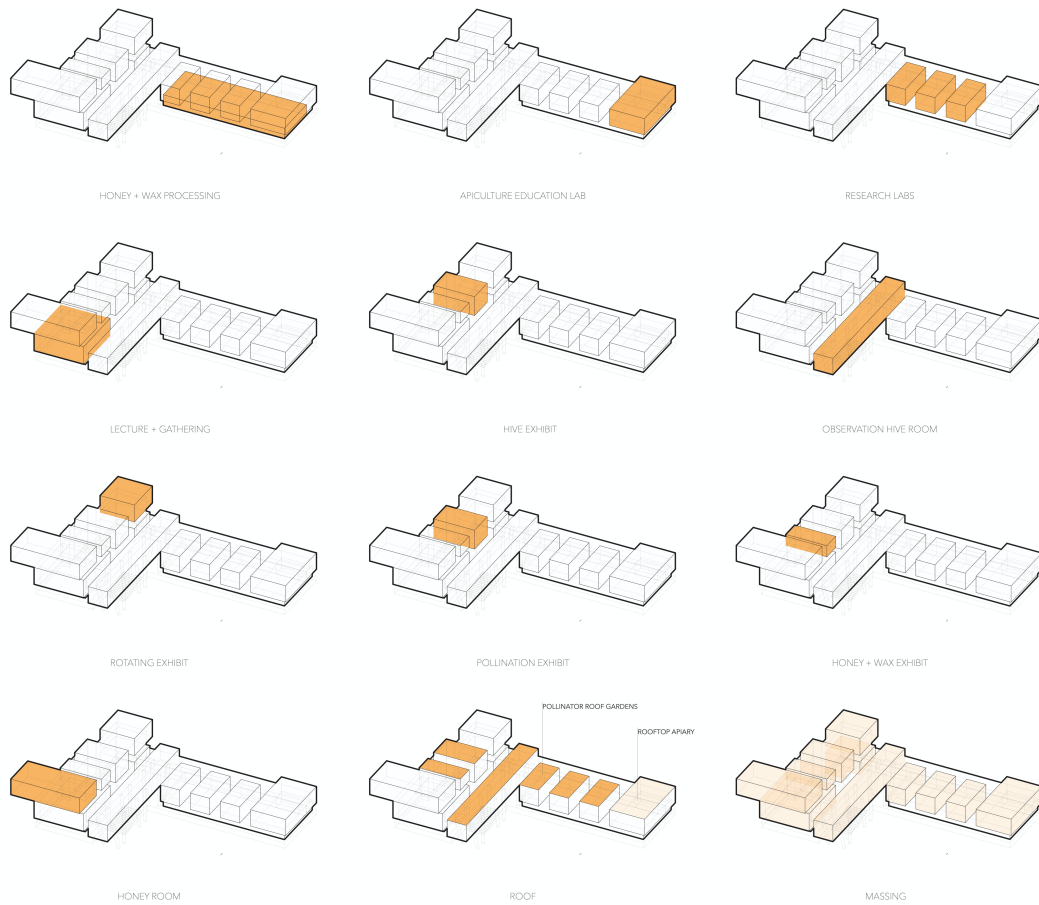


Figure 5.9 Building program articulated into stacked cellular volumes referencing the architecture of hives. (Source: Author, 2019)

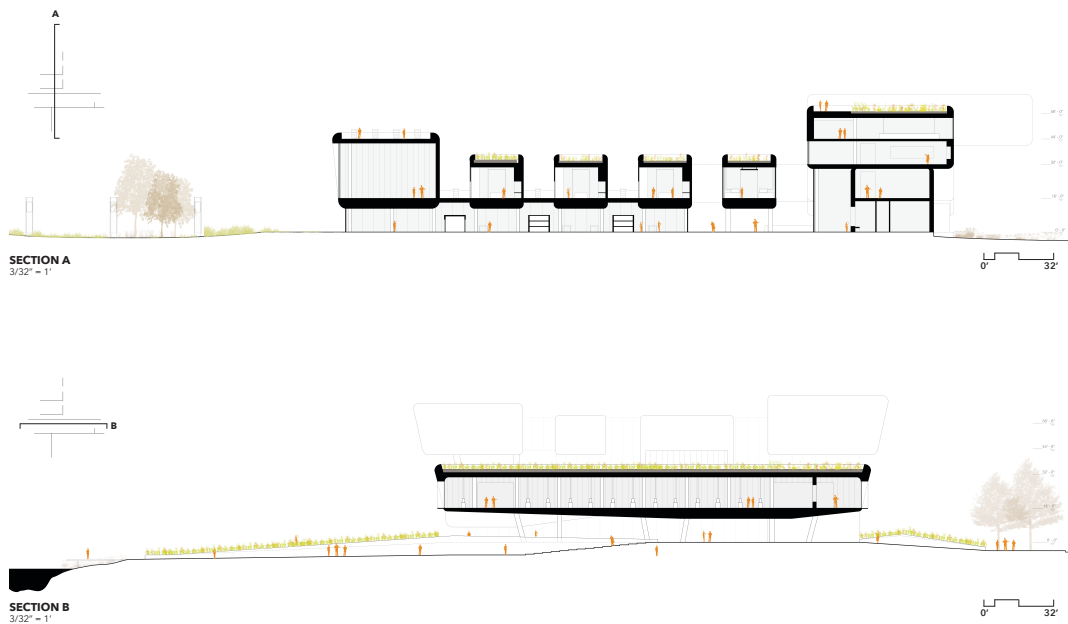


Figure 5.10 Building Sections. (Source: Author, 2019)



Figure 5.11 Honey room, providing honey tasting and offering views up the canal. The materiality of the room creates the sense of being encapsulated in honey. (Source: Author, 2019)



Figure 5.12 Observation hive room, acting as an exhibit for visitors and a bee sanctuary from which new beekeepers can buy a starter colony to begin their hive. (Source: Author, 2019)



Figure 5.13 Plans. (Source: Author, 2019)

Apiary Park – Hive as Urban Infrastructure

To the west of the Apiculture Center is an apiary park consisting of a matrix of sculptural totemic observation hives set within a rigid grid structure, 40 feet x 40 feet, double the structural grid of the building. These hives have a glazed bottom that invites visitors to observe the bees from below as they work. The educational nature of these infrastructural hives engages the public by day-lighting the often-hidden processes of apiculture, inspiring new generations of beekeepers and informing those passing by with bees' role in our ecosystem.

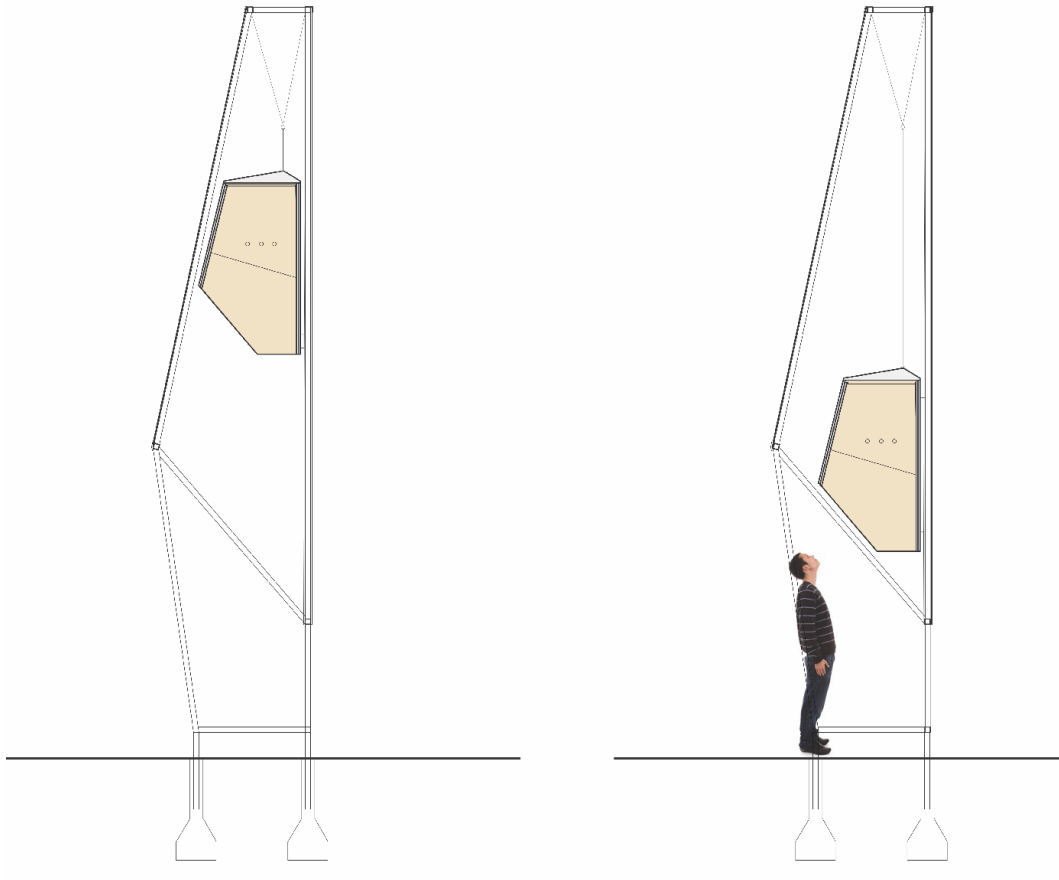


Figure 5.14 Observation hive, concealed and deployed. Supported by a steel frame, the backside of the hive is set within a track, while a pulley system allows the hive to be raised and lowered for viewing and maintenance. The totemic nature of the hive elevates 22' above the ground creating a flight path out of the void in the top of the hive frame that is well above the human occupied zone on the ground. (Source: Author, 2019)



Figure 5.15 Apiary Park. (Source: Author, 2019)

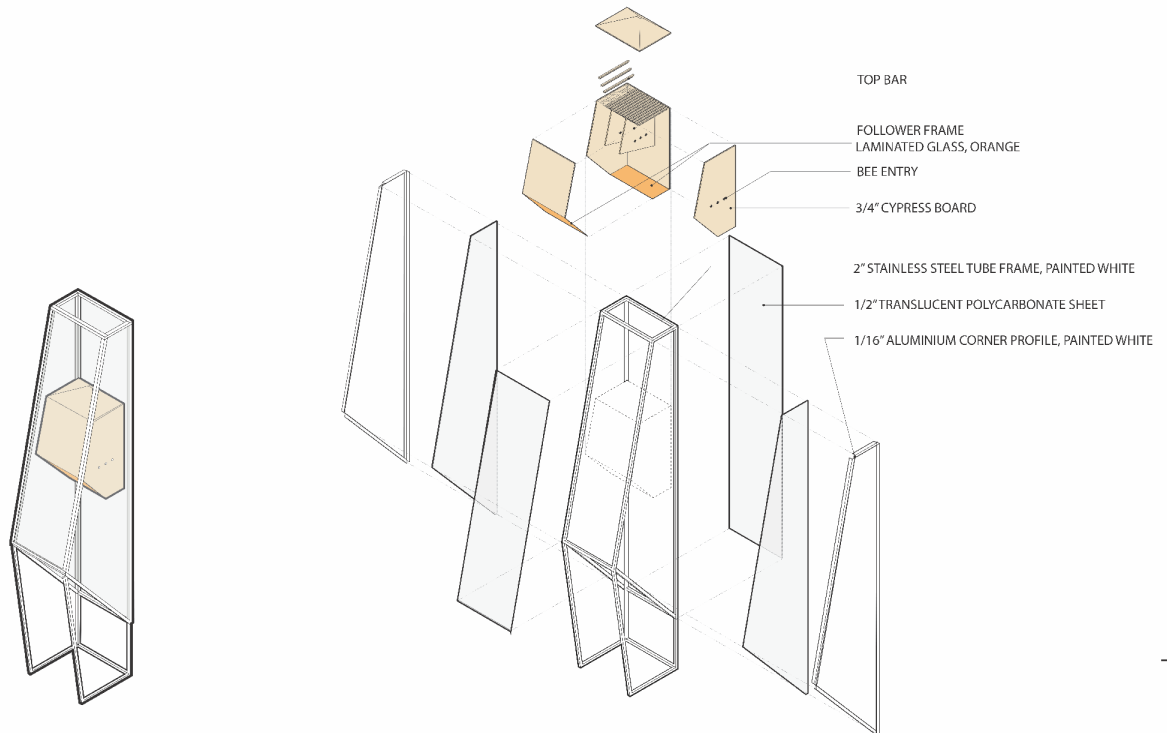


Figure 5.16 Observation Hive. The bright golden character of the wooden top-bar hive is concealed behind the waxy translucent shell of the larger infrastructure allowing each hive to glow. The bottom side of the hive is glazed with orange-tinted laminated glass, providing a viewing portal into the hive, allowing park goers to observe the bees as they work. (Source: Author, 2019)

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