

**MINESCAPE:
RE-ENVISIONING THE POST-MINE LANDSCAPE OF
YELLOWKNIFE, NWT**

by

David Stone

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

at

Dalhousie University
Halifax, Nova Scotia
July 2012

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DALHOUSIE UNIVERSITY
SCHOOL OF ARCHITECTURE

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ABSTRACT

This thesis explores the process of remediation and renewal in the context of decommissioned gold mining operations in Yellowknife, Northwest Territories, Canada. The work aims to demonstrate that architecture can facilitate understanding and bring awareness to the processes involved in reclaiming industrial sites by creating places for observation, interaction and reflection. Existing mine infrastructure will be adapted and augmented to support phytoremediation processes, clean energy generation and municipal waste treatment for adjacent Yellowknife residents. These interventions are based on a series of studies involving mineral extraction processes, historic mine development and geological formations. The architectural interventions are phased and are intended to be prototypical strategies for decommissioned mine sites in general, but are specifically relevant to those located in sub-arctic climates.

ACKNOWLEDGEMENTS

This thesis owes much to the input, advice and support of many people. Firstly, thank you to my family for their continuous encouragement, love and support over the past seven years of architectural education. I am particularly indebted to my wife Stephanie for her unending assistance, patience and understanding; I could not have done it without her.

Many thanks to Catherine Venart and Jonathan Mandeville for their excellent feedback and criticism. Also to Sam Lock, Nicole Riekman, Megan Carroll and Magda Gawlik for their model making skills.

Acknowledgements must be given to Ron Connel at Newmont Mining for the insightful tour of the Con Mine facilities in July 2011. Also to the many individuals who assisted with information, data, drawings and maps: Ryan Silke, Steve Clarke, and Walt Humphries (Mining Heritage Society), Hendrick Falck (NWT Geoscience office), Greg Griffiths and Sean Gorman (City of Yellowknife), Tom Hoefer (NWT Chamber of Mines), Jamie MacMillan (Nuna Logistics Ltd), Malcolm Robb (Indian and Northern Affairs Canada), Mike Borden and Manuel Lim (Giant Mine Remediation Managers). In particular, thanks to Garth Kirkham of Kirkham Geosystems Ltd for the amazing digital models of the Con Mine subterranean infrastructure.

Lastly, but certainly not least, I am indebted to the incredible people at Pin/Taylor Architects in Yellowknife who introduced me to the North and the awe-inspiring land and people of the Northwest Territories. Thank you to Gino Pin and Simon Taylor for the inspiration and early discussions concerning the thesis topic. Also to Becca Denley and Becky Messier for their assistance with information, photographs and stories.

CHAPTER 1: INTRODUCTION

It is often said that Yellowknife, Northwest Territories is a city quite literally paved with gold. In 1920, the current municipal boundary was nothing but fertile hunting and gathering land for the First Nation's inhabitants of the MacKenzie Valley. By 1933, two wondering prospectors had discovered gold while panning in the Yellowknife River, and by 1938, gold was being poured from a processing plant surrounded by a bustling boomtown of tents and log cabins on the shores of Great Slave Lake. By the end of the 20th century, just 65 years later, Yellowknife had matured into a thriving community of over 25,000 inhabitants, built almost entirely on the proceeds of the 15 million ounces of yellow metal extracted from the earth surrounding the city. Though the city was originally named after the copper-bladed implements carried by its aboriginal inhabitants, it has since become a fitting title for one of north America's largest gold producing communities.

By the turn of the century however, gold prices plummeted, labour costs were at an all-time high, and the two gold mines responsible for the creation of city could no longer operate at a profit. Their owners entered into insolvency, hundreds of men and women were left unemployed, and the future of 18km² of land surrounding Yellowknife and saturated with arsenic was left unknown. In addition to these blemishes on the surface, 237,000 tonnes of arsenic-trioxide dust lay buried in giant chambers beneath the city, potentially leeching into a complex network of lakes and rivers. Though Con mine's owners began long-term remediation efforts shortly after closure, the Giant mine property was appropriated by the Federal government and remediation efforts began entirely at the taxpayers expense. Of particular concern, is the fact that the governing body in charge of clean-up efforts is the very same responsible for enforcing environmental law. This conflict of interest poses the question of "who's monitoring the regulators?"

Today, remediation efforts continue to remain out of site and out of mind for neighboring Yellowknifers, with little public participation and minimal economic transparency. In the meantime however, fish are returning to the rivers, reeds are beginning to grow in tailing ponds, and open pits are filling with water. What remains is a desecrated landscape, and although life is slowly returning, the massive scars left in the landscape will be seen and felt for decades, if not centuries.

Currently, a subject of great contention is the future of these man-made scars in the landscape. Typically, these massive interventions are situated hundreds of kilometres from large communities, in remote pockets of the world. When their resources, or their owners pockets are depleted, they are abandoned, and often forgotten. But in this particular case, these scars bound, characterize, and symbolize a city that is once again thriving, and is for once, self sufficient. Due to its economic shift from the perils of industry to its more sustainable role as a Territorial capital of business and governance, the city is able to carry on without a network of mining operations to float the bill. So what then, can become of these vast manufactured landscapes?

It is the belief of this author, that abandoned mining infrastructure scattered throughout Canada's vast northern frontier, may partially hold an answer to some of the pressing afflictions suffered by nearby northern communities. With an abundance of geothermal heat, processing plants that can easily be converted to deal with municipal waste, and vast expanses of sculptable waste-rock, mine sites can contribute greatly to the sustainability of remote populations. With bioremediation strategies becoming more common throughout North America, mine sites can also convert these remediation techniques to industrial agriculture once clean-up efforts have subsided, making remediation a more economically viable activity. Together, these remnants of past mining operations can facilitate new employment opportunities, clean energy, and new food and waste infrastructures. While considering the future of these sites however, one must acknowledge the past - the role mining played in the creation of communities, and the deformation of their surrounding landscapes.

Socio-Economic Context

Canada's Far North

Canada's north is one of the least populated areas in the world, with a total demographic of roughly 100,000 people spread out across 3,921,739km², resulting in a density of nearly 40km² / person.¹ Despite it's lack of development however, the North is widely regarded as one of the last great natural resource frontiers on the planet. Though the Yukon was

1 Statistics Canada, "Population by Province and Territory." Statistics Canada. 2012.
<http://www.statcan.gc.ca>.

home to the great gold rush of the late 1800's, it was not until the mid 1900's that the full extent of Canada's northern resources were realized. After discovery of significant oil reserves in Norman Wells, followed by massive gold discoveries in the Yellowknife area, in addition to silver and uranium in the Great Bear Lake region, it soon became clear that the North would be exploited for its great abundance of wealth. By the 1980's, it was determined that 59% of the country's oil resources, and 48% of natural gas reserves were located within the arctic ecozone. At the time however, low demand, inadequate value, and expensive operating costs limited the development of mines and oil fields.

As of the late 1990's however, circumstances changed significantly in northern Canada. In 1991, hundreds of diamond-bearing volcanic shafts known as kimberlite pipes were discovered in the north-eastern area of the territory. As a result, Canada is now the world's third largest diamond producer by value behind Russia and Botswana. Concurrently, increased global demand for rare earth metals, nuclear fuel, precious metals and natural gas have all increased the potential of new resource extraction infrastructures. Today, as global warming increases, the associated costs of mining the permanently frozen arctic and sub-arctic landscape subsequently decreases, making many proposed mining operations economical for the first time since their discovery. The illustrate this fact, in 2011, \$396 million was spent on mineral exploration in Nunavut alone, up 23% from the previous year, making it the fourth largest investment in Canada during the fiscal year. There are currently over 50 proposed mines in Nunavut, and approximately 800 land claim beneficiaries are being trained at the Kivalliq Mine Training Society in Rankin Inlet. Further west, in the Yukon territory, exploration increased 21% in 2011. However, exploration only increased by \$1 million in the Northwest Territories in 2011 due to a waver in investor confidence on account of complicated environmental regulations and unsettled land claim issues.² In regards to this, it can be said that Canada has relatively short term thinking when it comes to resource extraction policies in the North, favouring investors and CEO's over local communities inhabiting and living off the mineral-rich land itself. Communities are often created by an opening mine or drill site, however their populations are quickly abandoned once extraction halts, sometimes only years later. These operations also have significant environmental implications. Though heavily regulated by the federal

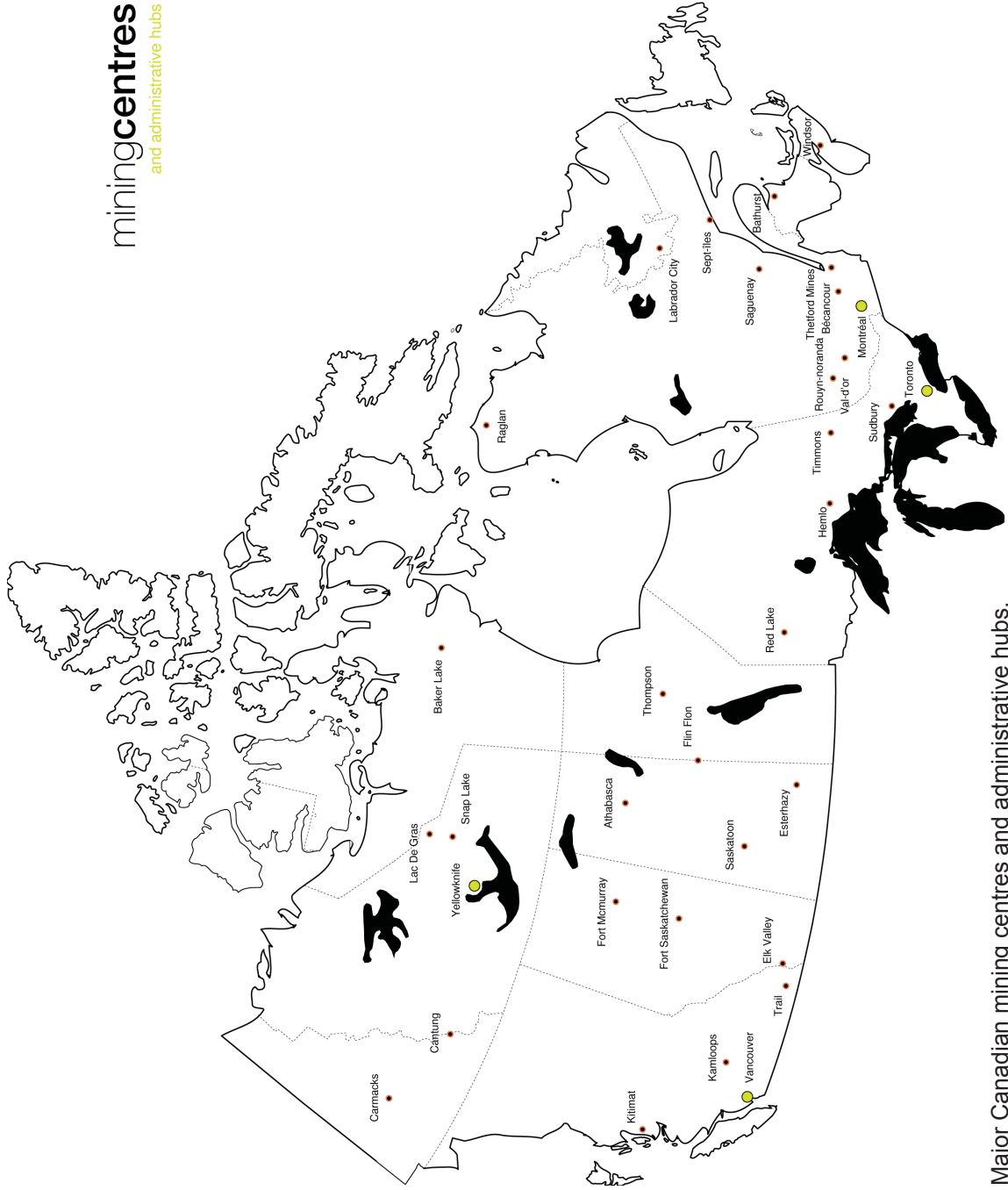
2 Northwest Territories Department of Industry, Tourism and Investment, "Minerals, Oil & Gas." *NWT Dept. of Industry, Tourism and Investment*. 2012. <http://www.iti.gov.nt.ca/mineraloilgas>.

government, the fragile ecosystems of the tundra and taiga ecozones are easily disturbed by large scale development, resulting in the creation of microclimates, thawing permafrost, and the diversion of migratory fish, birds and animals.

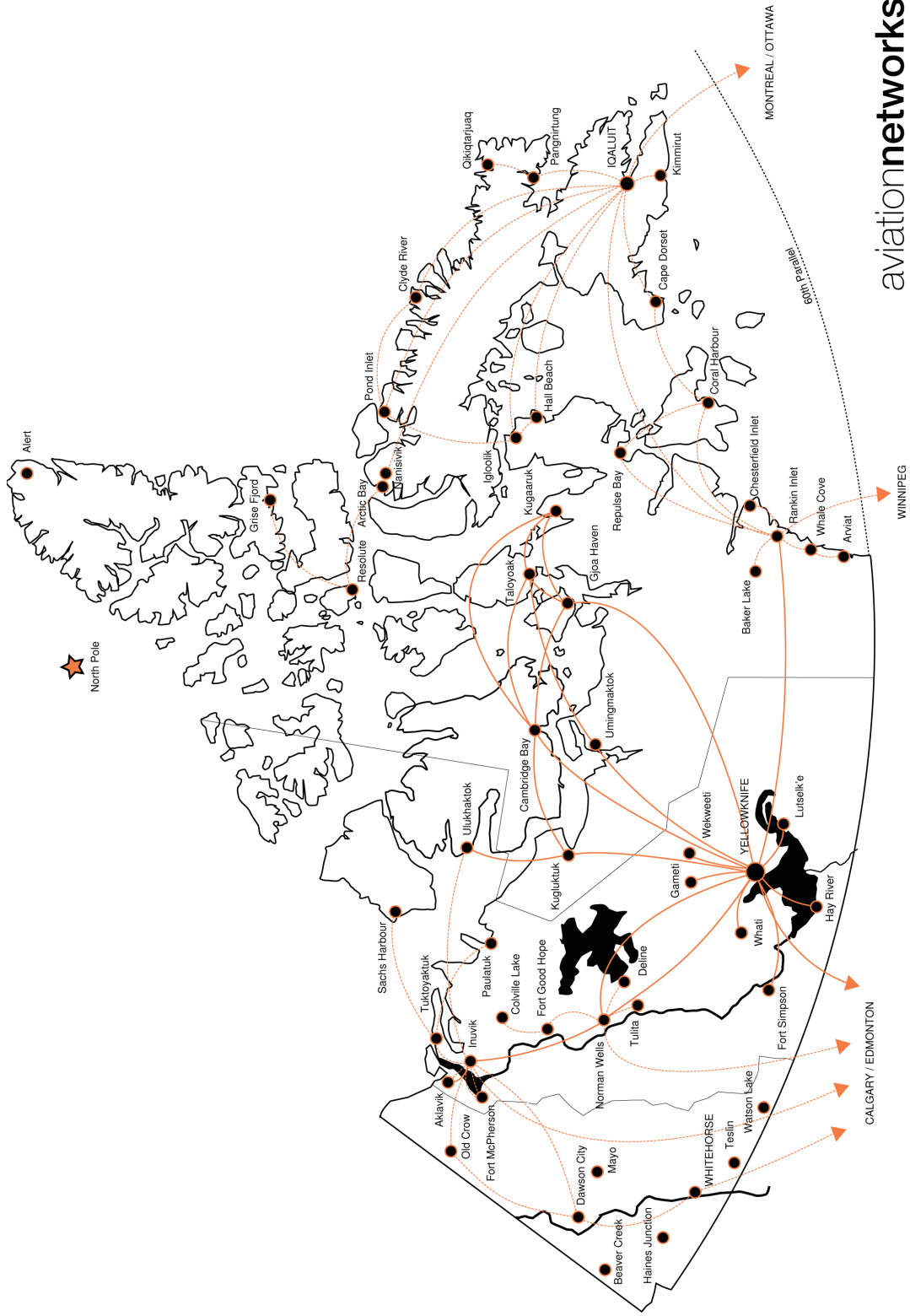
Although mineral and hydrocarbon extraction form the basis of northern Canada's economy, tourism is contributing an ever-increasing amount to the GDP of all three territories. As transportation to remote areas of the world becomes increasingly affordable, and international media exposure of global warming and its effects on the arctic landscape increases, visitors are streaming to see this awe-inspiring part of the world at staggering rates. To illustrate this trend, nearly 10,000 Japanese tourists visited Yellowknife in order to witness the northern lights in 2010 alone, spending nearly \$20 million dollars in total for their visit, a contribution of nearly 4% to the territories' annual GDP.³ These numbers are increasing yearly, and further contribute to the changing socio-economic landscape of Canada's north.

3 Tom Cohen, "Japanese Tourists are Drawn to the Fantastic Lights of the Northwest Territories." *The Associated Press* (Seattle). 9 May 2001.

miningcentres
and administrative hubs



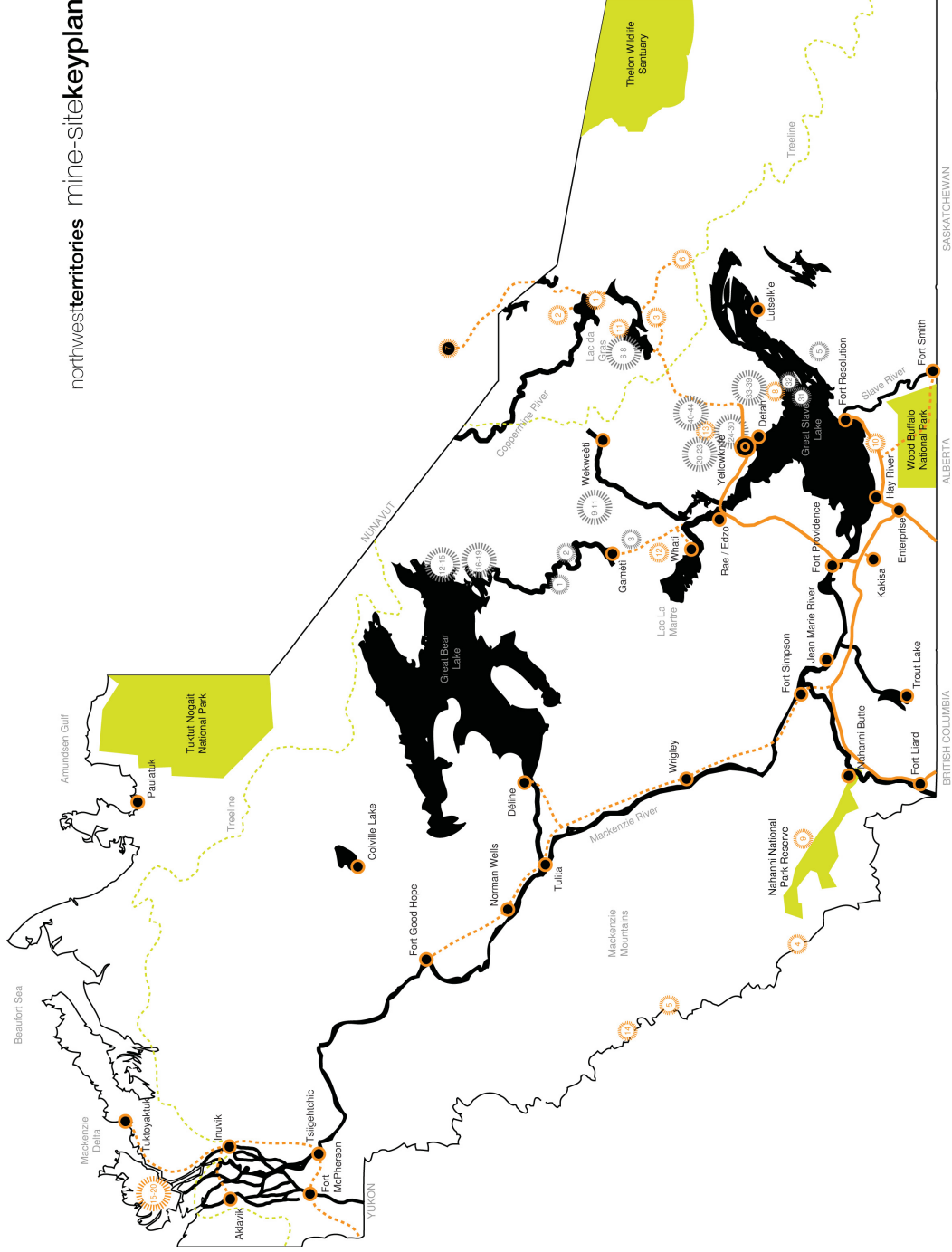
Major Canadian mining centres and administrative hubs.



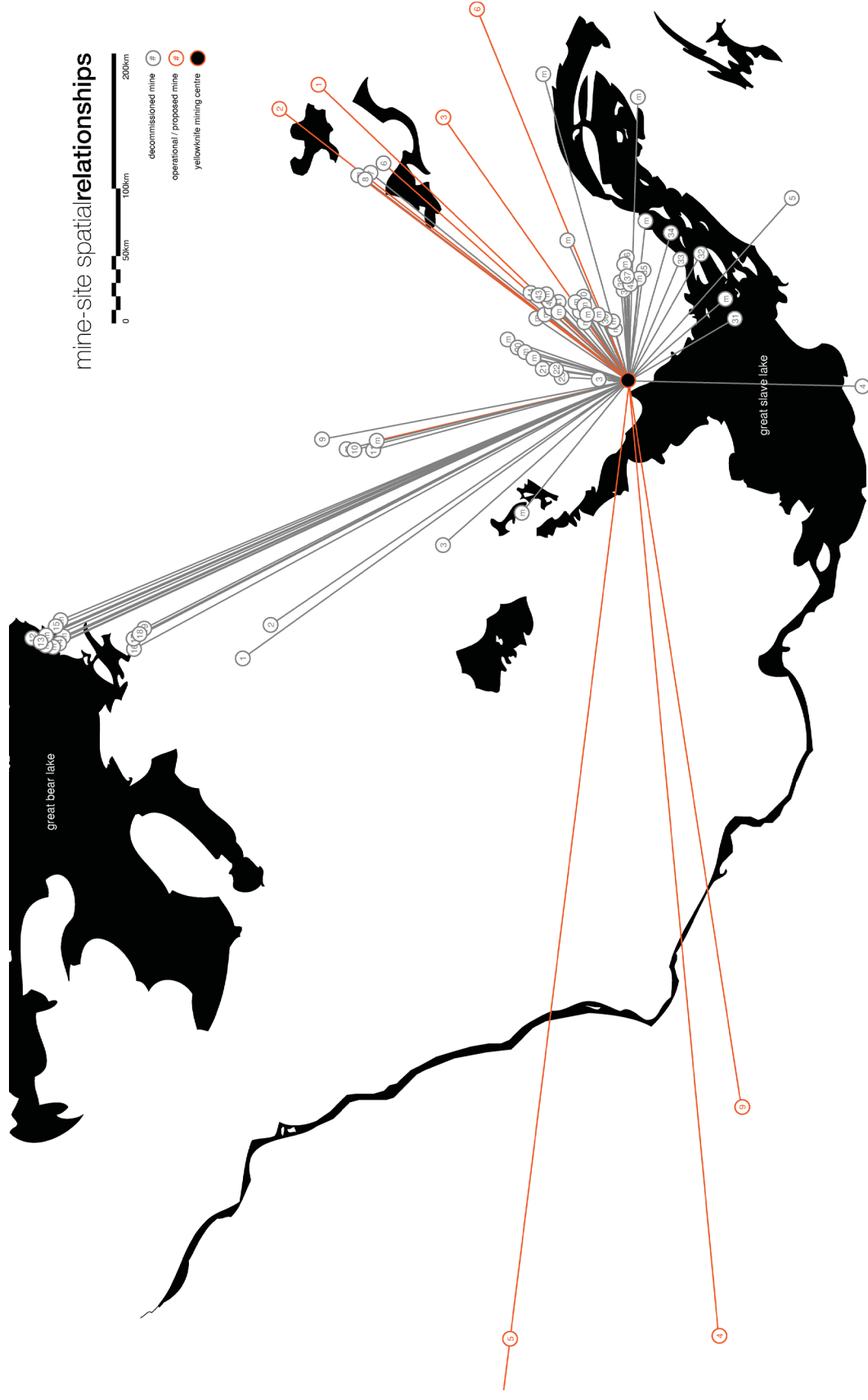
aviation networks

Northern aviation networks illustrate Yellowknife as a transportation hub for Canada's north. (created with data from Northwest Territories Department of Transportation)

northwestterritories mine-sitekeyplan



Northwest Territories mine site index: past, present and future.
 (created with data from Ryan Silke, *The Operational History of Mines in the Northwest Territories, Canada, and the Government of the Northwest Territories* Department of Industry, Tourism and Investment.)



Northwest Territories mines in relation to the city of Yellowknife; supply and administrative hub. (created with data from Ryan Silke, *The Operational History of Mines in the Northwest Territories, Canada, and the Government of the Northwest Territories* Department of Industry, Tourism and Investment.)

northwestterritories mine-siteindex

1 INDORE Indore Gold Mines Ltd service file: 1950-1956 jobs: 10 value: unknown	U
2 BETA GAMMA Consolidated Beta Gamma Mines Ltd service file: 1934 / 1956 jobs: 2 value: 11.51 sampled @ 41%	U
3 RAYBROCK Raybrock Mines Ltd service file: 1935-1939 (f) jobs: 145 value: 208f	U
4 PINE POINT Cominco Ltd service file: 1935-1988 jobs: 650 value: 2Mf Pf / 4.4Mf Zn	Zn
5 O'CONNOR LK American Yellowknife Mines Ltd service file: 1932 jobs: 30 value: 14f sampled	Pb
6 TUNDRA Tundra Gold Mines Ltd service file: 1932-1963 (f) jobs: 120 value: 1044750z	Au
7 SALMITA Giant Yellowknife Mines Ltd service file: 1951/63/97 (f) jobs: 18 value: 179,900z	Au
8 SALMITA RED24 Giant Yellowknife Mines Ltd service file: 1935-1983 jobs: 1687 value: 3,053z	Au
9 COLOMAC Royal Oak Mines service file: 1946/69/97 (f) jobs: 320 value: 335,799z	Au
10 NORTH INCA North Inca Gold Mines Ltd service file: 1947-1949 (f) jobs: 26 value: unknown	Au
11 BAR-BET Terronnes Exploration Ltd service file: 1938-1941 jobs: 2 value: 33f z	Au

12 ECHO BAY Cominco Ltd service file: 1934/64-74 (f) jobs: 19 value: 23,564,46f z	Ag
13 ELDORADO Eldorado Minerals Ltd service file: 1931/74-81 (f) jobs: 270 value: 13Mf Ag / 2,389f Cu	Ag
14 EL-BONANZA El-Bonanza Mining Corporation Ltd service file: 1935 jobs: unknown value: 30,1750z	Ag
15 CONTACT LK Echo Bay Mines Ltd service file: 1932/75-80 jobs: 20 value: 679,000z Ag / 2f U	Ag
16 TERRA Terra Mining & Exploration Ltd service file: 1965-1985 jobs: 65 value: 14,2Mf Ag / 2,284f Cu / 1z	Ag
17 NORTHTRIM Northern Mines Ltd service file: 1933/93-78 jobs: 12 value: 30,000 z	Ag
18 NOREX Norex Resources Ltd service file: 1979-1983 jobs: satellite operation value: 2,065,744 z	Ag
19 SMALLWOOD Terra Mining & Exploration Ltd service file: 1979-1983 jobs: satellite operation value: 169,720 z	Ag
20 DISCOVERY Discovery Mines Ltd service file: 1946-1989 (f) jobs: 128 value: 1,031,575 z	Au
21 JOHNSTON LK Cominco Ltd service file: 1941-1943 jobs: unknown value: 111 z	Au

22 CLAN LAKE Sibonit Yellowknife Mines Ltd service file: 1967 jobs: unknown value: 115 z	Au
23 MON Cominco Ltd service file: 1938/69-97 (f) jobs: 10 value: 3,327 z	Au
24 GIANT Giant Yellowknife Mines Ltd service file: 1937-2004 (f) jobs: 429 value: 7,166,590 z	Au
25 GOLD LAKE Giant Yellowknife Mines Ltd service file: 1985-1988 jobs: satellite operator value: 6,832 z	Au
26 CONRYCON Cominco Ltd / Merrimac service file: 1937-2003 (f) jobs: 13 value: 5,298,910 z	Au
27 NEGUS Cominco Ltd service file: 1938-1952 (f) jobs: 150 value: 255,807 z	Au
28 BURWASH Burwash Yellowknife Gold Mines service file: 1935-1936 jobs: 20 value: 200 z	Au
29 PTARMIGAN Terminor Resources Ltd service file: 1938/82-97 jobs: 30 value: 111,200 z	Au
30 THOMPSON Cominco Ltd service file: 1938-1949 jobs: 30 value: 13,782 z	Au

31 OUTPOST IS Langston Corporation of Canada Ltd service file: 1940/51-52 (f) jobs: 60 value: 54.3z Cu / 16.11 W / 0.29f Au	Cu
32 BLANCHETT IS Vision Explorers Ltd service file: 1969-1970 jobs: unknown value: 49,07N / 76.3z Cu	Ni
33 THOR LAKE Highwood Resources Ltd service file: 1965-1986 jobs: unknown value: 10,063,353 z	Be
34 DESTAFFANY Sorel Metallurgies Ltd service file: 1942-1954 jobs: 2 value: 13,184z Te / 401,728z U / Li	Li
35 BULLMOOSE Sorel Metallurgies Ltd service file: 1941/68/87 (f) jobs: 45 value: 17,742 z	Au
36 RUTH Cominco Ltd service file: 1941/1959 jobs: 50 value: 350 z	Au
37 STRIKE LK Sibonit Yellowknife Mines Ltd service file: 1977-1979 jobs: unknown value: 100 z	Au
38 GILMOUR LK Sorel Yellowknife Gold Mines Ltd service file: 1940/1932 jobs: unknown value: 16,460 z	W

39 CONSOLIDATION Langston Development Ltd service file: 1942 jobs: 4 value: 107,352 z	W
40 PEG Peg Tantalum Mines Ltd service file: 1945-1947 jobs: 20 value: 2,440 z Te / 3,259 z Cu	Ta
41 WEST BAY Cameron Mining Ltd service file: 1947-48/91 jobs: 4 value: 1,362 z	Au
42 CAMLAREN Sibonit Yellowknife Mines Ltd service file: 1963/80-81 (f) jobs: 70 value: 36,66 z	Au
43 ARGONAUT Geopac Gold Mines Ltd service file: 1939-1943 jobs: 10 value: 11,520 z	W
44 BURNT IS Cameron Mining Ltd service file: 1940/84-90 jobs: unknown value: 1,980 z	Au
45 BEAULIEU Beaulieu Yellowknife Mines Ltd service file: 1942-1948 jobs: 66 value: 30 z	Au

1 DIAVIK Rio Tinto Group / Harry Winston service file: 2003-20+ jobs: 700 value: 6,000,000 carats / yr	Dia
2 EKATI BHP Billiton Canada Inc service file: 1998-18 jobs: 700 value: 4,090,000 carats / yr	Dia
3 SNAP LAKE Diamonds Ltd service file: 2009-28 jobs: 500 value: 1,400,000 carats / yr	Dia
4 CANTUNG DeBeers Canada / Mountain Prov. service file: 2002-13 jobs: 179 value: 238,000f / yr	W
5 MACTUNG North American Tungsten Co. service file: 2013-24 jobs: 150 value: 33,000,000f	W
6 GAHCHO KUÉ DeBeers Canada / Mountain Prov. service file: 2014-25 jobs: 360 value: 3 - 4,000,000 carats	Dia

7 JERICHO Terra Diamond Corp / Shear service file: 2006-2008 / 2012+ jobs: 160 value: 790,000 carats	Dia
8 NECHALACHO service file: 2015-35 jobs: 139 value: 226,660,000f	RM
9 PRAIRIE CREEK Canadian Zinc Corporation service file: 2014-29 jobs: 10 value: 6,133,000f	Zn
10 PINE POINT service file: unknown jobs: unknown value: 111,603z Zn / 30,100f Pb	Zn
11 COURAGEOUS Seabrook Gold service file: 16 years jobs: unknown value: 6,128,000z	Au
12 NICO Fortuna Minerals service file: 2011-19 jobs: unknown value: 759,700z Au / 27,500f Co	Au
13 ORMSBY Thyssen Gold Corp service file: 2015-uk jobs: unknown value: 1,800,000z	Au

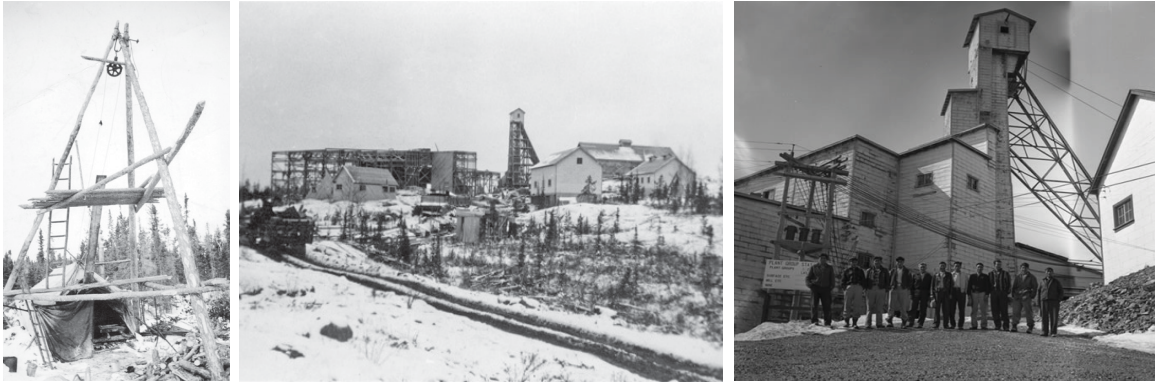
14 SELWYN service file: unknown value: 12,250,000f Zn 4,900,000f Pb	Zn
15 NIQLINTGAK Shell Canada service file: 2010-35 jobs: 739 value: 28,300,000m ³	C / NG
16 TAGLU Impregmet service file: 2010-40 jobs: 15 value: 84,950,000m ³	NG
17 PARSONS LK ConocoPhillips / Exxon Mobil service file: 2010-20 jobs: 20 value: 59,460,000m ³	NG
18 ITIYOK service file: unknown jobs: unknown value: 268,019,000m ³	NG
19 KENALOOK service file: unknown jobs: unknown value: 5,653,000m ³	NG
20 IVIK Impregmet service file: unknown jobs: unknown value: 280,337,000m ³	C
21 MEADOWBANK Agnico-Eagle Mines Limited service file: 2011-19 jobs: unknown value: 399,000z / yr	Au
22 MELIADINE Agnico-Eagle Mines Limited service file: 2015-uk jobs: unknown value: 2,600,000z	Au

abandoned mines

existing / proposed mines

Northwest Territories mine site index with information on major mineral mined, owner, jobs created, amount of precious metal extracted and dates of production. (created with data from Ryan Silke, *The Operational History of Mines in the Northwest Territories, Canada*)

A Brief History of Mining in the NWT



Con Mine construction and early workings in the 1930's.
(from Prince of Wales Northern Heritage Centre Archives)

1898 Ore samples from near the mouth of the Yellowknife river submitted to the Geological Survey of Canada for assay by prospectors en route to Yukon gold rush.

1921 Mackintosh Bell and Charles Camsell of the Geological Survey of Canada conduct the first geological mapping of the Yellowknife River area.

1934 Gold discovered by Johnny Baker, Major Burwash, and Huey Muir in the Yellowknife Bay area. The first mine in the region, named Burwash, is subsequently established.

1934 The U.S. raises the price of gold from \$20.67 to \$35.00/ounce, making large scale mining economical in the Yellowknife region.

1935 Norman Jennejohn and Fred Joliffe discover gold on the west side of Yellowknife Bay.



NWT miners at work in the 1940's / Gold pouring at Con Mine.
(from Prince of Wales Northern Heritage Centre Archives)



Giant Mine construction, residences, and early workings in the 1950's.
(from Prince of Wales Northern Heritage Centre Archives)

1937 Mining camps grow among Dene settlements near the mouth of the Yellowknife River. Burwash mine closes and Con Mine begins production.

1938 The first gold brick in the NWT is poured at the current Con Mine property.

1944 An unprecedented rush to stake, restake, and prospect throughout the Yellowknife area begins when Frobisher exploration finds spectacular results during an extensive drilling program on the Giant Mine property.

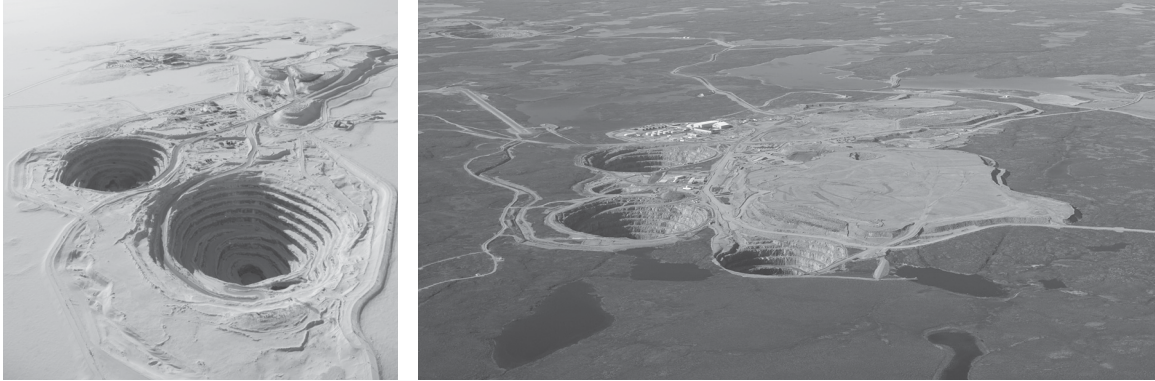
1948 Initiation of milling at the Giant Yellowknife Mines.

1970s Due to rising operational costs and an artificially low price of gold, mines begin closing throughout North America. Market price is allowed to inflate as a result and a new era of gold mining in Canada is ushered in. Giant mine begins open pit operations and Con mine sinks the 6100' deep Robertson shaft, one of the deepest in Canada. The resultant headframe is 250' high, making it a major landmark on Yellowknife's skyline.

1980s All-time high price of gold results in the resurrection of many closed gold mines, including Yellowknife's Ptarmigan mine which had been closed since 1942.



Aerial views of NWT's largest gold mining operations (1990's); Yellowknife's Con and Giant mines.
(from Aboriginal Affairs and Northern Development Canada)



Aerial views of NWT's Diavik and Ekati diamond mining operations
(from Infomine Inc / photographs by Rio Tinto and Jason Pineau)

1992 Bitter strike at Giant mine claims the lives of 9 miners after an explosion is deliberately set. A miners monument is erected at the Prince of Wales Heritage Centre to commemorate the lives of the miners killed in one of Canada's most tragic labour dispute.

1992 Diamonds discovered in the Lac de Gras area 300km northeast of Yellowknife.

1999 Giant mine owner Royal Oak Mines Inc goes into receivership and the mine's future is in doubt. Owners of the Con Mine buy the site, and continue operating the mine, though all ore processing is done at the Con property

2000 Northwest Territories Mining Heritage Society is formed to begin plans for an NWT mining museum and interpretive centre. Proposal is made to re-use existing recreation hall at the Giant mine town site for the main exhibition space

2003 Con mine underground operations officially end on November 28. Processing continues for ore from the Giant mine property

2004 Giant Mine ceases mining operations on July 7, marking the last day of the Yellowknife gold mines legacy.

2005 The Department of Aboriginal Affairs and Northern Development Canada (AANDC) takes control of Giant property and grants a surface land lease to the Government of the Northwest Territories (GNWT).

2006 AANDC continues maintenance and environmental management activities via Deton 'Cho-Nuna joint venture.

2007 Federal and Territorial Governments (AANDC & GNWT) partner to propose remediation plan for Giant mine property. Miramar Con mine submits final closure and reclamation plan to the city of Yellowknife and remediation begins.

2008 Giant Mine Remediation plan commences, including the freezing of 237,000 tonnes of toxic dust consisting of 60% arsenic, stored in underground purpose-built chambers.

2010 As part of Con Mine abandonment and restoration plan, Miramar Con Mine Ltd demolishes the iconic C-1 headframe and adjacent processing and roaster complex. Although plan also entailed demolition of the Robertson Headframe, city residents successfully save the landmark from destruction.⁴

4 Information for timeline collected from:

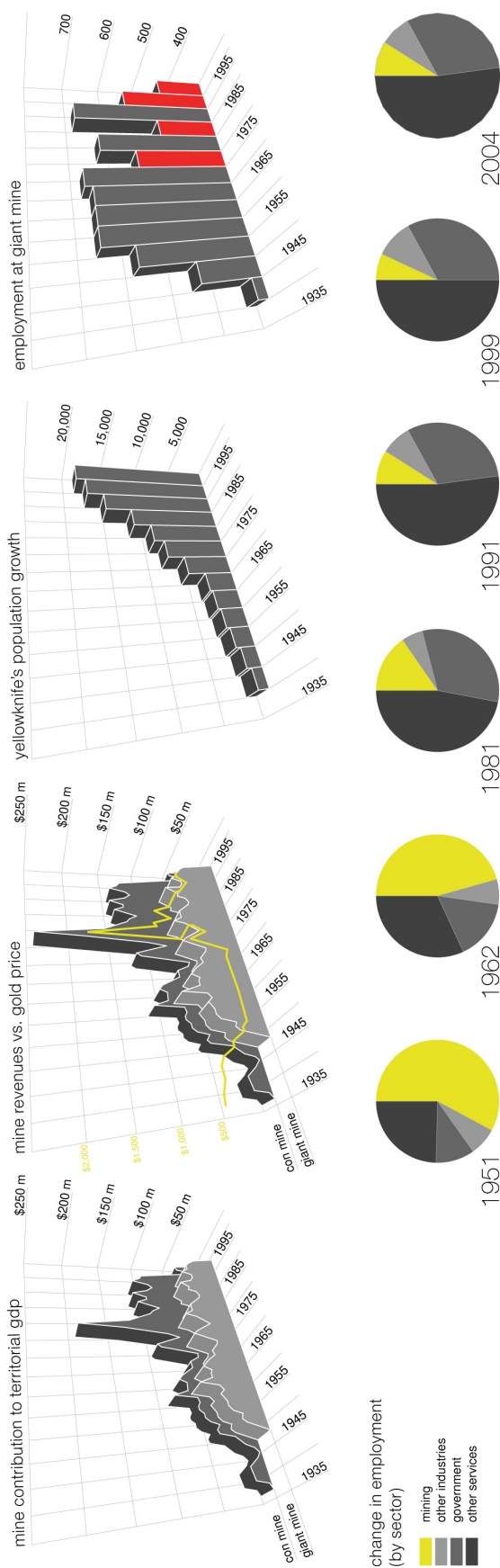
C.D. Anglin, *Gold in the Yellowknife Greenstone Belt, Northwest Territories: Results of the EXTECH III Multidisciplinary Research Project* (St. Johns, NL: Geological Association of Canada, Mineral Deposits Division, 2006)

Susan Jackson, *Yellowknife N.W.T: An Illustrated History* (Sechelt, BC: Nor'West Publishing, 1990)

Ryan Silke, *The Operational History of Mines in the Northwest Territories, Canada* (Yellowknife, NT: NWT Geoscience Office, 2009)

— — —. *The Gold Mines Built Yellowknife* (Yellowknife, NT: NWT Mining Heritage Society, 2010)

Stephen A Wolfe, *Living With Frozen Ground: A Field Guide to Permafrost in Yellowknife, Northwest Territories* (Ottawa: Geological Survey of Canada, 1997)



miningstatistics

Statistics illustrate the economic importance of Yellowknife area mines to the NWT. Graphics also compare the city of Yellowknife's growth in relation to the diminishing number of residents employed in the mining industry. (created with data from C.D. Anglin, *Gold in the Yellowknife Greenstone Belt, Northwest Territories: Results of the EXTECH III Multidisciplinary Research Project, and Living with Frozen Ground.*)

Yellowknife: Settlement and Growth

The city of Yellowknife is located on the northern shore of the mighty Great Slave Lake, some 2000km directly north of Edmonton, and only 400km shy of the Arctic Circle. It is essentially the end of the road in the Northwest Territories, with one access point from the south, and a winter only commercial “ice” road extending to the north. In addition to its current role as economic and political capital of the Territory, the city also functions as a transportation hub for much of the Arctic, with the majority of goods arriving by truck and dispersed by aircraft. With its current population of 20,000 people, and its developed land area measuring 13km², the city is remarkably dense considering the remote location. This is in part, due to mining developments in close proximity to the city.



Yellowknife's "Old Town" area / Aerial view of "Downtown" under development in the 1950's. (right) (from Prince of Wales Northern Heritage Centre Archives)

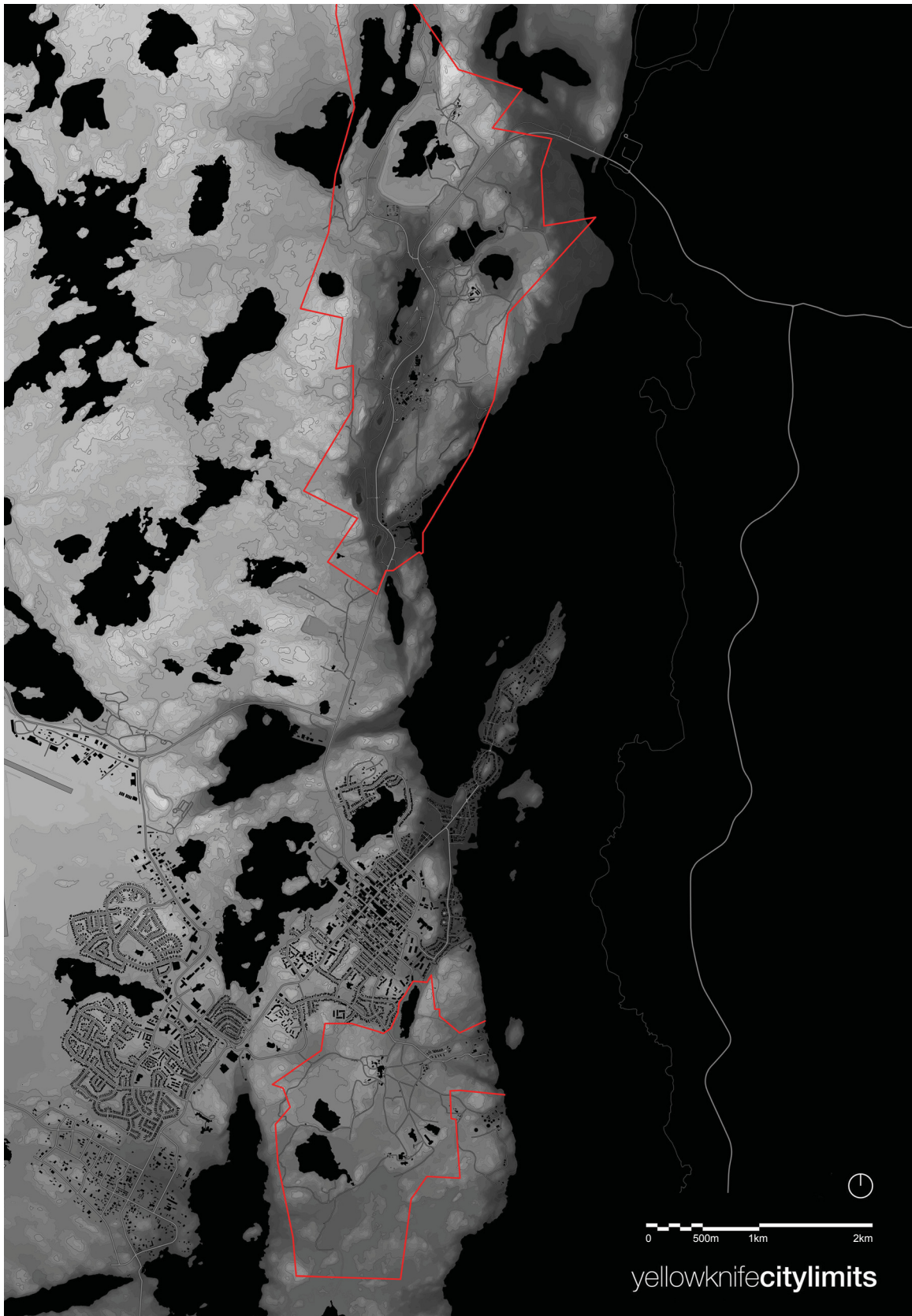
Yellowknife was first settled in 1936 after the massive property staking rush that commenced the year previously when considerable gold deposits were discovered in the area. By 1938, the townsite was booming, with many businesses newly opened, including a bank, drug store, hotel and pool hall. Located between the two major mining operations north and south of the settlement, Yellowknife served as a supply centre and transportation hub for the mining operations in the area. Just two years later in 1940, the population had increased to over 1,000 people, many of whom were employed by the five gold mines operating in the region. Though mining ceased and populations dwindled throughout World War II, new gold deposit discoveries north of the city created a second population boom in the late 1940's. By 1953, the town was declared a municipality, along with the appointment of a small council and building of a town hall. The majority of building occurred on the northern peninsula of the region along with Latham Island, now referred to as old

town. Rocky outcroppings and rugged topography made for a myriad of building types, configurations and styles, each unique to their particular parcel of land. Growth occurred southwards from the water-locked old town area, as a large sandy plateau was surveyed for a standard grid development in the 1950's.⁵ Due to its economic prosperity, Yellowknife was declared capital of the Northwest Territories in 1967, marking a third building boom in order to accommodate the new influx of government workers. Growth continued to extend south of the newly established downtown core, with standardized subdivisions for prefabricated trailer homes and new commercial corridors occupying the majority of the area. Though desirable by many of the city's residents, these subdivisions lacked much of the character and charm associated with the historic old town neighborhood further north. An industrial zone is located southwest of the city, though residential development has since encroached upon the area. Today, the city is bounded by lake-front on the east, industrial development and mining properties to the south, a conservation area, municipal dump and quarry to the west, and another mine to the north. These constraints further encourage greater density in regards to new development - a unique scenario for such a remote population.

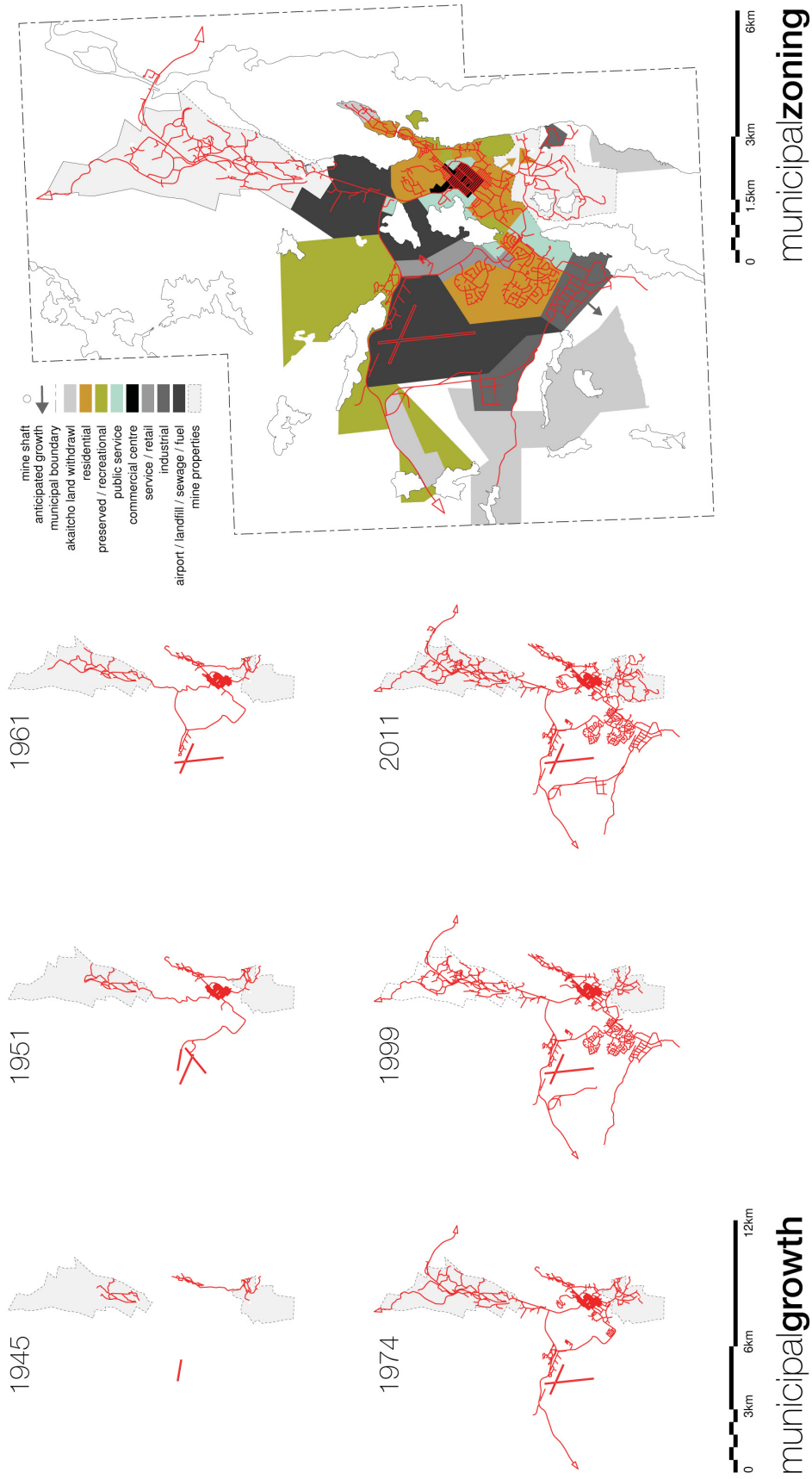
5 Barbara Bromley, Terry Foster and Ronne Heming, *Yellowknife Tales* (Yellowknife: Outcrop, 2000), 111.



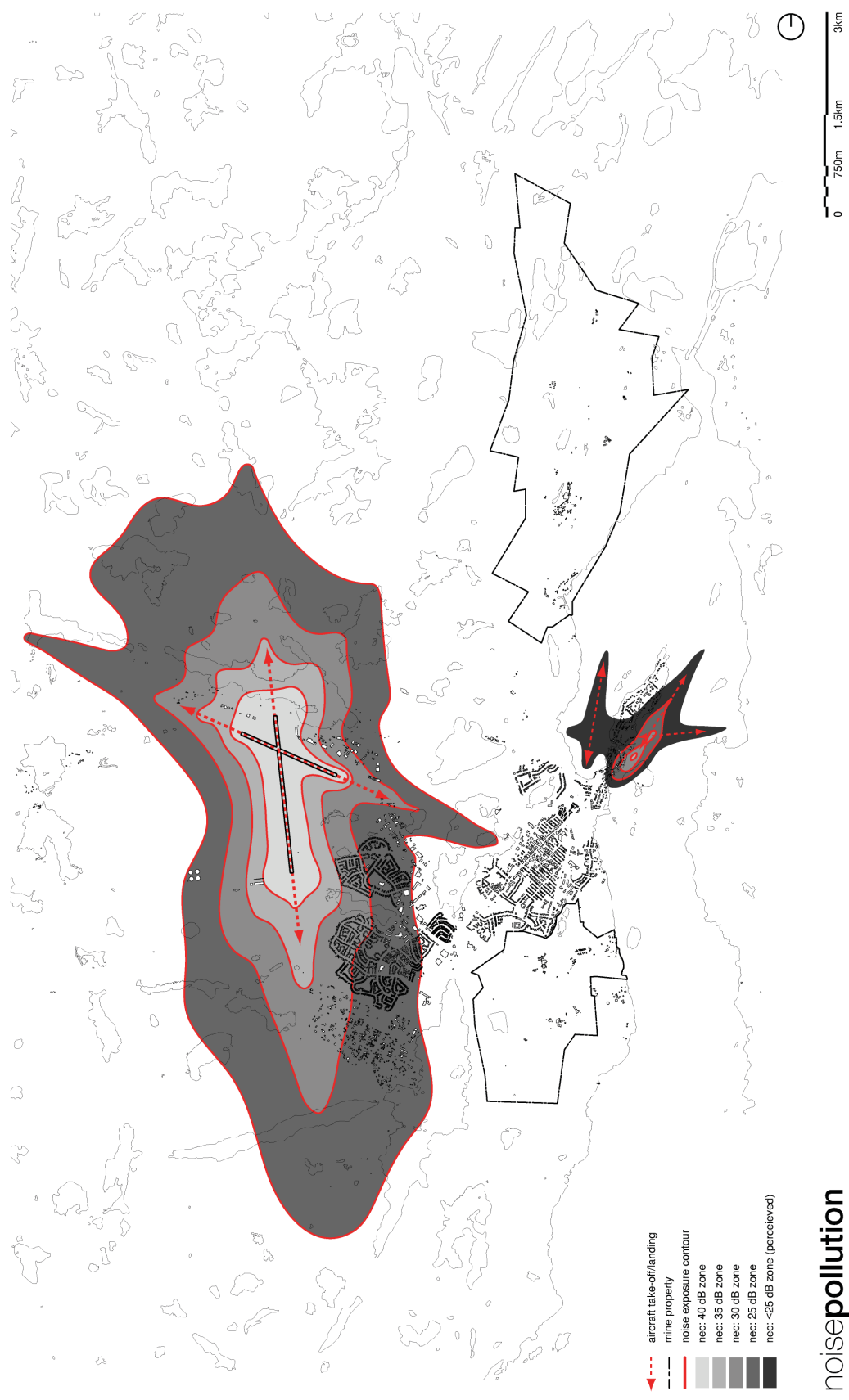
Aerial view of Latham Island and "Old Town" with Yellowknife's downtown beyond.
(from City of Yellowknife)



Map of Yellowknife indicating Con mine to the south and Giant mine to the north.
(created with data from the City of Yellowknife Department of Public Works)



Maps indicating the growth of Yellowknife from 1945 to 2011, and current municipal zoning. (created with data from the City of Yellowknife, Prince of Wales Northern Heritage Centre, Susan Jackson, *Yellowknife Northwest Territories, An Illustrated History*, and Peter Ostergaard, *Quality of Life in a Northern City: A Social Geography of Yellowknife NWT.*)



noise pollution

Map indicating sources of noise pollution in the Yellowknife area. The municipal airport and float base on Back Bay are the primary contributors. (created with data from *Yellowknife Airport (YZF) Development Plan*)

Building and Material Culture

Here houses and towns should open up like flowers to the sun of spring and summer, but also, like flowers, turn their backs on the shadows and the cold northern winds, offering sun-warmth and wind protection to their terraces, gardens and streets. They should be most unlike the arcaded towns and matt-shadowed streets of the south Europeans and Arabs, but most similar in their basic function...helping people to maintain their skin at a comfortable 25 degrees C... When studying the beautiful towns of the south, whether old or new, it is not the forms themselves which should interest us, but the inventiveness and artistry with which people solved their needs which were peculiar to their situation and time, the comfort and beauty which they created. Only by such methods can arise a personal and indigenous Alaskan, Canadian, Scandinavian or North Russian tradition.⁶

Ralph Erskine, Architect, Sweden

It is an understatement to imply that building is a difficult task in Canada's north. Climatically, the sub-arctic environment makes standard Canadian home construction unviable due to temperature extremes, day-lighting factors, discontinuous permafrost, and considerable snow drifting. Traditionally, aboriginals of the McKenzie Valley were migratory in nature, following caribou herds to the edge of the tundra in the summer months, and retreating to the Taiga's abundant lakes and rivers in the winter. Their shelters were typically designed to be transportable, with conical light-timber frames covered in hides designed for two families at most, and heated by a single fire. Conical log shelters were also utilized in bitterly cold winters, chinked with moss and partially covered with dirt to increase insulative value. Today, smaller buildings in the Territories are typically of a pre-fabricated nature due to the costs associated with labour and material transportation to remote areas. For larger buildings, steel framing is preferred due to the lack of locally available lumber and the extremely high cost of concrete. Furthermore, the moisture content of concrete is troublesome in a climate with a nearly 80-degree temperature differential throughout the year. In terms of insulation, buildings in Yellowknife are generally treated as hermetically sealed containers, limiting all forms of air penetration inside the envelope. In addition to standard batt insulation, most buildings are also "outsulated" with exterior rigid insulation panels to further increase R-values when possible. Metal siding is often the material of choice due to its durability. This approach to insulation provides difficulties in the very warm summer months, as air conditioning is not viable for such a short period of time,

6 Patrick Coleman, "Welcome to the Winter Cities Institute," *Winter Cities Institute*. 2012. <http://www.wintercities.com>.

and operable windows are limited due to their inability to withstand temperature extremes. Windows also provide an interesting predicament, as constant darkness throughout the winter negates the need for them throughout much of the year, and extremely long days in the summer make for considerable heat gains in buildings. These issues combined, diminish the desire for a large quantity of windows in most homes and buildings throughout Yellowknife. Lastly, and of most significant importance, snow drifting and discontinuous permafrost conditions typically result in buildings being lifted off the ground to promote both permafrost continuity and beneficial snow scouring. Though Yellowknife experiences little precipitation in the form of snow, large expanses of flat topography result in heavy wind gusts, blowing substantial quantities of snow against buildings and obstacles. It is common to have doors and windows completely buried overnight in a heavy winter wind storm. As one can imagine, permafrost plays an equally destructive role on the buildings and infrastructure of the north. Thaw settlement as it is termed, can happen at two temporal scales, the first of which occurs very dramatically. If water has an opportunity to drain rapidly as permafrost melts, very quick settlement can occur beneath a building, sometimes resulting in the complete failure of a structural system. Buildings in Yellowknife have literally cracked in half due to this extremely quick settlement. More commonly however, if water is unable to drain rapidly from melting permafrost, as is the case in the clay rich soils common in Yellowknife, a building can settle unevenly over the course of years or even decades. This often results in air infiltration, cracks in interior drywall, and fissures in exterior sheathing and cladding.⁷

Currently, there are four accepted foundation systems utilized in the north, however all have inherent vices. Firstly, and most commonly, is the piling of steel posts. These are typically anchored to bedrock if possible, or in the case of deep sandy soil, helical piles are used to bear sufficient friction on the soil. Moisture penetration and accumulation can cause a failure in the anchoring of the pile, and permafrost formation or seasonal freezing often heaves piles upwards, causing catastrophic damage to the building above. Secondly, thermosyphons or blankets of insulation are embedded in the ground beneath a slab-on-grade insulation in order to maintain a frozen ground condition year-round. The thermosyphon technique is prone to occasional mechanical system failure, and both re-

7 Stephen A Wolfe, *Living With Frozen Ground: A Field Guide to Permafrost in Yellowknife, Northwest Territories* (Ottawa: Geological Survey of Canada, 1997), 19.

sult in snow drifting due to the proximity of the building to the ground. Thirdly, triodetic, or multi-point “space-frame” foundation systems are utilized as an above-grade typology. These aluminium frames act as a large torsion-box which sits lightly on the ground. The entire building above moves as one intact object as the ground conditions change. Though successful in its general approach, the foundation does not actually anchor to the ground, and can sometimes result in instability during harsh weather and heavy winds. Also, the numerous “pads” need to be adjusted several times a season to ensure even load distribution on the space-frame. This is very time consuming and difficult due to the tight confined space between structural members. Lastly, simple timber cribbing is used for most small residences in Yellowknife, however this involves constant maintenance and the utilization of heavy hydraulic jacks to ensure a level building. The first of these two approaches involves heavy machinery, skilled workers, and extremely costly labour. The latter two are more economical for the average homeowner, but they require a great deal of maintenance to ensure proper leveling over the course of the changing seasons.



An innovative condominium project by Pin/Taylor Architects in "Old Town" Yellowknife, 2008.
(From Pin/Taylor Architects, photo by Ihor Pona)

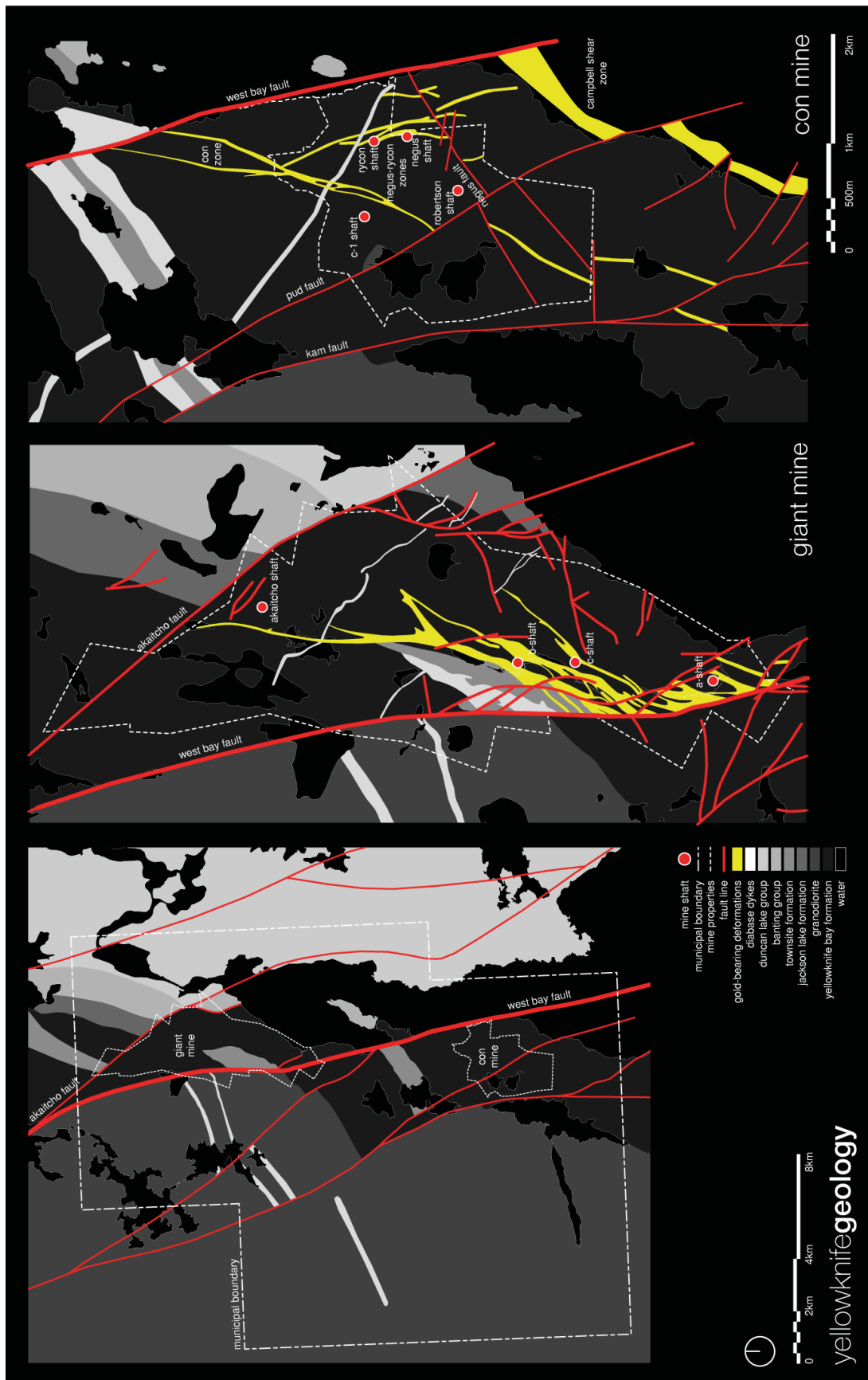
Environmental Context

Geology

Geologically, the city of Yellowknife straddles two types of Precambrian bedrock, granitic and volcanic, both dating back to 2.7 billion years ago, making it some of the oldest rock formations on the planet. This Archean-aged formation is termed the Yellowknife Greenstone Belt, and extends northwards from Yellowknife for more than 50 kilometres. The belt is of a homoclinal nature, meaning all of the underlying strata is oriented and tilted in the same direction. It's dip, defined as the angle of inclination, falls from the east to the west at a 45-80 degree angle. The belt is composed of several major shear zones oriented north-south and containing gold-bearing ore, each being host to mining operations in the Yellowknife region. The originally discovered Rycon and Negus shear zones are 35 metre-wide, planar discontinuous zones composed of chlorite-carbonate and sericite-chlorite-carbonate schist, with ore zones composed of gold-bearing quartz-sericite veins. Beneath them, the Campbell and Con shears are the largest gold-bearing ore bodies south of the city and are composed of the same type of rock as those above extending to depths of over 2km beneath the surface.⁸ Subsurface hydrogeology is also of importance in regards to mining operations in the Yellowknife region. The Greenstone Belt is hydraulically tight, except near major shear zones and fault lines, the largest of which is known as the West Bay Fault, extending north-south through the area. These fractured zones funnel migrating ground water due to their lack of hydraulic pressure, thereby reducing and preventing large-scale regional groundwater flows. This results in a large amount of water discharge throughout the mine infrastructure, requiring major pumping operations to continue well beyond the closure of mining operations. Groundwater throughout the Con Mine differs depending on depth, with high-salinity Shield Brine typical of the greatest depths. Glacial melt water from 10,000 years ago, old meteoric water and recently recharge meteoric water compose the remainder of the strata, from deep to shallow respectively. Generally speaking, from the 2300ft level (700m) and below, groundwater is highly brackish in nature.⁹

8 Wolfe, *Living With Frozen Ground*, 5-7.

9 Miramar Mining Corporation, *Miramar Con Mine, Ltd: Final Closure and Reclamation Plan* (Yellowknife, NT: Miramar Con Mine Ltd, 2007), 7-8.



Maps indicating gold-bearing formations of the Yellowknife area. (created with data from C.D. Anglin, *Gold in the Yellowknife Greenstone Belt, Northwest Territories: Results of the EXTECH III Multidisciplinary Research Project*)

Geography and Landscape

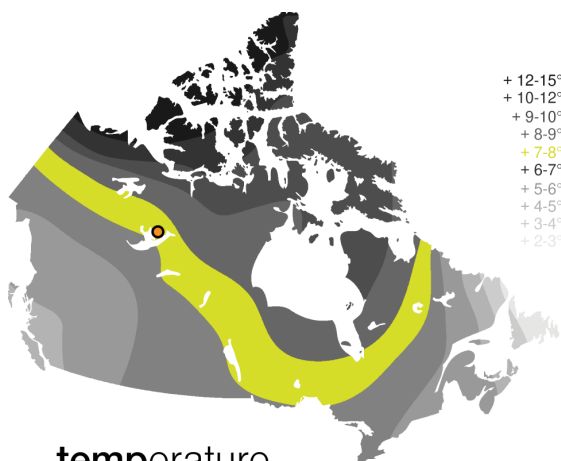
A passage from Harold Strub's *Bare Poles* beautifully illustrates the aura of the sub-arctic landscape surrounding northern communities such as Yellowknife.

Well below freezing the air inside the plane turns breath to fog and windows to ice. Heat from a hand pressed against the glass makes a patch of window transparent long enough for a glimpse of the snow-blown expanse of rock three hundred metres below. Evidence of the bruising contact between the continental ice sheet and the bedrock persists in massive striations running straight to the horizon, in pillowed rock fissured by freezing water, and in lakes and ponds separated by glacial till deposited during the last ice retreat ten thousand years ago. Too smooth and exposed to nurture plant life taller than ten centimetres, the rock forces the black spruce to take root in sheltered crevices where dust, nutrients, rain, and snow drop out of the wind. Even the low stratus just above the aircraft seems to have taken its shape from the rock.¹⁰

The Yellowknife region has been sculpted and defined by numerous periods of glaciation, the most recent of which occurred during the Quaternary Period in the late Holocene Epoch. It was then, approximately 10,000 years ago, that glaciers receded from the McKenzie Valley scraping the surface of this rugged Canadian Shield clear of most organic matter. What remained was an ice-scoured planar topography characterized by grooved, polished and striated rock surfaces, with interspersed erratics and rounded rock knobs. Subsequently, as the Laurentide Ice Sheet melted, the majority of the McKenzie Valley was flooded to an elevation of almost 100 metres above current conditions. This enormous water body was later termed Lake McConnell, and at one point encompassed all of present-day Great Bear, Great Slave and the Athabaska Lakes. This submergence resulted in the deposition of small silt and clay deposits in geographic lows. Today, this glaciated bedrock, dotted with small soil deposits, form a unique ecozone known as the Taiga Shield, extending 250km north of Yellowknife until the sedge-dominated tundra ecozone begins. Due to the limited silt and clay-based soil deposits, the Taiga is characterized by stunted coniferous trees interspersed with small pockets of oxygen depleted peat bog wetlands.¹¹

10 Harold Strub, *Bare Poles: Building Design for High Latitudes* (Ottawa: Carleton University Press, 1996), 8-9.

11 Wolfe, *Living With Frozen Ground*, 5-7.



- + 12-15°
- + 10-12°
- + 9-10°
- + 8-9°
- + 7-8°
- + 6-7°
- + 5-6°
- + 4-5°
- + 3-4°
- + 2-3°

temperature
 anticipated climate change in degrees
 (over next 10 years)



- 90-100%
- 50-90%
- 10-50%
- 0-10%

permafrost
 percent of permanently frozen surficial geology



- arctic cordillera
- northern arctic
- southern arctic
- montane cordillera
- taiga shield
- hudson plains
- taiga cordillera
- boreal shield
- boreal cordillera
- mixedwood plain
- pacific maritime
- atlantic maritime
- mountain cordillera
- boreal plains
- prairie

ecozones



sea-levelrise
 areas of anticipated coastal flooding

Maps indicating climatic information for Canada, with those applicable to the NWT in yellow.
 (created with data from Wolfe, *Living with Frozen Ground* and Environment Canada)



Typical landscape of the Yellowknife Region.

Climate and Permafrost

Climatically, Yellowknife experiences a continental subarctic climate influenced by arctic air masses in winter and spring. These chilled air masses that have traveled thousands of kilometres over pack ice, result in the city having an average annual temperature of -5.2°C , and a record minimum temperature of -51.2°C . Wind generally blows from the north in the winter months, and from the south in the summer, with fairly consistent average speeds year-round. In terms of precipitation, the region is fairly arid with averages of 200-300mm a year, 116mm of which typically arrives as snowfall. The majority of snowfall occurs in October and November, though blowing snow and drifting is still a major issue for Yellowknife residents throughout the remainder of the winter.¹² Interestingly, it is important to note that climate normals have changed significantly throughout sub-arctic Canada in the last few decades. Average temperature and precipitation amounts have increased dramatically in Yellowknife recently, with a projected increase in mean annual temperature expected to be nearly 10 degrees in the next 30 years.

To elaborate on the issue of “global warming” and its consequence on the surficial geology of the Yellowknife region, it’s critical to understand the principles of permafrost. The city is currently located on the divide between widespread discontinuous permafrost and sporadic discontinuous permafrost, a dynamic threshold which has been moving for millions of years as mean annual temperatures in the area have risen and fallen due to glaciation, volcanic activity, and a tilting earth axis. These two regions of varying discontinuous permafrost divide the areas of Canada where the ground below an active layer is permanently frozen, and where it is permanently un-frozen. Although permafrost is heavily influenced by factors such as snow accumulation, sun shading by vegetative cover, hydrological processes, topography, and subsurface geology, it can typically be found as pockets, or islands beneath peat bogs, where the accumulation of non-decomposed organic matter forms an insulative barrier above the ground. Pockets of permafrost in the Yellowknife region are relatively warm, with an average annual temperature ranging from 0°C to -1°C , and only extend to a depth of 50 to 85m below the surface.¹³ This is due to an average geothermal gradient of 12 to $16^{\circ}\text{C}/\text{km}$ of depth. Unlike ground conditions in

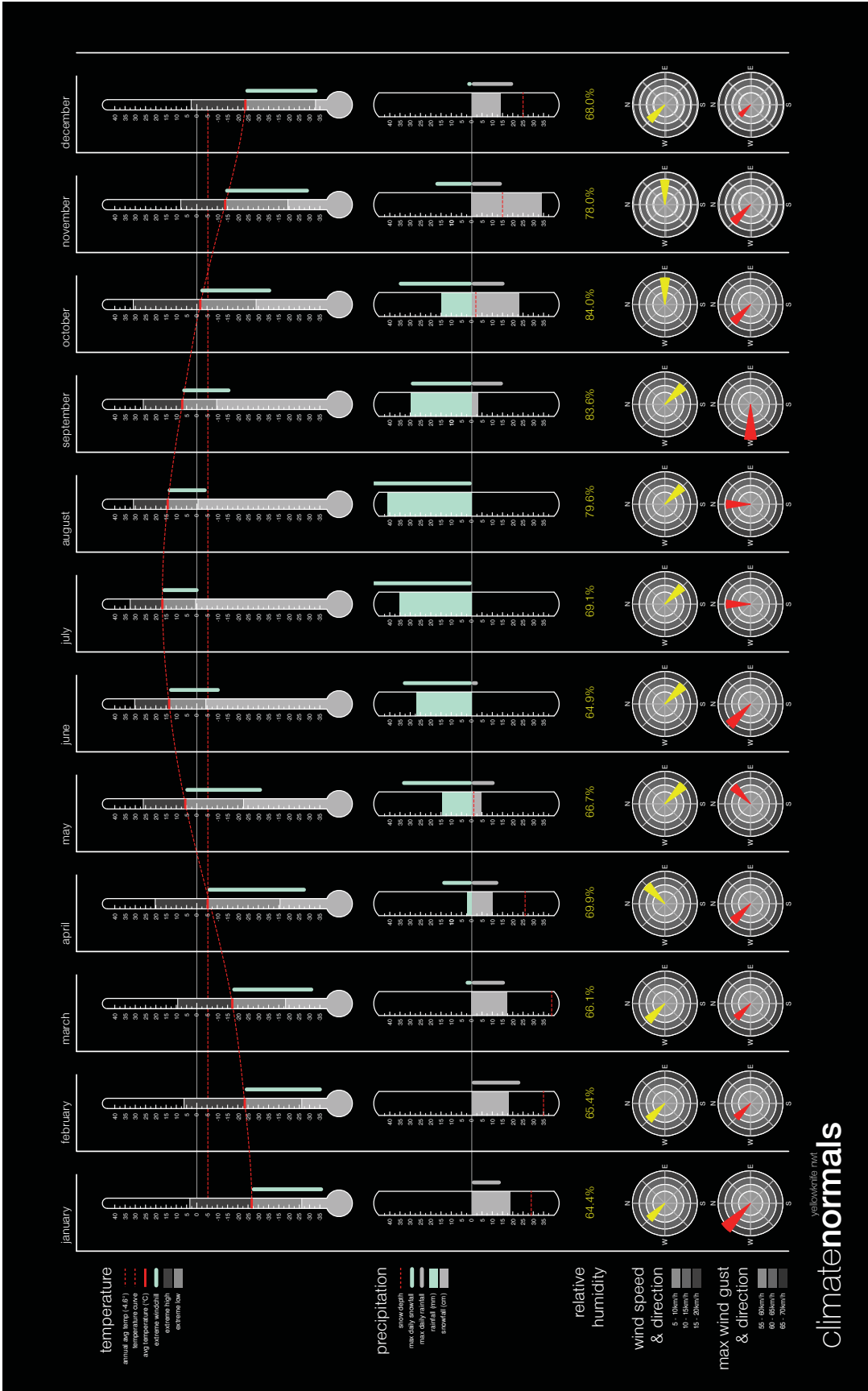
¹² Miramar Mining Corporation, *Final Closure and Reclamation Plan*, 5.

¹³ Wolfe, *Living With Frozen Ground*, 3.

Southern Canada, the active layer in northern environments consists of a small depth of soil below the surface that thaws for a short period of the year. In Yellowknife, the active layer varies from 1m in areas insulated by organic matter, to 3m or more where there is little insulation. The area is also prone to Talik formations, which consist of unfrozen zones beneath otherwise frozen ground.¹⁴

To illustrate the effects of permafrost on a landscape, one can look to the formation and decay of peat plateau's. These plateaus are typically formed in wetland areas underlain by silt and clay deposits. Due to the accumulation of non-decomposed organic matter on the bed of wetlands and bogs, peat layers can form upwards of 1 metre in thickness. These layers then act as insulative blankets, resulting in ground maintaining a frozen state throughout the year. As the process of freezing expands the soil, the surficial layer of peat domes upwards, forming peat plateau's which are essentially islands of organic matter. This densely rich soil becomes oxygenated once exposed to the elements, and thus the process of decomposition supports the growth of vegetation. These plateaus are often cyclical in nature however and at a certain critical mass, hydrological cycles and other environmental factors begin to decay the permafrost pocket below the surface. As this happens, the plateaus begin to settle resulting in what is commonly referred to as a "drunken forest." This process of uneven soil settlement results in the vegetation above to lean, tilt, and sometime uproot altogether. Thaw settlement as it is termed, can happen at two temporal scales, the first of which occurs very dramatically. If water has an opportunity to drain rapidly as permafrost melts, very quick settlement can occur. More commonly however, if water is unable to drain rapidly from melting permafrost, as is the case in the clay rich soils common in Yellowknife, the ground can settle unevenly over the course of years or even decades.

14 Ibid., 16-20.



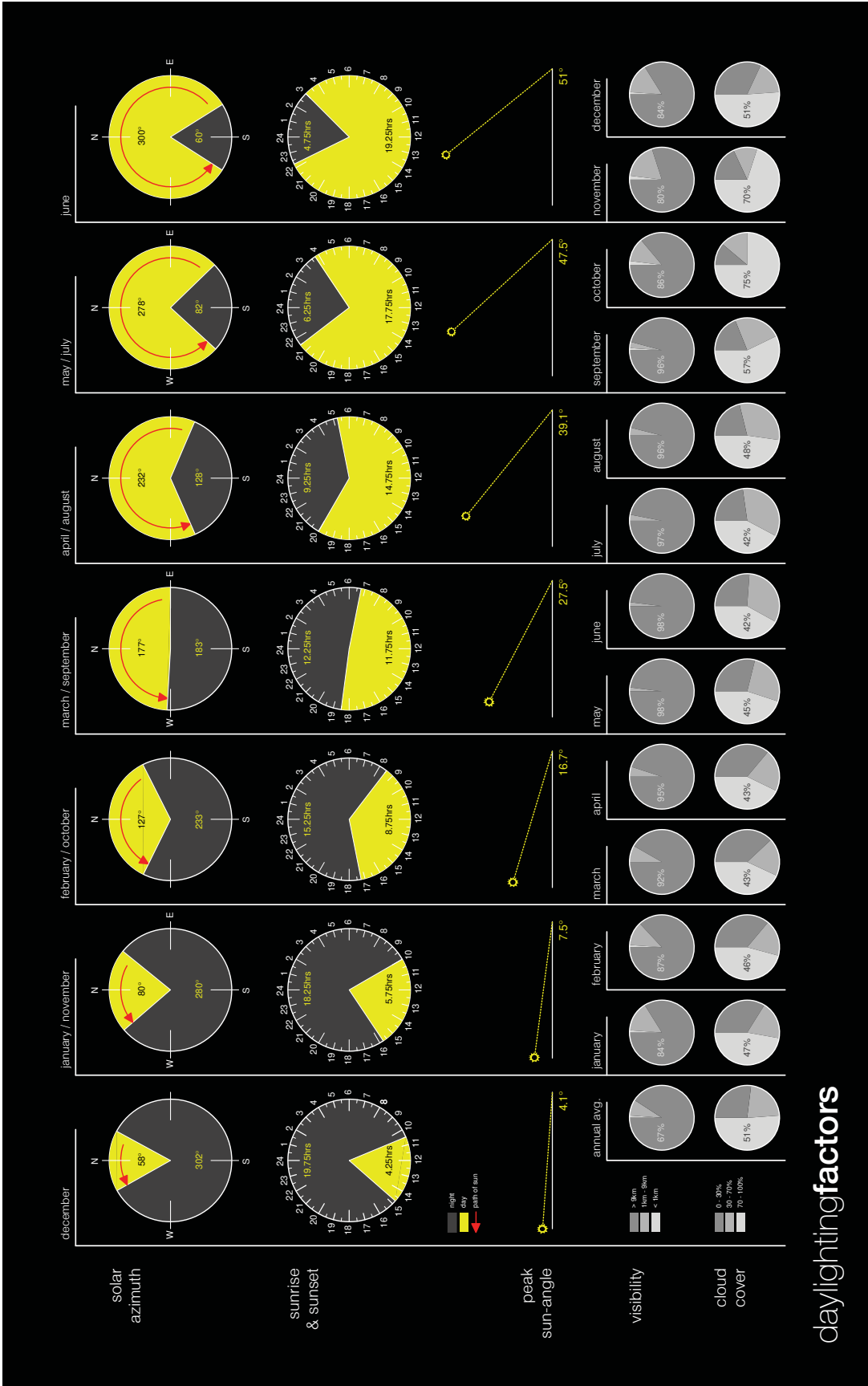
Climate normals for the city of Yellowknife, including snow and rain accumulation, temperature, relative humidity, and wind speed and direction. (created with data from Environment Canada)

Daylighting Factors and the Aurora Borealis

Due to the fact that the Earth's axis is tilted with respect to the elliptic by approximately 23 degrees, Northern latitudes such as Yellowknife experience extended periods of daylight in the summer months, and extending periods of darkness in the winter. This translates to 4.25 hours of sun exposure on the winter solstice, compared with 19.25 in late June. Subsequently, this results in a mere 58 degrees of solar azimuth in December, and almost 300 degrees on the summer solstice. It is important to note however, that throughout much of the modern world, there exists an astronomical myth that the entire arctic is shrouded in complete darkness or illuminated in total light for half of the year respectively. This myth seems to negate the existence of twilight, an important factor in daylighting theory throughout Canada's north. On the contrary, the sun continues to illuminate the earth's surface until its upper rim has passed more than 18-degrees below the horizon. Civil twilight is a term for when daytime outdoor activities can still be safely conducted, and corresponds to the sun being less than 6 degrees beneath the horizon. This is an important phenomenon to consider when consulting the subsequent daylighting infographic. Twilight exists during all 4.75 hours that the sun is absent during the summer solstice. Despite 24 hours of atmospheric light however, the sun is still positioned relatively low on the horizon throughout much of the day, resulting in consistent low-intensity sunlight. The sun's peak angle at noon during mid summer is a mere 51 degrees in Yellowknife, compared with 4.1 degrees during mid-winter.¹⁵ As for visibility and cloud cover, the skies above Yellowknife are generally clear year-round, although a phenomenon known as "ice-fog" can commonly occur during extreme cold-spells.

In addition to these unusual daylighting conditions, Yellowknife is also uniquely positioned to experience the Aurora Borealis almost nightly during the darker months of the year. Scientifically, this incredible light show is produced by the collision of charged particles from Earth's magnetosphere. This occurs in a ribbon formation around the Earth's upper latitude, with the city of Yellowknife being positioned almost directly underneath its path, one of the only cities in the world to be so fortunate.

15 Environment Canada, "Canadian Climate Normals, Yellowknife NWT," *Environment Canada*. 2012. http://www.climate.weatheroffice.gc.ca/climate_normals.



daylighting factors

Daylighting information for the city of Yellowknife including azimuth, sunrise and sunsets, sun angles, and visibility data. (Created with data from Environment Canada)

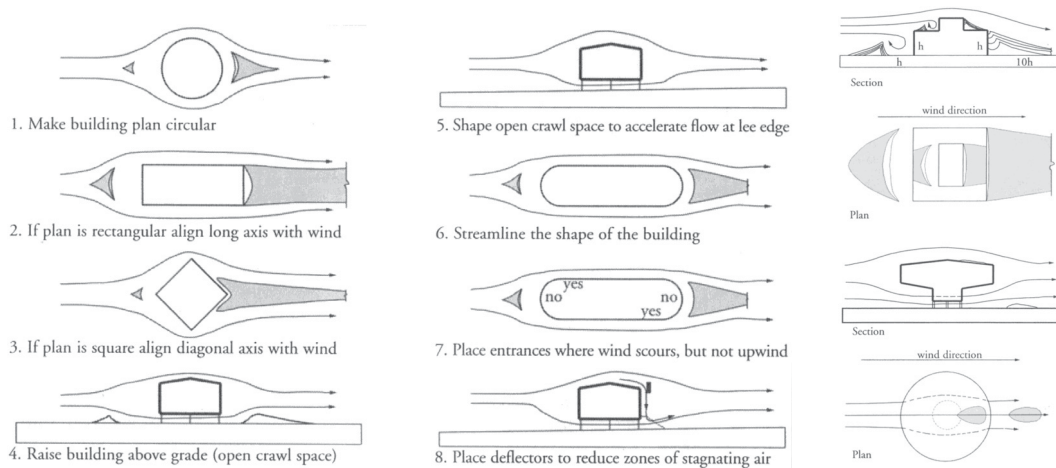


Northern lights over the Robertson headframe at Con mine.
(image from Canadian Space Agency)

Principles of Snow Drifting

Though little precipitation falls in the form of snow throughout much of Canada's north, snow drifting is a major concern when designing and siting a building or neighborhood, particularly in areas north of the treeline. There are many site-specific characteristics that influence drifting, mainly wind direction and speed, topographic formations, spatial relationships with other buildings, the form of the building, and the quantity of snow particles in the air stream. Understanding these complex variables is essential to preventing the dangerous accumulation of snow on, and around a proposed building. Common strategies to prevent accumulation involve the correct orientation and shape of a building. To illustrate, a circular building lifted off the ground on piles with gently curved roof and soffit surfaces will minimize air turbulence and allow wind to accelerate above and beneath the building, similar to the effects of an aircraft wing. To contrast this result, a slab-on-grade rectangular building oriented perpendicular to the prevailing wind direction encourages the deposition of snow on both the windward, and the leeward elevation.¹⁶ In addition to the drifting that occurs, the air turbulence resulting from this orientation can be quite powerful, impacting pedestrian circulation and interior occupant comfort. With these principles in mind, it is critical to position entrances where snow is scoured by the wind, and turbulence is minimal. To date, water flume trials are the most accurate simulations to determine the effects of snow drifting considerations, as they entail a building model being placed in a tank filled with water and very fine sand particles.

16 Strub, *Bare Poles*, 95-96.



Eight rules of thumb for controlling snowdrifts around buildings and a drift pattern comparison between a building with a closed crawl space, and a building designed to minimize air turbulence. (images from Harold Strub, *Bare Poles: Building Design for High Latitudes*)

Flora and Fauna

Due to the extreme temperature differential and limited soil cover typical of the Taiga ecozone, relatively few species of flora and fauna call the Great Slave Lake region home. What may be lost in diversity however, is certainly made up for in strength, persistence and beauty. In terms of vegetation, the Taiga forest is principally comprised of stunted Black Spruce, Jack Pine, Paper Birch, and Trembling Aspen, all of which have adapted to extremely shallow soil conditions, a short growing season, limited sunlight, and cold annual temperatures.¹⁷ Incredibly, these tree species flourish on bedrock outcroppings, sprouting from cracks and fissures with miniscule amounts of soil from which to find sustenance. The landscape is also dominated by bogs and other wetlands typical of low-lying silt, clay, and sand deposits. These oxygen deprived aquatic conditions result in the formation of peat, a critical component for the growth of a wide selection of grasses and sedges. It is here that low-lying flowering plants, wild roses, edible berries, lichens, and mosses can be found. In autumn, these muskeg landscapes produce incredibly vivid colours - a truly inspiring palette of fiery reds and oranges, along with vibrant blues, purples and pinks. The Northwest Territories is also home to an interesting array of fauna, many of which are migratory due also in part to the extreme temperature range of the ecozone. Though migratory Elk, Caribou and Bison sometimes frequent the Yellowknife area, it is bird and fur-bearing species that are most commonly witnessed by humans. Though lynx, wolves, black bears and moose explore the area in relative stealth, it is the marten, beaver, fox, mink and hare that are most prevalent. Their abundance was of great importance to the warmth of early Yellowknifers. As for aquatic life, only a few fish species populate northern fresh-water lakes, with pike, lake trout, walleye and grayling being the most common in Great Slave Lake and its surrounding tributaries. Interestingly, of the 184 bird species that frequent the area in the warm summer months, only 40 remain during winter, with birds of prey, crows and ptarmigan being the most common.¹⁸ Though few insects and only one reptile call the Yellowknife region home, mosquitoes and blackflies all but make up for this lack of variety. Long days and consistently warm temperatures make for very abundant populations of both biting insects.

¹⁷ Wolfe, *Living With Frozen Ground*, 8-9.

¹⁸ Strub, *Bare Poles*, 37-38.

Trees & Shrubs:



Alaska Birch
(*Betula neotasiensis*)



Balsam Poplar
(*Populus balsamifera*)



Black Spruce
(*Picea mariana*)



Dwarf Birch
(*Betula nana*)



Green Alder
(*Alnus viridis*)



Jack Pine
(*Pinus banksiana*)



Lodgepole Pine
(*Pinus contorta*)



Tamarack
(*Larix laricina*)



Trembling Aspen
(*Populus tremuloides*)



White Birch
(*Betula papyrifera*)



White Spruce
(*Picea glauca*)



Arctic Willow
(*Salix arctica*)

Wildflowers:

Aquatics:



Common Mare's Tail
(*Hippuris vulgaris*)



Marsh Cinquefoil
(*Potentilla palustris*)



Small Yellow Pond Lily
(*Nuphar variegatum*)



Water Arum
(*Calla palustris*)

Buckwheat:



Western Dock
(*Rumex occidentalis*)



Dogwood
(*Cornus canadensis*)

Buttercup / Crowfoot:



Prairie Crocus
or Pasque Flower
(*Anemone patens*)



Yellow Marsh Marigold
(*Caltha palustris* var.
arctica)

Crowberry:



Crowberry
(*Empetrum nigrum*)



Common Horsetail
(*Equisetum arvense*)

Daisy:



Alpine Arnica
(*Arnica alpina*)



Common Blue Lettuce
(*Lactuca tatarica*)



Common Yarrow
(*Achillea millefolium*)

Evening Primrose:



Arctic Fireweed
(*Chamaenerion latifolium*)



Dwarf Fireweed
(*Chamaenerion latifolium*)



Marsh Willow Herb
(*Epilobium palustre*)

Health:



Alpine Bearberry
(*Arctostaphylos alpina*)



Lapland Rosebay
(*Rhododendron lapponicum*)



Northern Labrador Tea;
Small Hudson Bay Tea
(*Ledum decumbens*)

Mint:



Marsh Skullcap
(*Scutellaria galericulata*)



Wild Mint
(*Mentha a venensis*)

Mustard:



American Winter Cress
(*Barbarea orthoceras*)



Hairy Rock Cress
(*Arabis hirsuta*)



Northern Tansy-Mustard;
Flaxweed
(*Descurainia, sopheroides*)

Pea:



Hooded Ladies' Tresses
(*Spiranthes romanzoffiana*)



Northern Green (flowered)
Bog-Orchid
(*Habenaria hyperborea*)



Round-Leaved Orchid
(*Orchis rotundifolia*)

Primrose:



Mealy Primrose
(*Primula incana*)



One-sided wintergreen
(*Pyrola secunda*)

Saxifrage:



Northern Grass of
Parnassus
(*Parnassia palustris*)



Prickly Saxifrage;
Three Toon Saxifrage
(*Saxifraga incuspidata*)



Purple Saxifrage
(*Saxifraga oppositifolia*)



Yellow Marsh Saxifrage
(*Saxifraga hircullis*)

Poppy:



Arctic Poppy
(*Papaver alpinicum*)

Primrose:



Mealy Primrose
(*Primula incana*)

Wintergreen:



One-sided wintergreen
(*Pyrola secunda*)

Rose:



Arctic Avenas;
Mountain Avenas
(*Dryas integrifolia*)



Croudberry;
Baked-Apple
(*Rubus chamaemorus*)



Dewberry;
Hairy Dewberry;
Rumpel; Rascoberry
(*Rubus pubescens*)

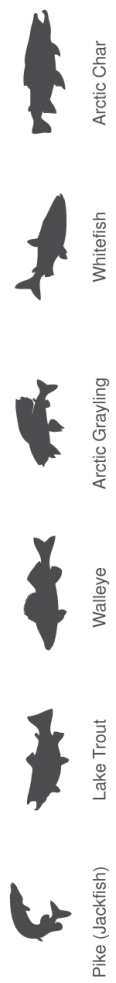
Flora of the Northwest Territories organized by Genus.
(created with data from Agriculture and Agri-Food Canada)

Sub-Arctic Fauna:

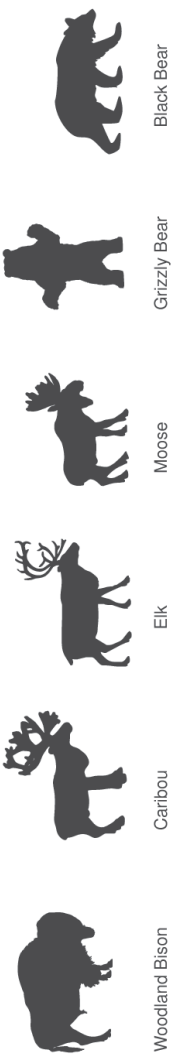
Birds:



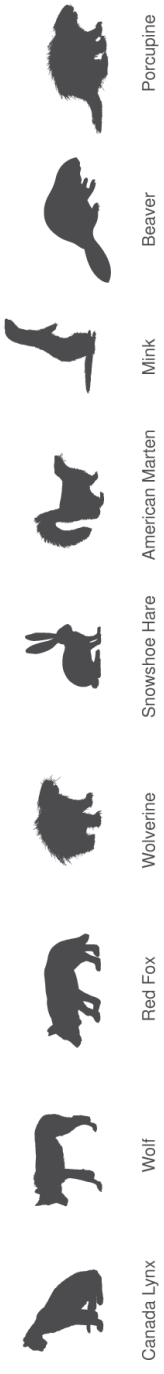
Fish:



Magafauna:



Furbearers:



Fauna of the Northwest Territories organized by Genus.
(created with data from *Canadian Geographic*)

Site Selection

Mines of the Yellowknife Area

Mineral claim staking first began in the Yellowknife area during the summer of 1934, instigated by a mapping party of the Geological Survey of Canada. Only a year later the entire Yellowknife Greenstone belt had been staked, and when the dust settled, only two companies controlled interest of the area and its bountiful golden resource. The Falconbridge company, and Consolidated Mining and Smelting Limited (or Cominco as it was commonly termed) soon began major production based out of two operations; the Con and Giant mines. Despite there being dozens of minor producers located near Yellowknife over the last 75 years, these two mining operations are most notable in both their economic prosperity and cultural permanence.¹⁹

Bounding Yellowknife on the south, is the Con Mine property, an 8km² site now decommissioned and under remediation by US owned Newmont Mining Company. The surface of this property was mainly scarred by tailing ponds, as no open pit mining was conducted here. Beneath the surface however, is a vast complex of tunnels and shafts, the deepest of which reach nearly 2km below the surface. To the north, is the 10km² Giant Mine Site, currently owned by the Department of Aboriginal Affairs and Northern Development Canada. This site however, contains a large percentage of surface contamination, as vast tailing ponds and waste depositories interweave 8 massive open pit mines. Though extensive horizontally, the underground infrastructure of Giant Mine is relatively shallow compared to Con Mine, with the deepest shafts reaching just over 600 metres in depth.²⁰

Con mine was the founding industrial centre of Yellowknife, having first achieved gold production in 1938. It was among the first of many gold mines in the Northwest Territories, and would continue producing gold until 2003, when it was closed indefinitely and remediation efforts on the site were initiated. Located immediately south of the current city centre, and encroached upon by sprawling subdivisions, the mine site occupies a large swath of undeveloped land. Today, few structures remain on the property, the most notable of

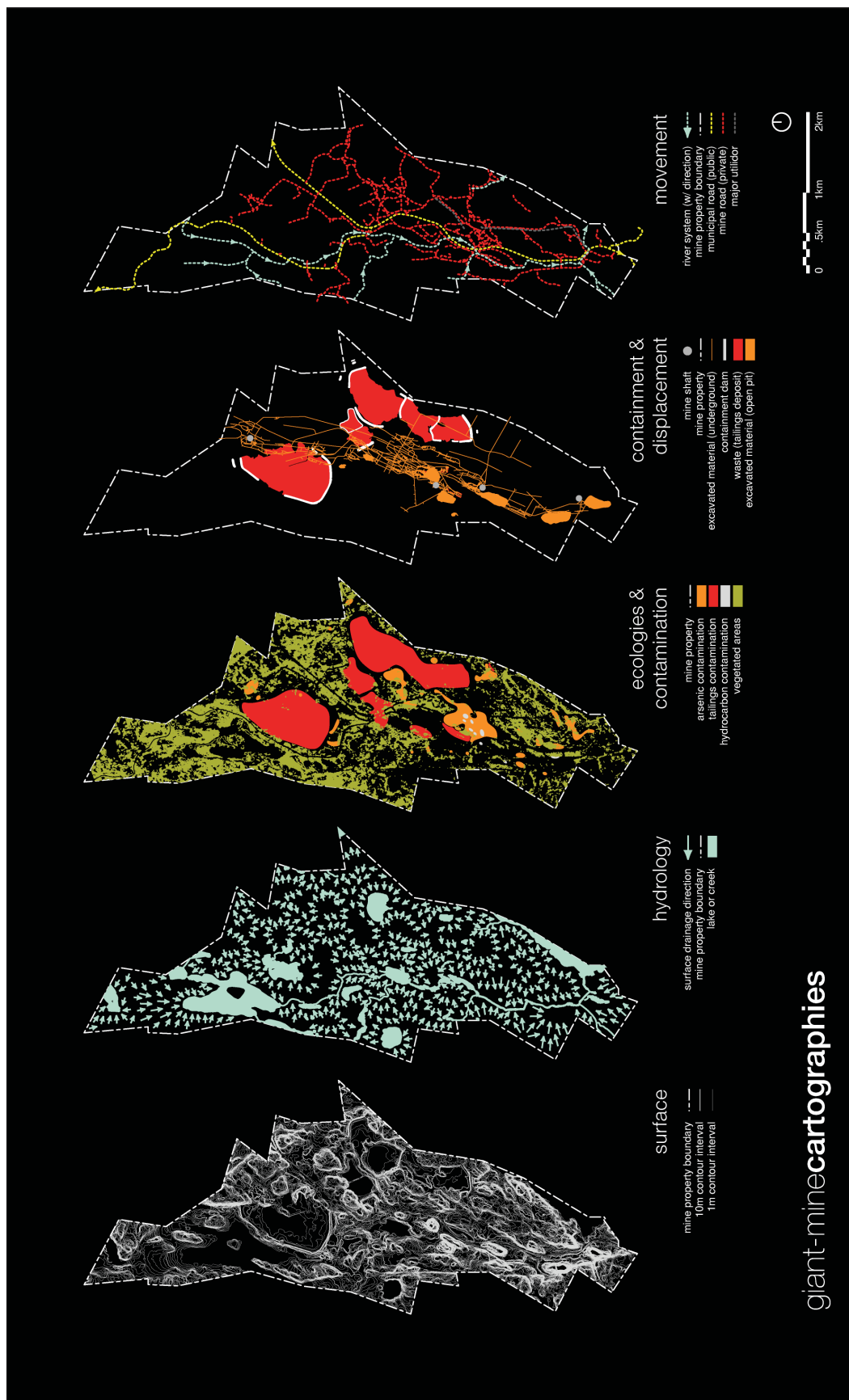
19 Susan Jackson, *Yellowknife N.W.T: An Illustrated History* (Sechelt, BC: Nor'West Publishing, 1990), 14-16.

20 Ryan Silke, *The Operational History of Mines in the Northwest Territories, Canada* (Yellowknife, NT: NWT Geoscience Office, 2009), 112.

which is the Robertson Headframe, a remarkable structure erected to hoist the vast quantities of ore and men up from the 2km deep shaft below. The 76 metre high structure was built during the modernization efforts of the 1970's, and towers above Yellowknife as the tallest building in the Canadian territories. The building was slated for demolition after the mine was closed in 2003, however Yellowknife residents successful fought to preserve the iconic structure. Pilots and boaters alike swear by the reliability of the red "cap" to usher them home safely, and the building and shaft are currently the subject of a proposed geothermal district energy proposal for the downtown core. Potentially, the consistently warm shafts of Con Mine will warm hundreds of offices throughout the brutally cold northern winter.

Located directly north of Yellowknife, Giant Mine was opened during the city's second major staking boom after a massive gold-bearing zone was discovered on the property in 1944. The mine entered production in 1948, and produced nearly 7 million ounces of gold until it closed in 2004. The site was the focus of a major labour dispute that culminated in the killing of 9 strike breakers in September 1992. The event was later featured in a CBC television movie entitled "Giant Mine". Currently, the 950 hectare site is home to 8 open pits, 4 tailings ponds, 325,000m² of contaminated soil, and over 100 buildings, some of which are condemned due to arsenic and asbestos contamination. The clean-up is being handled by Aboriginal Affairs and Northern Development Canada, and is expected to cost upwards of \$400 million.²¹

21 Ibid., 246.



Analysis of the Giant mine property including surface contours, hydrology, circulation, vegetative cover and contamination, along with subterranean and surface excavations and deposits.
 (created with data from *Giant Mine Remediation Project*)

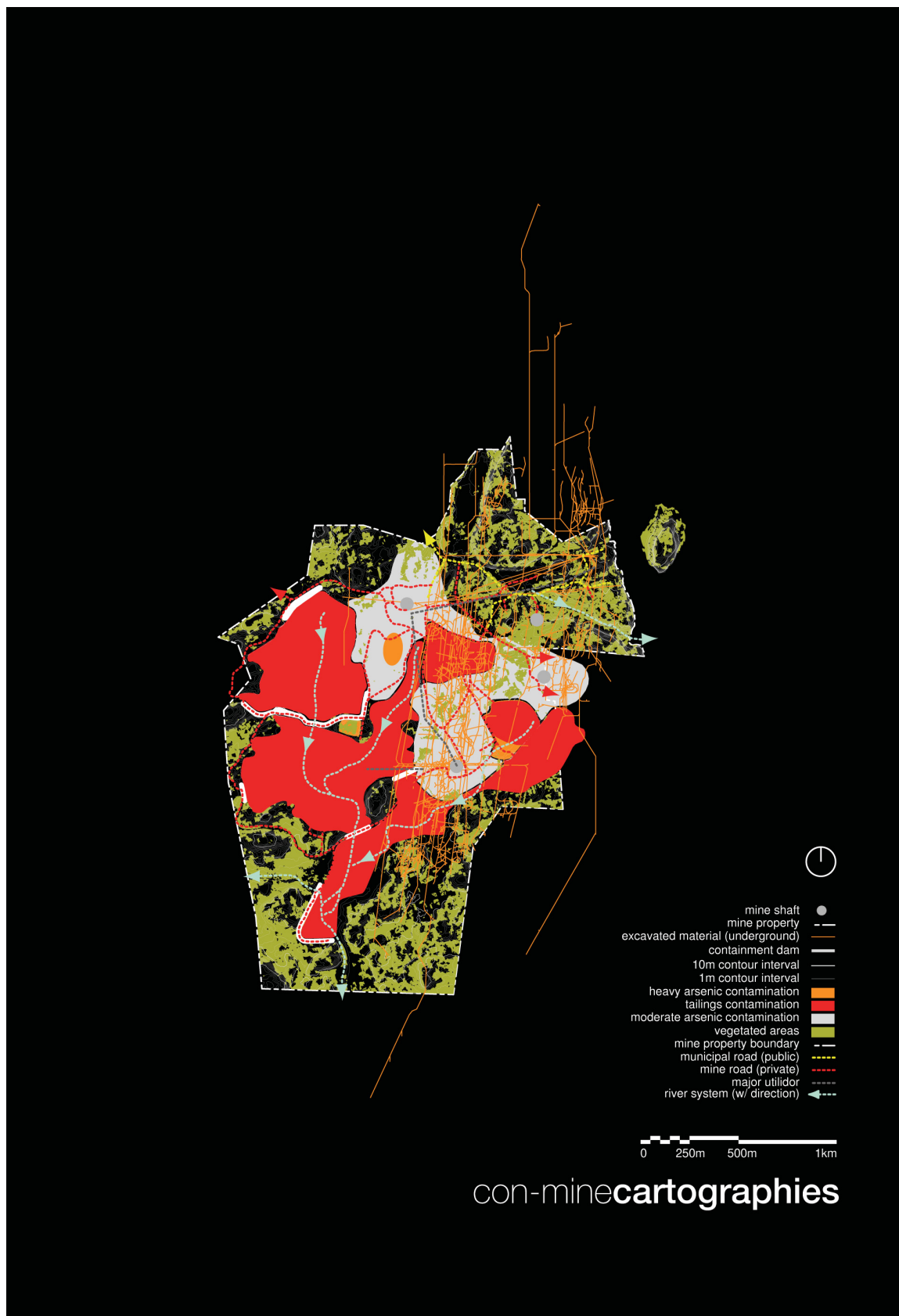


Composite overlay of Giant mine analysis.

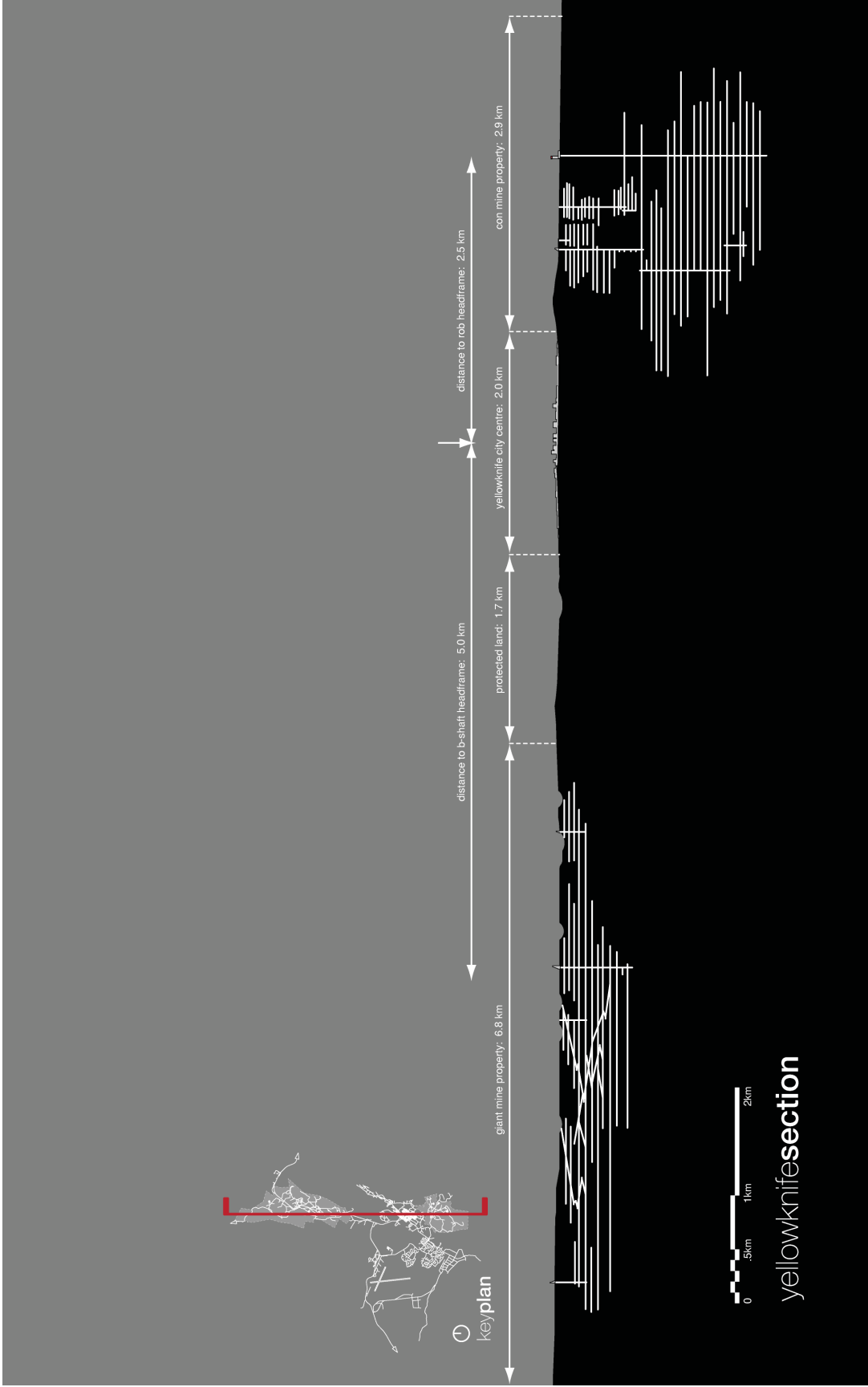


Analysis of the Con mine property including surface contours, hydrology, circulation, vegetative cover and contamination, along with subterranean and surface excavations and deposits.

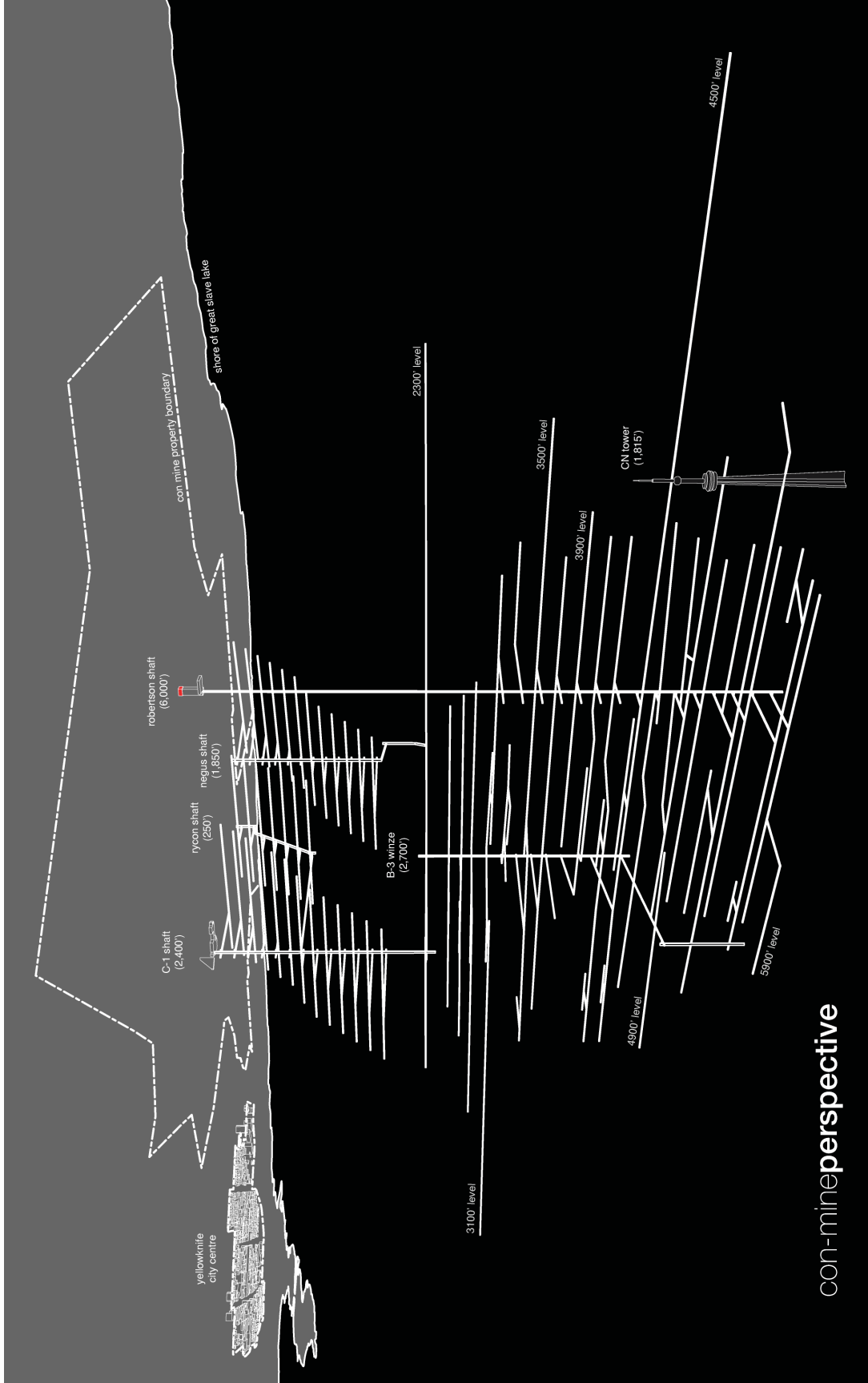
(created with data from *Miramar Con Mine, Ltd: Final Closure and Reclamation Plan*)



Composite overlay of Con mine analysis.



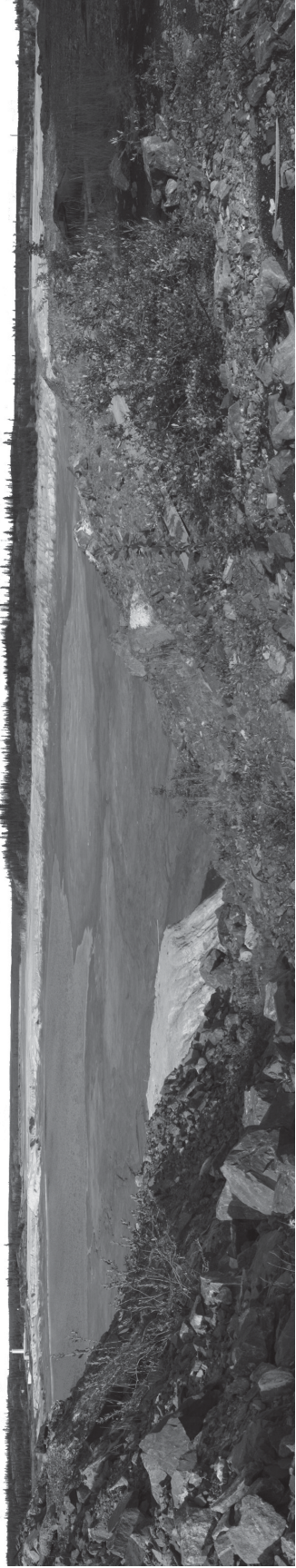
Section through the Yellowknife municipal area showing the extents of the subterranean voids at both Con and Giant mine. (created with data from Ryan Silke, *The Operational History of Mines in the Northwest Territories, Canada*)



Worms-eye view of subterranean working at the Con mine with the downtown core of Yellowknife beyond. CN Tower is present for scale. (created with data from Kirkham Geosystems Ltd and the Northwest Territories Geoscience Office)



Quarry at Giant mine property, summer 2011.



Tailing pond at Giant mine property, summer 2011.



Tailing pond and waste heap at Giant mine property, summer 2011.



Tailing pond and tailing treatment facility silos at Giant mine property, summer 2011.

Selection Justification



Aerial view of the Con mine property with Yellowknife city centre beyond, 2003
(from Nuna Logistics Ltd, photograph by John Zigarlick)

In order to manage the scale and complexity of the thesis exploration, it was decided that only one of the many mine properties surrounding Yellowknife would be the benefactor of a total re-envisioning. It is important to note however, that the strategies and considerations included in the following project intend to be prototypical in their application. There is no debate as to the cultural and historic significance of the Giant Mine property to the north of the city. Past labour disputes and accidents resonate indefinitely with Yellowknifers and mining alumni alike. Furthermore, it's relatively intact building stock, picturesque in it's condition, offer endless photo opportunities for passing visitors. With its vast manufactured landscapes of varying scale, configuration and complexity, the property could without doubt act as a comprehensive prototype for many of the abandoned mines located throughout Canada's north, regardless of typology or scale. Despite all of these factors however, it was decided that the Con mine would make a more appropriate demonstration project due mainly to one principle factor; its physical distance and presence from the city of Yellowknife. The proximity to the city makes for some interesting possibilities and complications, some of which will be explored fully in the resultant thesis project. Despite the fact that the Giant mine is currently being considered for the site of new residential development and a mining heritage centre, it is the belief of this author that the Con Mine presents far more valuable possibilities for the city of Yellowknife.

Site Analysis

Con Mine Site Overview

The Con mine property was originally shared by three separate mining operations; Rycon, Con, and Negus. Due to the fact that Con and Rycon were controlled by the same company, they were effectively considered the same producer, often referred to as the Con-Rycon Mine. These two production shafts shared a common townsite and milling operation at the C-1 shaft complex until the Rycon shaft ceased production in 1979 at which point its subterranean infrastructure was utilized for ventilation purposes only. All surface buildings were removed and today there is almost no visible evidence of the headframe and surrounding support buildings that once occupied the north-eastern portion of the property. The Con Mine continued operations until 2004, having expanded to include a second production shaft in the 1970's known as the Robertson shaft. The massive headframe still remains on the site, as does the adjacent administrative office and garage to its immediate south. The townsite slowly diminished as neighboring Yellowknife grew in the 1950's, with only a few residents remaining, and several historic buildings including a recreation hall and cookery slated for preservation. The nearby Negus mine was effectively run as an entirely independent operation until 1953, having its own townsite and milling operation until that point. From that time onwards, staff housing, processing and administration were all amalgamated with the Con mines facilities, though the Negus reserves proved to be fairly depleted by that point in time. Much of the Negus mine facilities and townsite were slowly demolished during concurrent remediation efforts throughout the 1970's and 80's. Like Rycon, the Negus shafts and tunnels were also utilized for ventilation purposes in the adjacent mine. Today the site of the shaft and processing plant is used as a gravel parking lot and repair garage for heavy machinery. As for the property's primary complex, the C-1 headframe, processing plant and auxiliary structures have all been removed, though foundations still mark the location of these facilities.²²

Over Con mine's 75 year history, more than 1.5km² of land have been used for the disposal of arsenic laden tailings. Sequentially, natural fresh water basins were used for disposal until maximum capacity was reached. Today, the seven original water bodies on the property

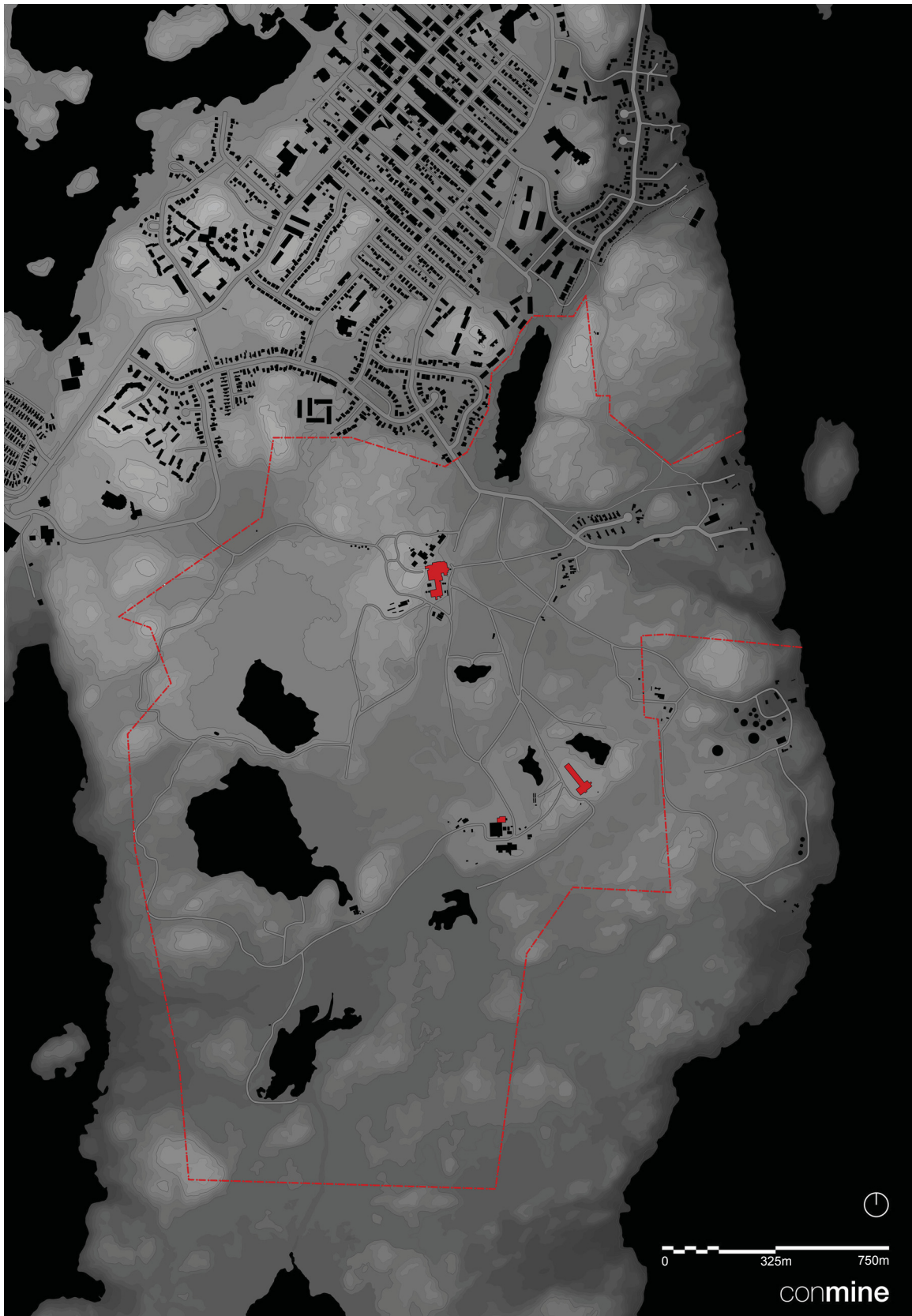
²² Miramar Mining Corporation, *Final Closure and Reclamation Plan*, 2-4.



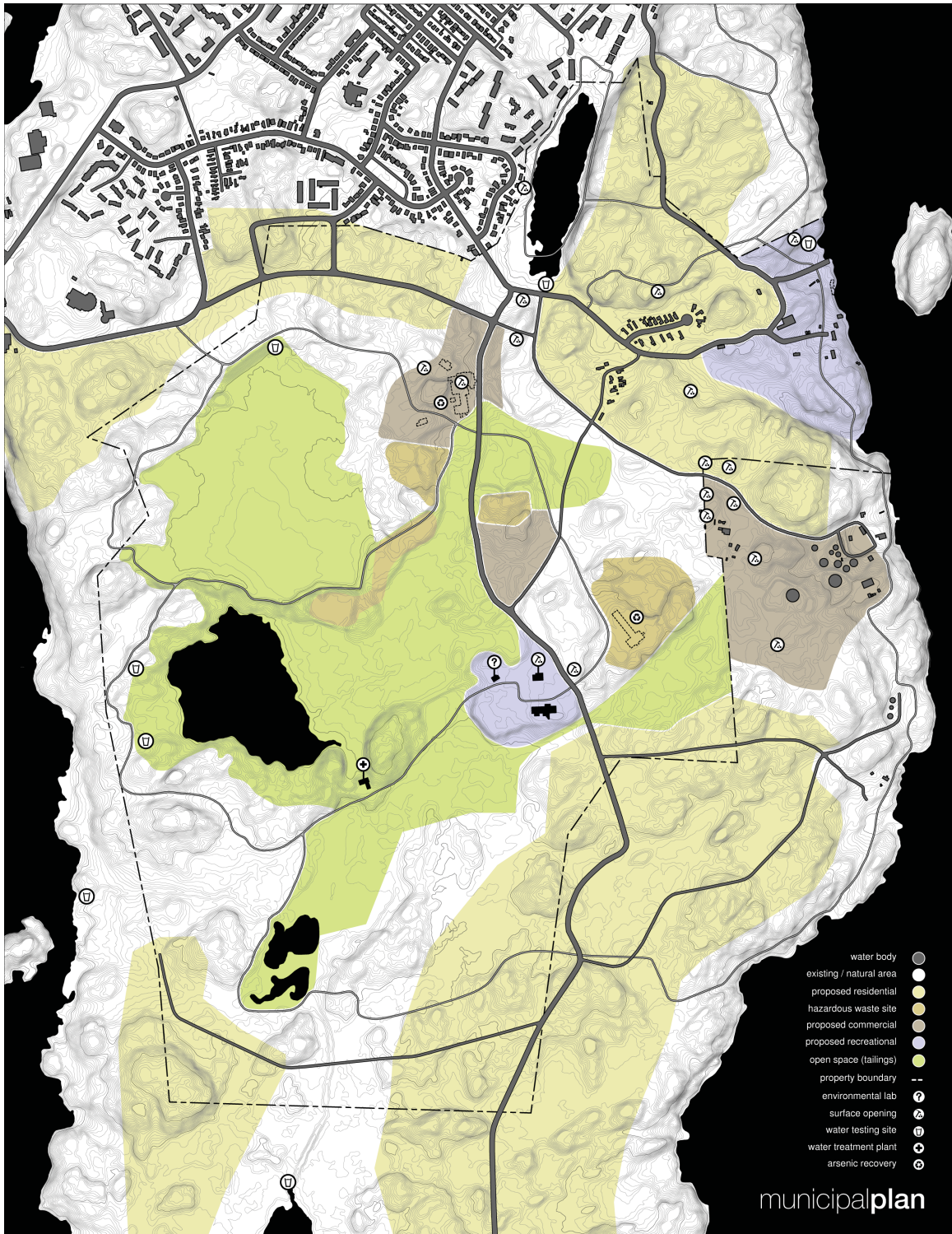
Aerial view of the Con mine's C-1 headframe and processing plant, with tailings ponds beyond (from City of Yellowknife Department of Public Works)

are now a unified, relatively flat basin of settled fine particulate. Though the majority of the area has long dried out and subsequently settled, the Middle Pud tailings containment area (TCA) is still very saturated due to its more recent use. Most of the surface water run-off is also directed to this portion of the site, further contributing to its shallow pool of water, estimated to be nearly 10m deep. The water collected in this pond is highly laden with arsenic, and very brackish due to the nature of the ore mined from below the surface. Current remediation plans call for the creation of "islands" on top of the tailings, consisting of coarse waste-rock piles covered in collected overburden from elsewhere on the site. This will subsequently be seeded yearly to encourage revegetation, and it is anticipated that the islands will eventually encourage the spread of vegetation over the remainder of the tailings surface. This entire zone will be fenced until vegetation occurs, at which point the ponds will be accessible for non-motorized recreational activities only, such as hiking. No development will be allowed to occur on the tailings for a considerable period of time.²³ In addition to the tailings ponds, there are four waste heaps currently situated on the property. All of these heaps are located over areas that historically contained leach pools of arsenic or mounds of calcines. These have been covered with construction and demolition waste from the closure of the mine and capped with coarse waste rock. Three of these mounds are non-hazardous, however the fourth is considered hazardous, and will be surrounded with large boulders to signify their danger.

²³ Ibid., 17-19.



Map of the Con mine property indicating boundaries, important structures and contour information. (created with data from the City of Yellowknife Department of Public Works)



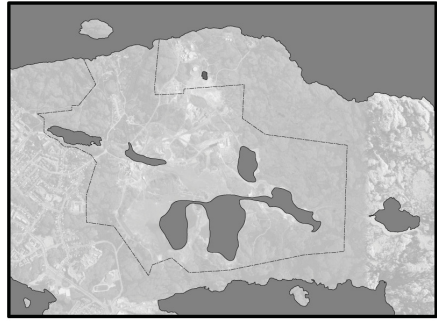
Current municipal plan for the Con mine property.
(created with data from the *City of Yellowknife Urban Design Initiative: Smart Growth Plan*)

Toxicity and Contamination

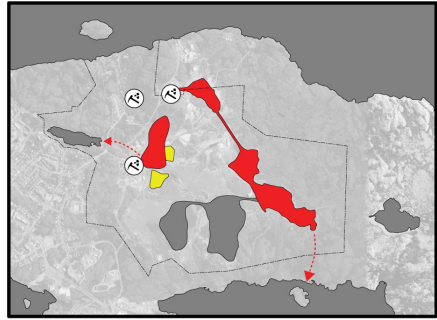
There are several major contributions to surface and subsurface contamination on and beneath the Con Mine property. Principally, surface "tailings" are the major contributing factor of environmental pollution on the site to date. To define the term in greater detail, "tailings" are the material left over after the process of separating valuable minerals from the non-valued portions of an ore-body. Due to the fact that a large portion of the ore beneath Yellowknife is of a "refractory" nature, major processing needs to be conducted in order to separate the gold from the rock it is contained within. This is typically achieved with a large quantity of chemicals, much of which is released with the waste rock after processing. Due to the fact that the majority of ore in the Yellowknife region is of the Arsenopyrite variety, this also means that a large quantity of arsenic is present in the waste material.²⁴ Consequently, tailings at the Con mine property are highly toxic due to the extremely high level of arsenic present within them. Distribution history also plays a large role in the varying toxicity of the six tailing containment areas (TCA's). Prior to the invention of more environmentally friendly pressure oxidization (or autoclave) technology in the 1960's, refractory ores were traditionally treated by high-temperature roasting which produced by-products such as arsenic sludge and calcines.²⁵ Although these concentrated waste products were stored in concrete-lined hazardous waste ponds throughout the site, their subsequent tailings were also of greater hazard than more recently disposed waste-rock. As a result, this means that earlier, or "historic TCA's" as they are termed, have a greater toxicity than more recent areas. Historic TCA's include the Negus, Neil Lake, Crank Lake, and Lower Pud Lake areas. More recently, the Upper Pud TCA reached full capacity in 2004 and the Middle Pud TCA is still being used to store treated waste rock during remediation efforts.

²⁴ Ibid., 8.

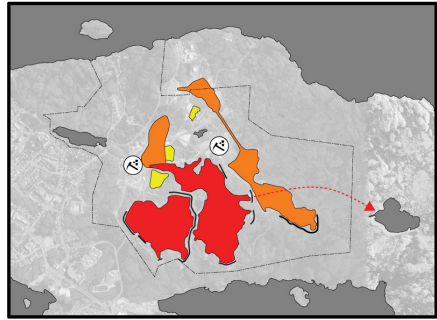
²⁵ Ibid.,11-13.



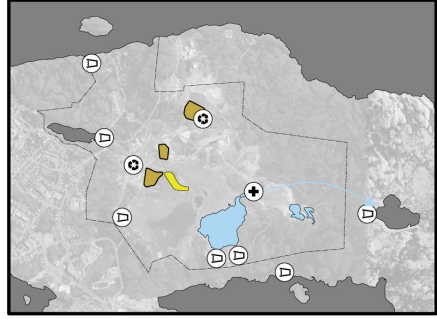
pre-mine



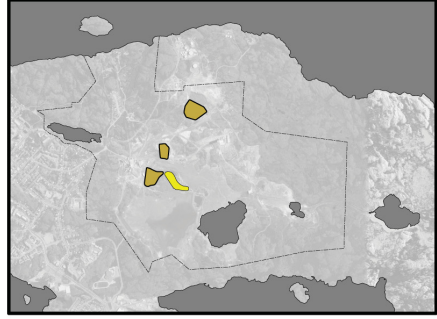
early mine production period
(1940 s)



major mine production period
(1970 s+)



remediation / monitoring period
(2000 s - 30 s+)



post remediation / monitoring



tailings-pond development

Con mine tailing distribution history.
(created with data from *Miramar Con Mine, Ltd: Final Closure and Reclamation Plan* and City of Yellowknife Department of Public Works)

Natural and Artificial Landscapes

The landscape throughout and surrounding the Con mine property is a fascinating combination of natural and artificial landforms. Due to the fact much of the Yellowknife area is covered with very consistent flora and surficial geology, the massive artificial landforms associated with mining stand in stark contrast to that of the natural environment. As subsequent drawings will illustrate, there are three typical ecological zones that surround and partially occupy the Con mine site: exposed bedrock with minimal vegetative cover, stunted Taiga forest, and wetland "muskeg" (also known as peat bogs). Surprisingly, a large number of large mammals have been known to wonder through the property including black bears, moose, wolves, fox, and coyotes. Due to heavy contamination and backfilling of the water bodies on the site, few fish species occupy the ponds and streams on the mine property, however surrounding lakes are still well stocked with fish species despite elevated levels of arsenic present in the water. In terms of artificial landforms, there are four major typologies present on the site, in addition to the large tailings deposits referred to earlier in this chapter. The first of these are open-pit quarries. Though heavy surface mining was conducted at the Giant mine operation, all mining was conducted underground at Con. However, recent remediation efforts that include capping TCA's with gravel, have required the quarrying of locally available bedrock. This has been done at three locations throughout the property in order to minimize transportation of the rock to various TCA's spread around the site. Another artificial landform common to the Con mine are large deposits of waste rock from early shaft-sinking operations. These piles of relatively uncontaminated rock were deposited near the locations of the various shafts around the site, and most act as large foundation pads for buildings. Thirdly, hazardous and non-hazardous waste piles occupy several areas surrounding the C-1 and Robertson complex's. These piles exist where hazardous chemicals such as calcine and arsenic were stored, or where demolished structures and mining equipment were deposited. As removal of these materials and chemicals proved too costly, they were simply covered with geotextile membranes and waste rock in-situ.²⁶ Lastly, open drainage culverts are currently being constructed throughout the site in order to direct surface run-off towards the Middle Pud pond and water treatment facility.²⁷

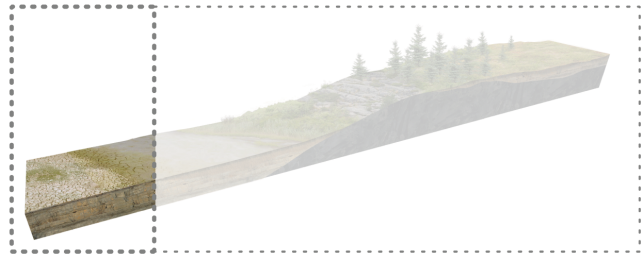
26 Ibid., 53-54.

27 Ibid., Figure 5.8.

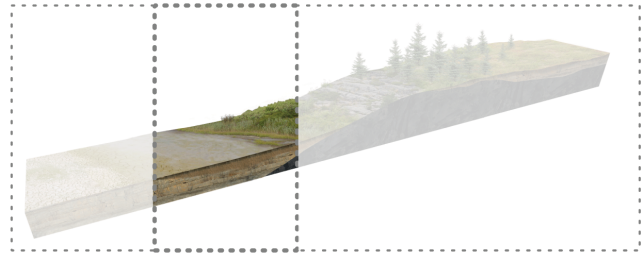


Study of the Con mine's various ecological zones.
(base image from City of Yellowknife Department of Public Works)

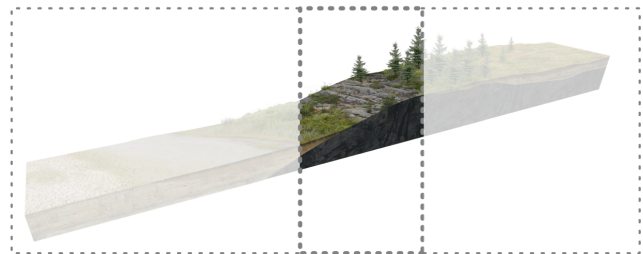
● Non-Natural (Human Development)



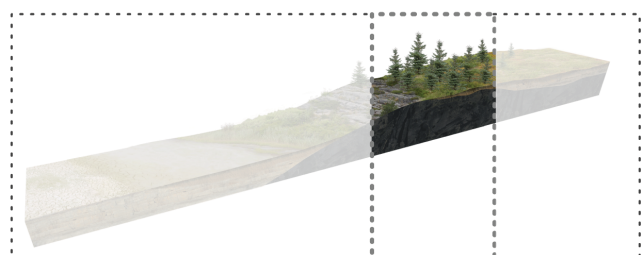
● Water Body / Linear Riparian



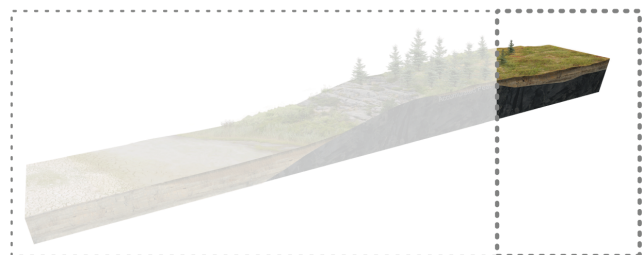
● Canadian Shield Outcropping



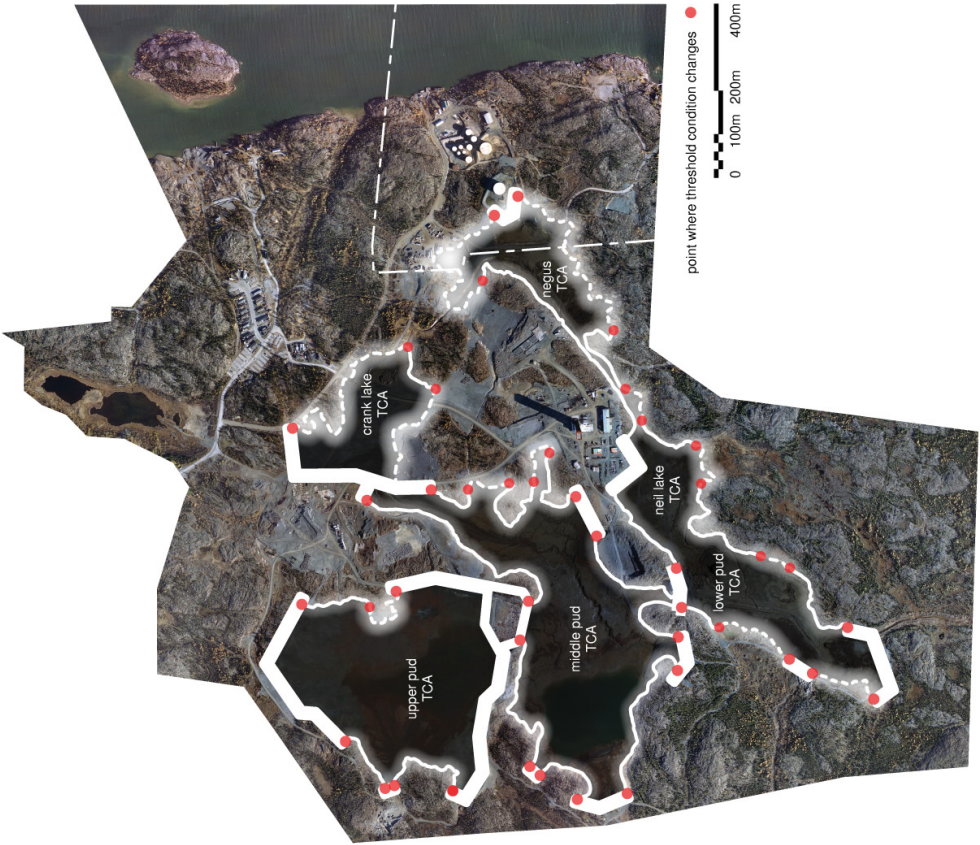
● Taiga Forest (Stunted)



● Muskeg (Peat Bog) w/ discontinuous permafrost

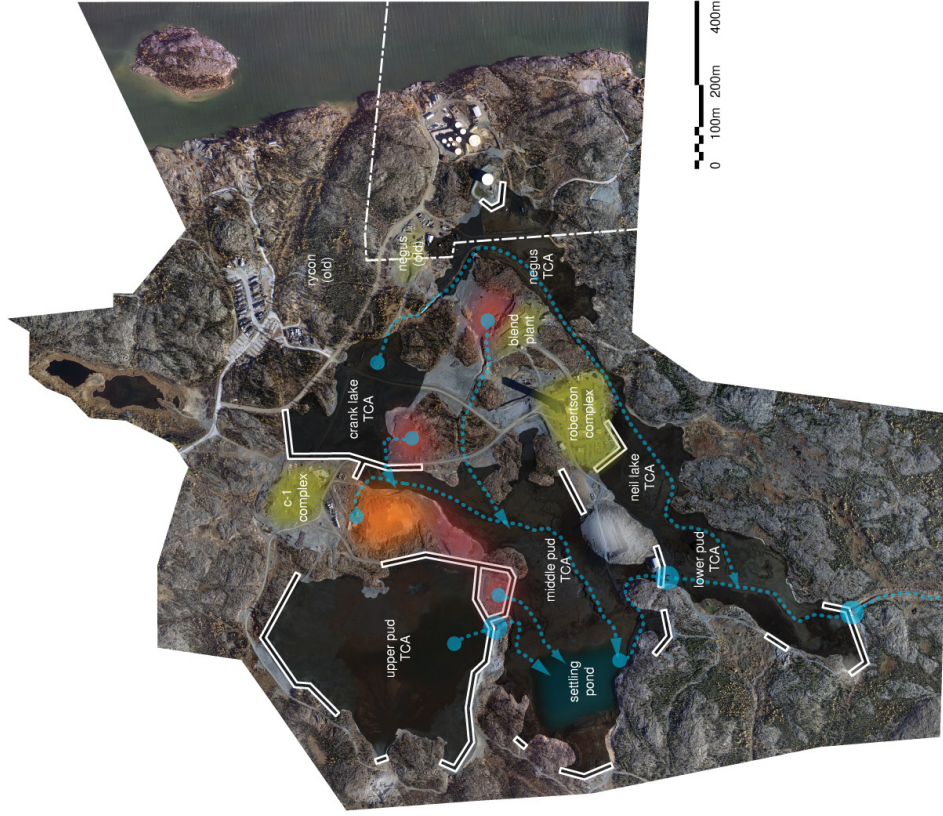
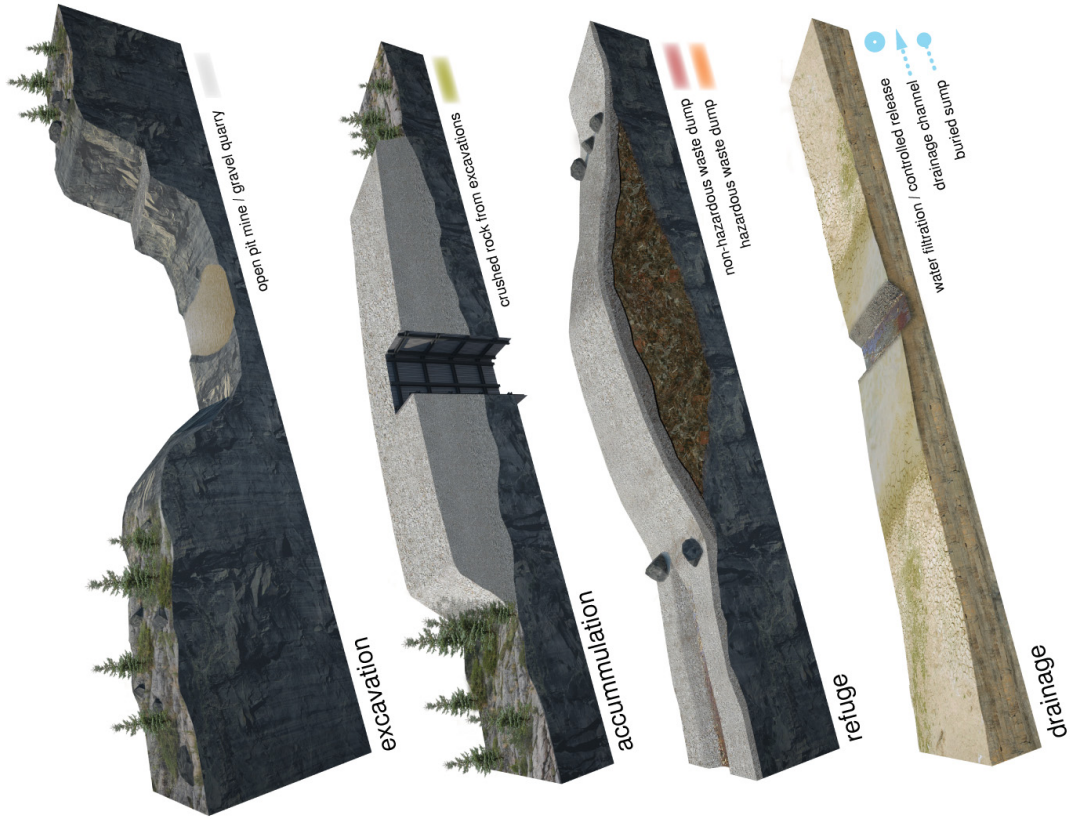


Study of the Con mine's various ecological zones. (continued)



threshold conditions

Study of the various threshold conditions around the perimeter of Con mine's six historic tailing containment areas (TCAs).
(base image from City of Yellowknife Department of Public Works)

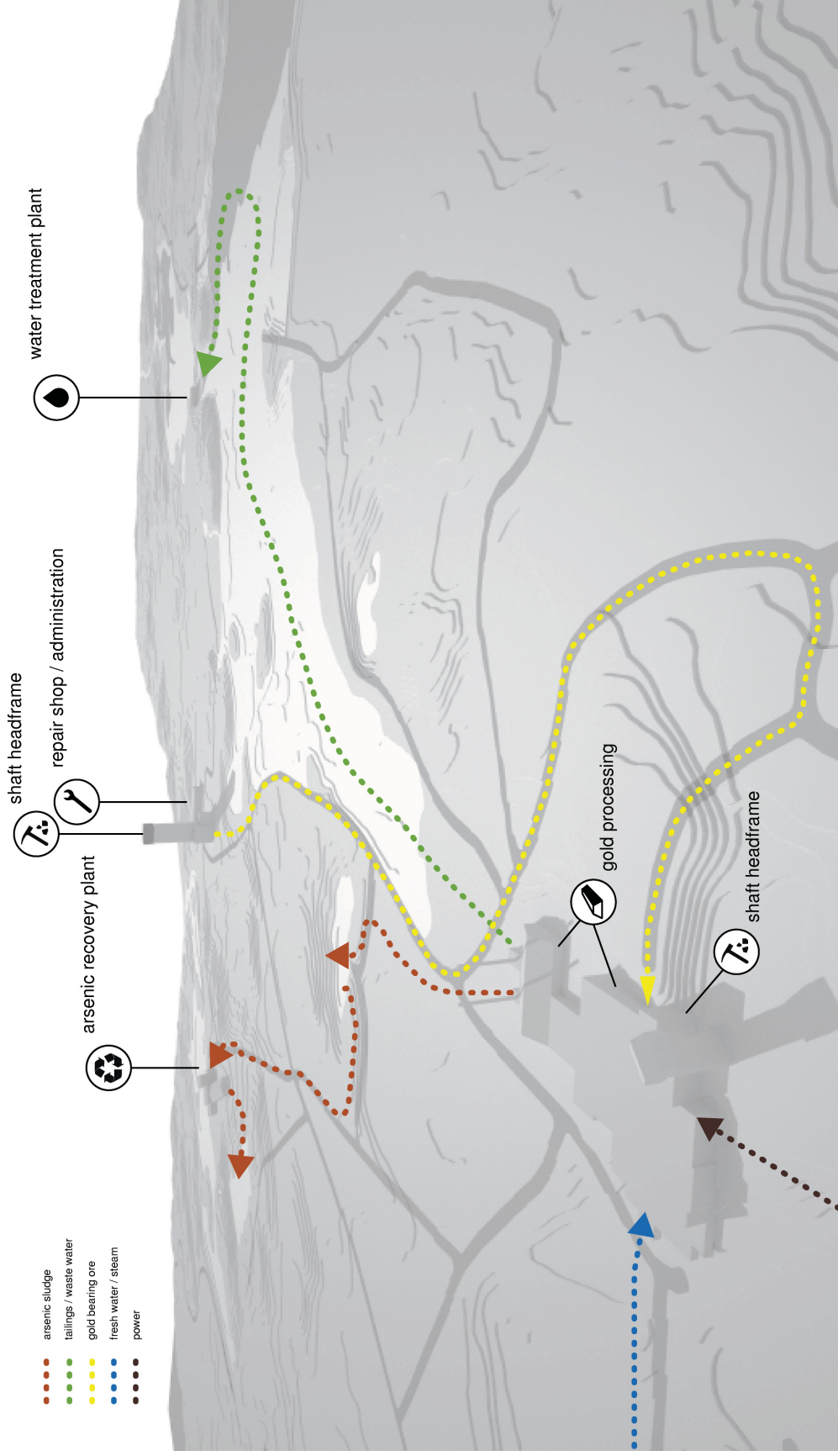


manufactured landforms

Study of the various manufactured landforms present throughout the Con mine property. (created with data from Miramar Con Mine, Ltd: Final Closure and Reclamation Plan / base image from City of Yellowknife Department of Public Works)

Programmatic Context

It is of critical importance to the thesis exploration that new interventions on the Con mine property be respondent to historical context. By programming new uses of the site in a similar way to those of historic relevance, it will make the history of the place far more relevant and tangible than a museum or interpretive display could ever hope to be. Thus, a great deal of analysis was undertaken in regards to understanding former processes and activities on and within the site and its buildings. The following section aims to document and distill the ways in which the Con mine operated over its 75-year history.



Operational processes of the Con mine surface facilities. Gold bearing ore was extracted from the Robertson and C-1 shafts, transported to the C-1 mill, processed, and then waste materials were deposited to the TCA's. Hazardous waste materials were deposited at the calcine and arsenic ponds or the arsenic blend plant depending on the era. Heat and power for the mining operations were delivered from the Slave Lake boiler complex or the Bluefish hydro dam depending on the era.

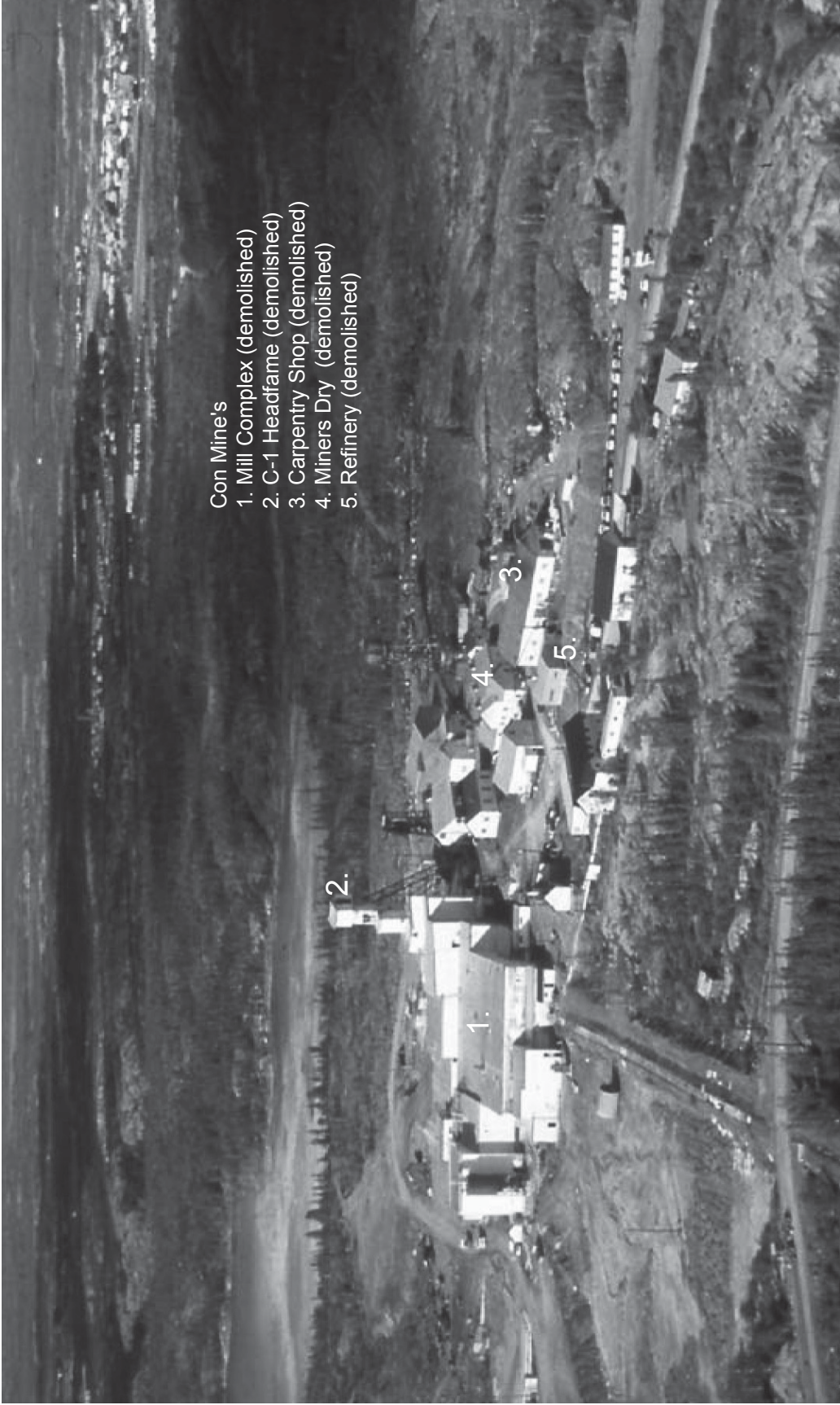
Existing Building Analysis

The Con mine property currently contains two areas with existing building stock, or parts there-of. As mentioned earlier, these areas are the C-1 mill complex and the Robertson complex, both of which will be analysed for their historic evolution, architectural merit, and programmatic relevance.

The C-1 Mill Complex

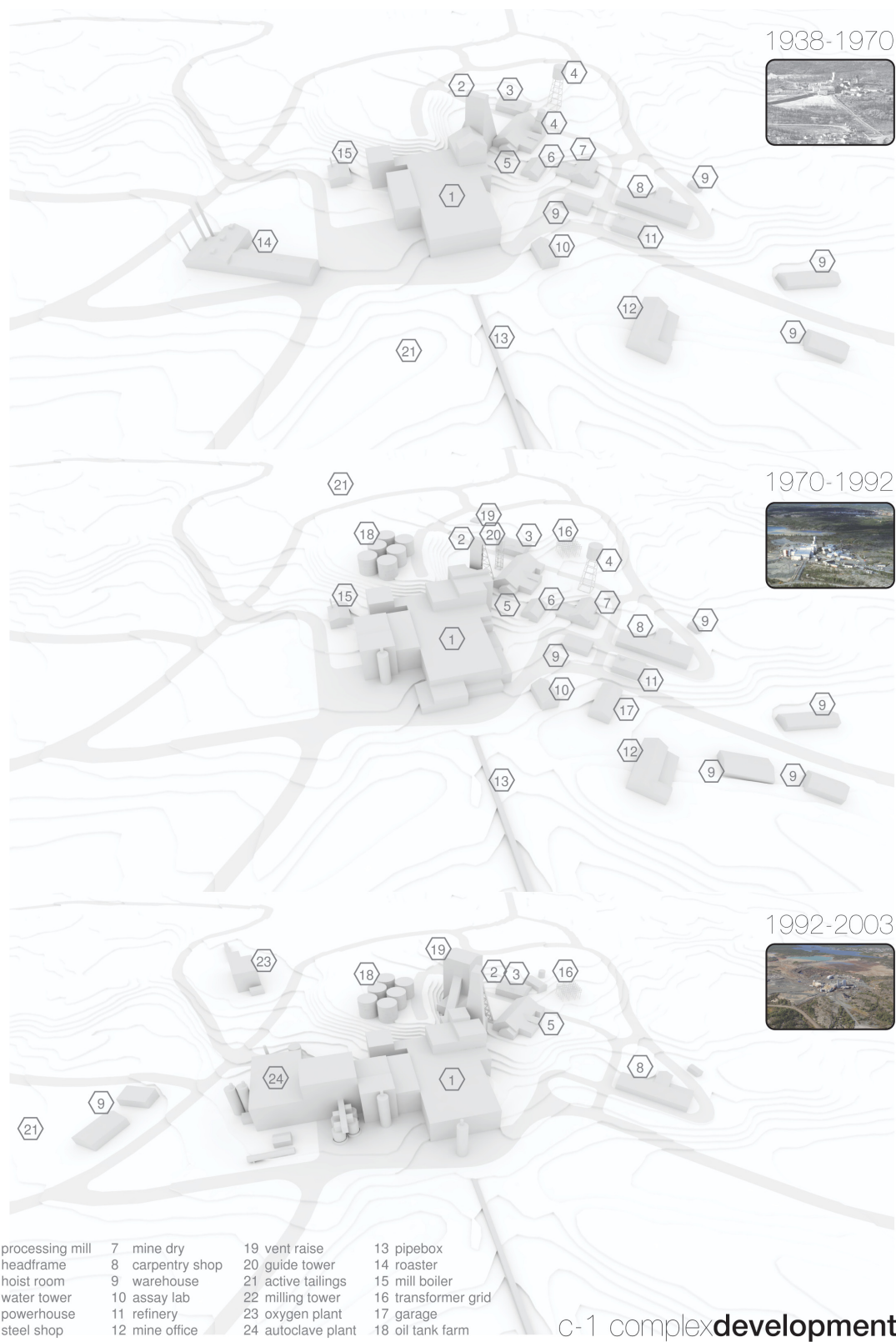
The C-1 mill complex was one of the first permanent mining structures to take shape in the Yellowknife region. In the mid 1930's, during its original construction, the complex included the mine's first production shaft and the region's largest ore-processing mill. The mill is located at the northern extent of the site near its primary access from the city of Yellowknife. The mill building has evolved quite significantly over 75 years of mining operations, but essentially it has included crushing and grinding circuits, flotation and agitation tanks, a roaster and bag house, and more recently, an autoclave. Though originally of wood frame construction, most of the mill is now comprised of structural steel framing with metal cladding due to numerous additions and renovations over its lifespan. Other buildings associated with the mill were once located in close proximity, and include warehouses, shops, offices and laboratories.²⁸

28 Ibid., 21.

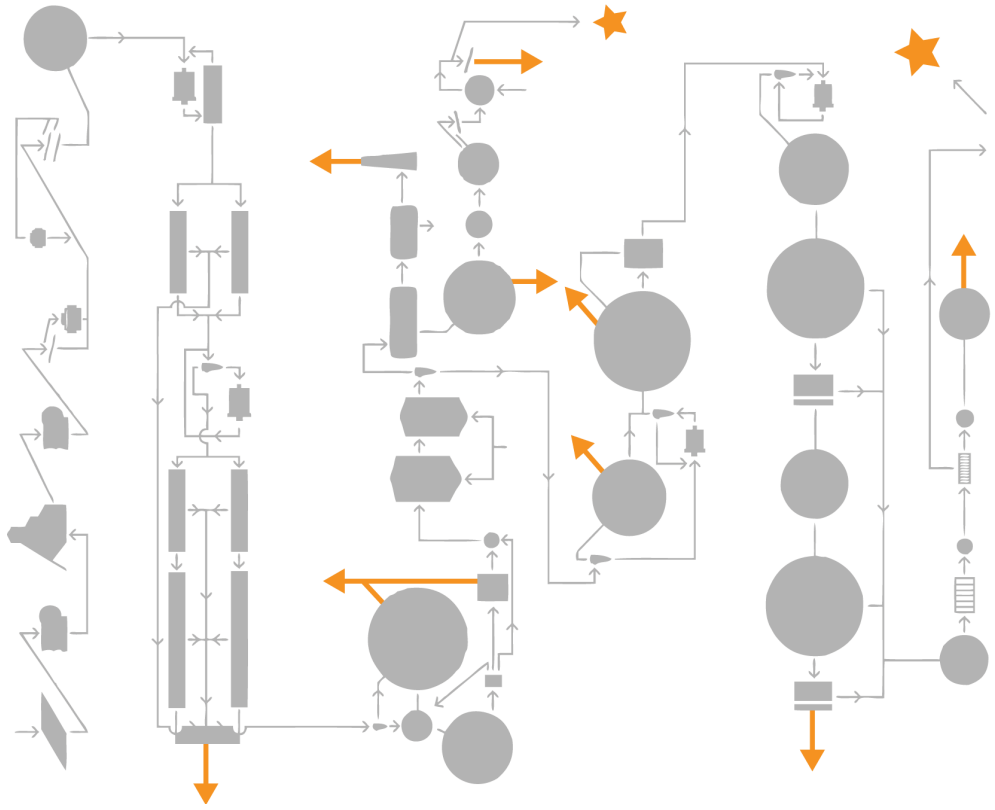


- Con Mine's
1. Mill Complex (demolished)
 2. C-1 Headframe (demolished)
 3. Carpentry Shop (demolished)
 4. Miners Dry (demolished)
 5. Refinery (demolished)

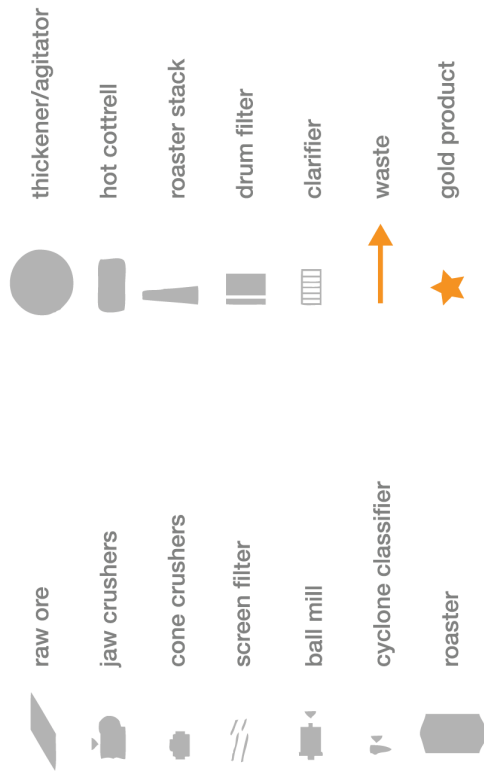
Buildings at the Con mine C-1 mill complex. (from Prince of Wales Northern Heritage Archives)



Historical development of the C-1 mill complex, 1938-2003. (created with information from the Prince of Wales Northern Heritage Archives, City of Yellowknife Public Works Department, and Ryan Silke, *The Operational History of Mines in the Northwest Territories, Canada.*)



extraction waste **crushing**
grinding waste **flotation**
fluo waste **solids-roasting** waste **carbon-treatment**
cal waste **cine-washing** waste **calcine-cyanidation**
precipitation waste **refining**



Typical milling circuit for a gold mining operation in the 1960's.
 (created with data from Ryan Silke, *The Operational History of Mines in the Northwest Territories, Canada*)

The Robertson Complex

The Robertson Headframe

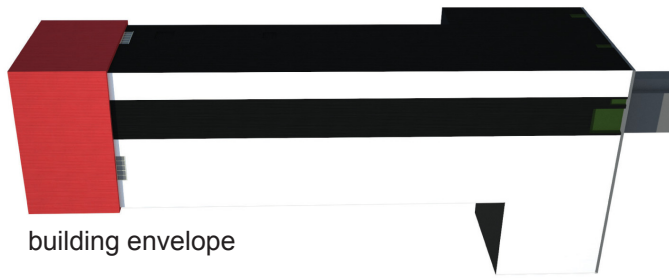
The Robertson headframe is a 76 metre tall steel framed structure that dominates the skyline of the city. Standing taller than any other building in the territories, the headframe is highly respected by boaters and pilots alike due to its ability to help navigate the difficult waters and dangerous skies of the Yellowknife region. Originally built in 1977, the headframe was completed as part of modernization efforts at the Con mine, undertaken to extend the life of the operation well into the future. Due to this considerable depth, a cutting edge Koepe Hoist was imported from Germany and is located at the uppermost level of the headframe, over 60 metres above the ground. The hoist, controlled by an operator in an adjacent booth, facilitated the vertical movement of ore and men in balance, and could hoist 34 men or 15 tons of ore top-to-bottom in roughly 2.5 minutes.²⁹ Below the hoist floor, 6 intermediate floor plates housed deflector sheaves, electrical, cooling and ventilation equipment, and back-up generators for the underground workings. These floors were rarely inhabited by employees, as only the ground level ushered equipment, ore and men to and from the workings below. A single 2-man lift serviced the hoist operator to and from the uppermost level of the tower, where only 3 small windows illuminated the large open space around the hoist.

²⁹ Outcrop Communications Ltd, *Robertson Headframe Pre-Feasibility Study* (Yellowknife, NT: Outcrop Communications Ltd, 2009), 4.



Con mine's Robertson complex
1. Robertson Headframe
2. Administration and Repair Building
3. Arsenic Plant
4. Miners' Dry (demolished)

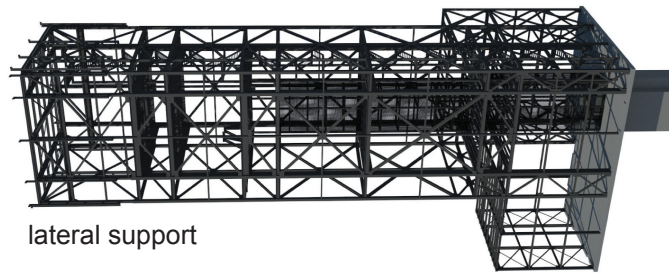
Building's at the Con mine Robertson complex.
(photograph from *Robertson Headframe Pre-Feasibility Study*)



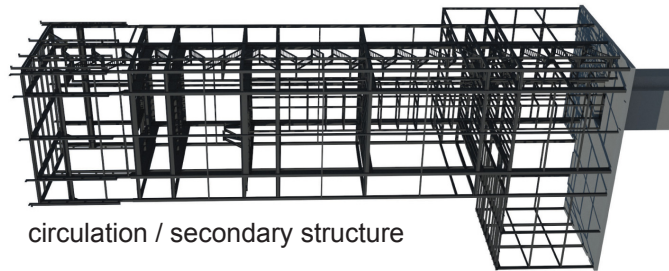
building envelope



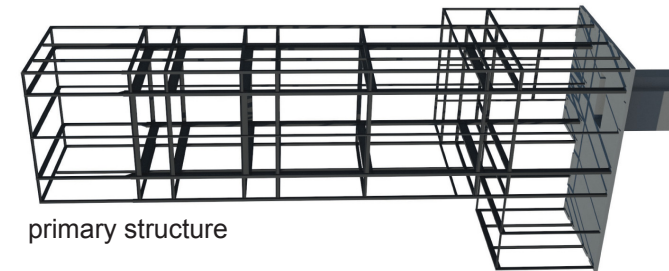
flooring / equipment / tertiary girts



lateral support

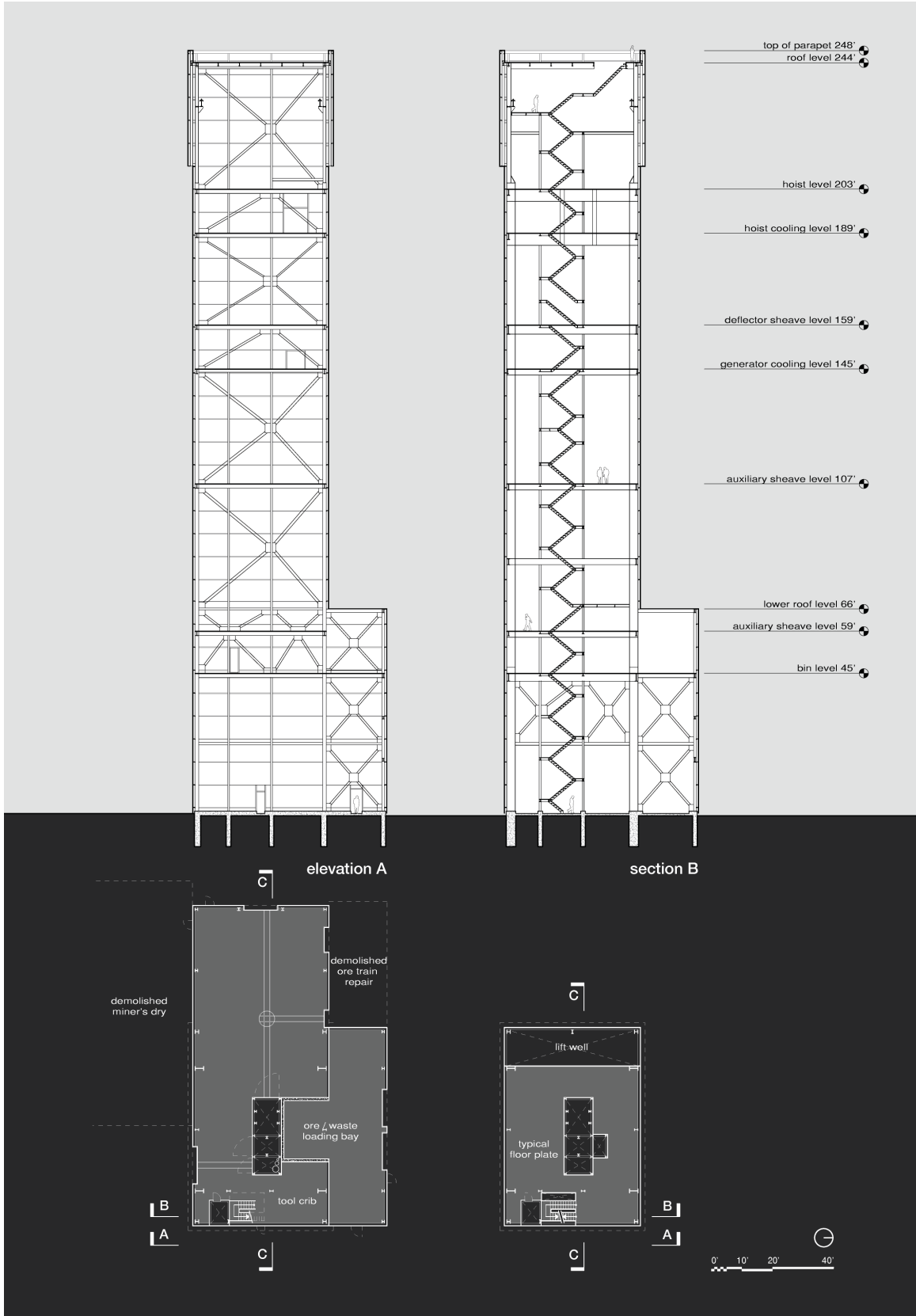


circulation / secondary structure

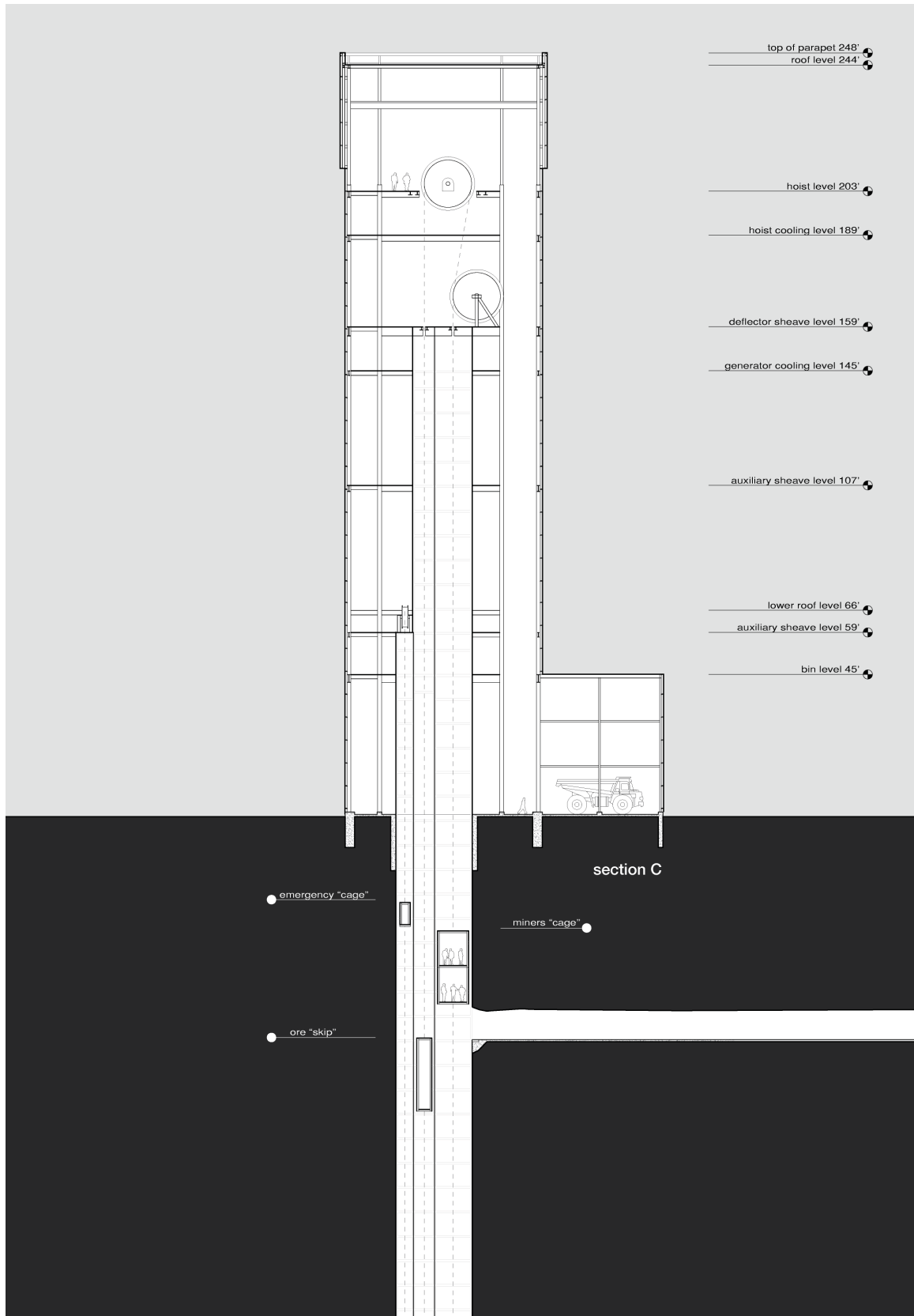


primary structure

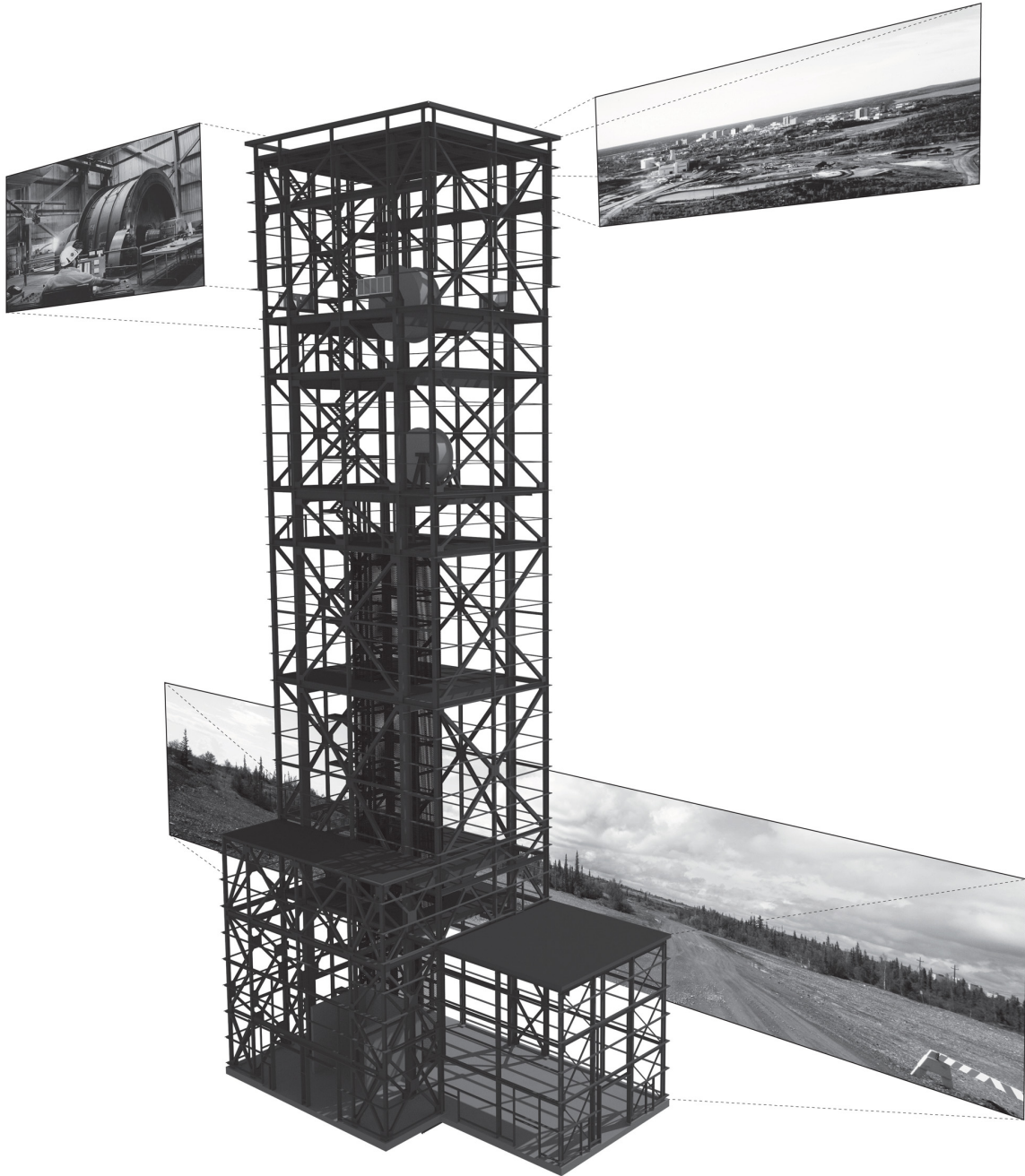
Structural analysis of the Robertson headframe.
(created with information from Miramar Mining Corporation)



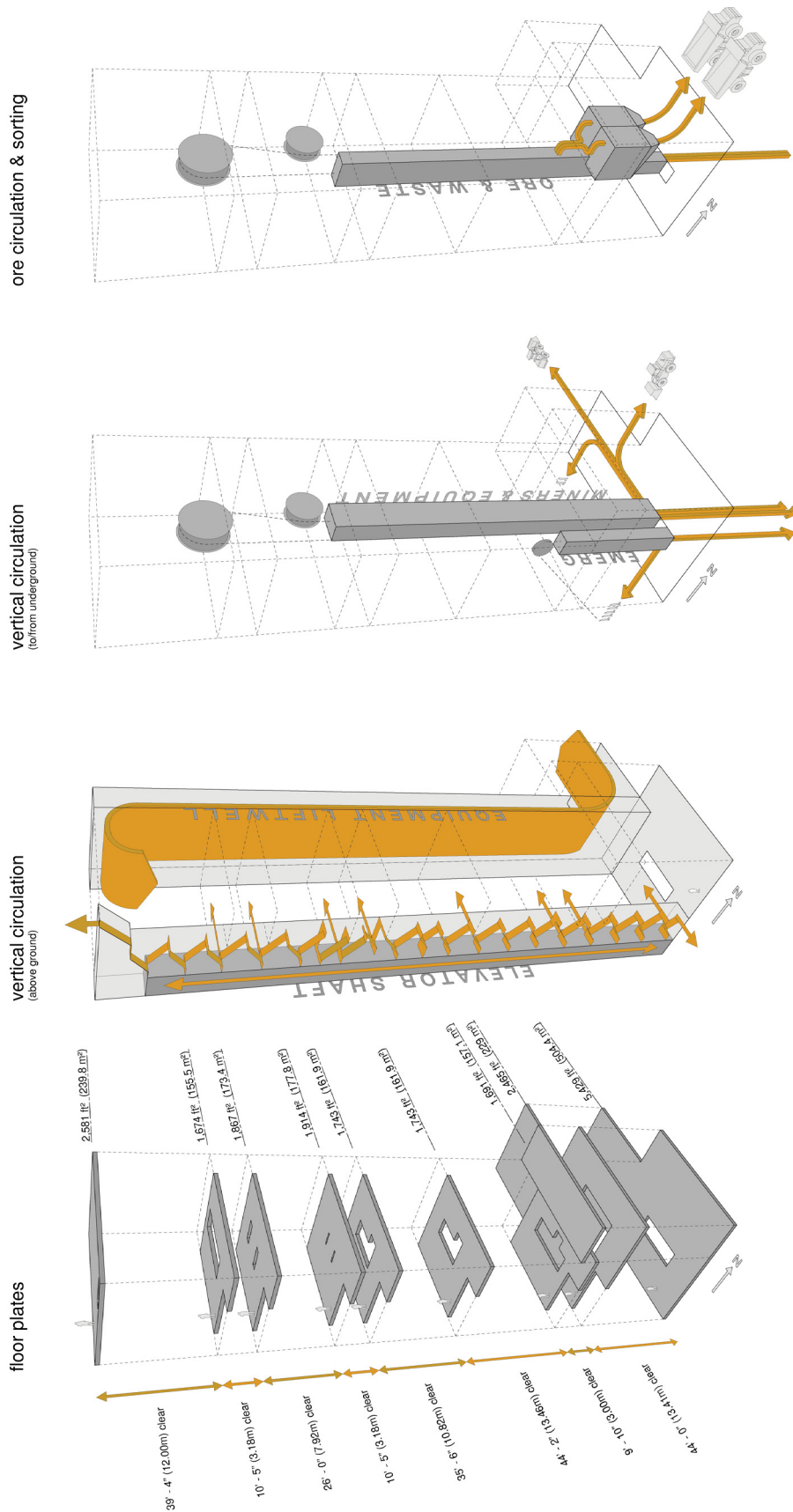
Sections and corresponding floor plans for the Robertson headframe.
(created with information from Miramar Mining Corporation)



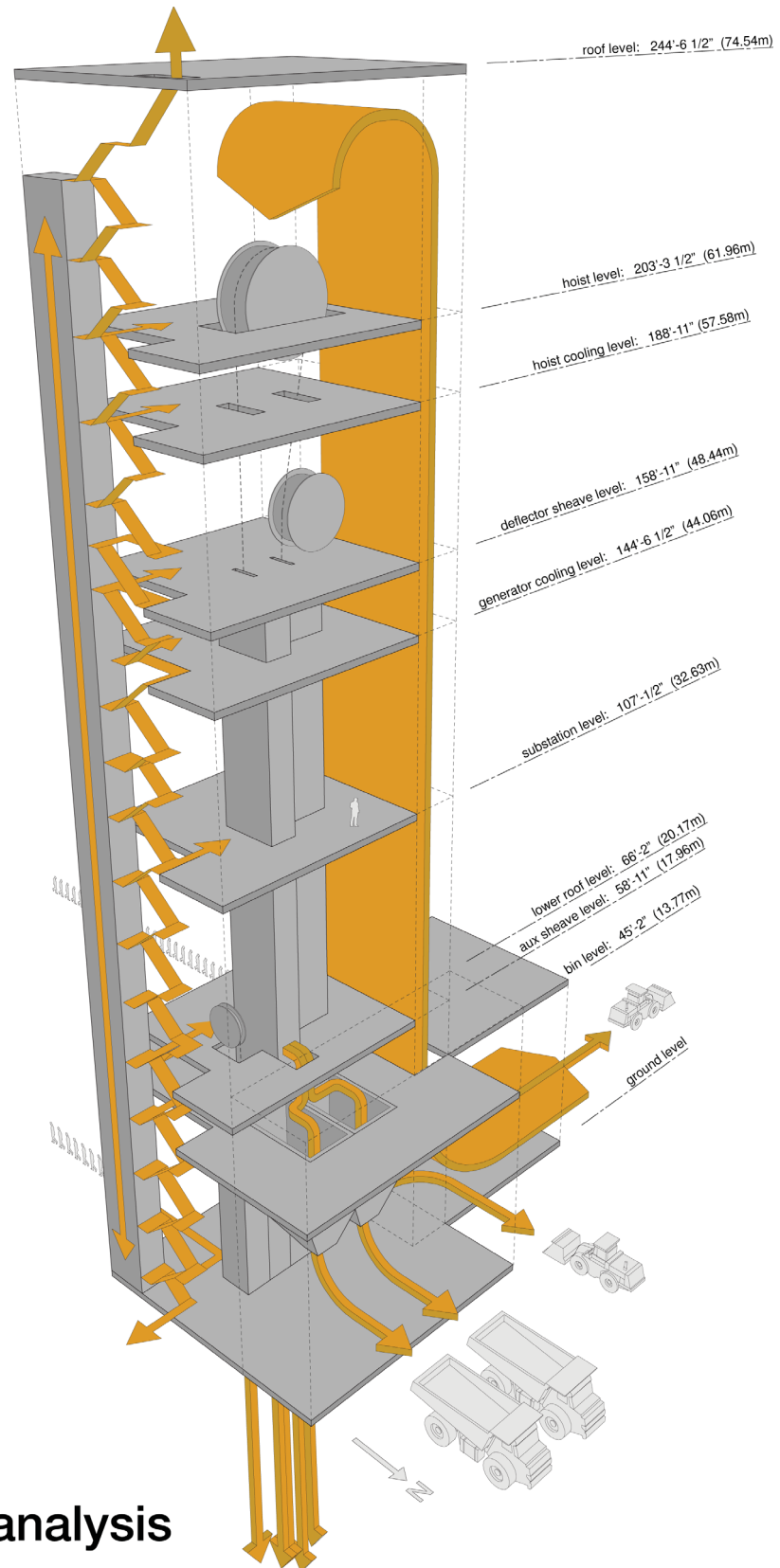
East-west section through the central shaft and skip tower of the Robertson headframe.
(created with information from Miramar Mining Corporation)



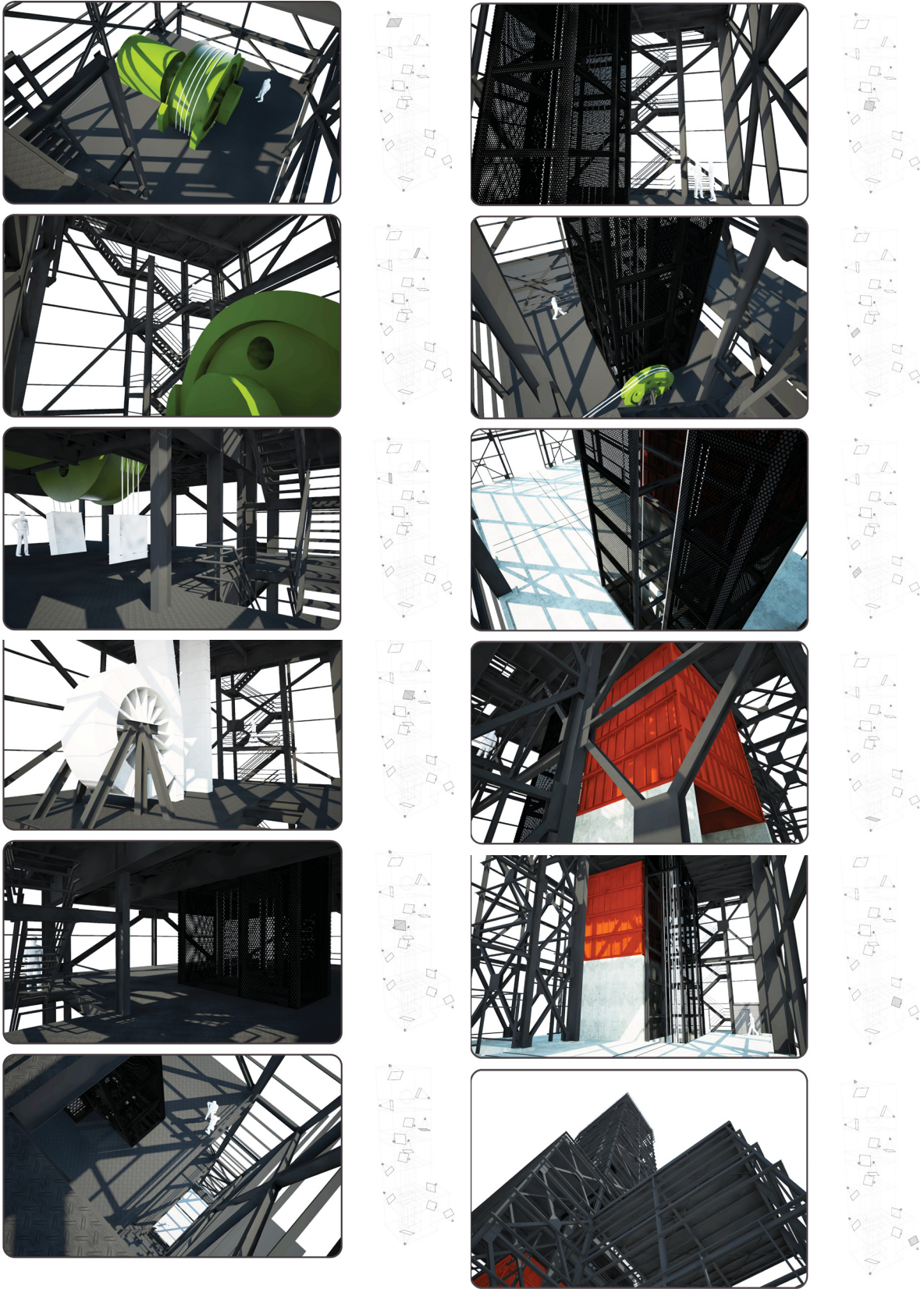
Study of headframe view-planes.
(created with information from Miramar Mining Corporation)



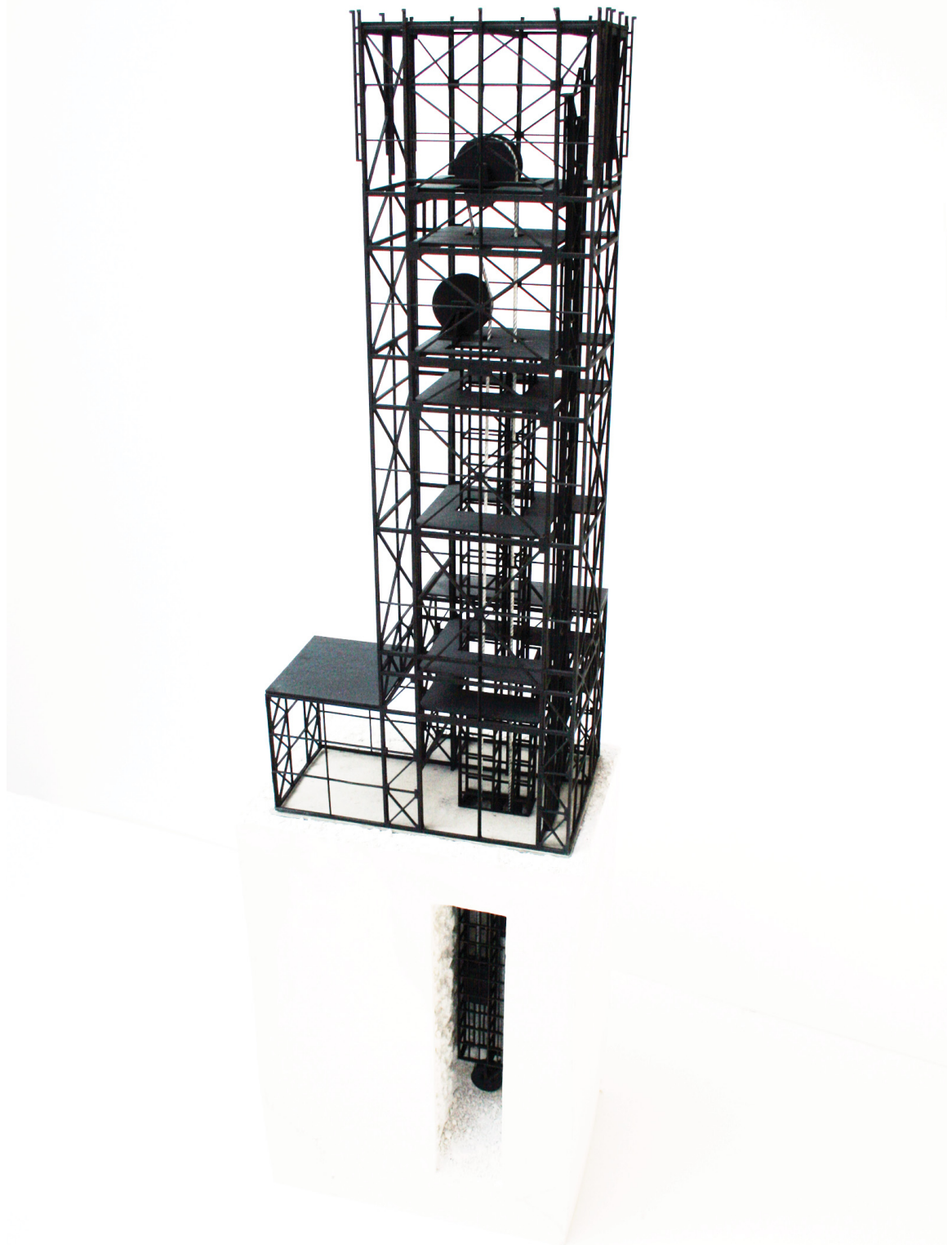
Operational analysis of the Robertson headframe.



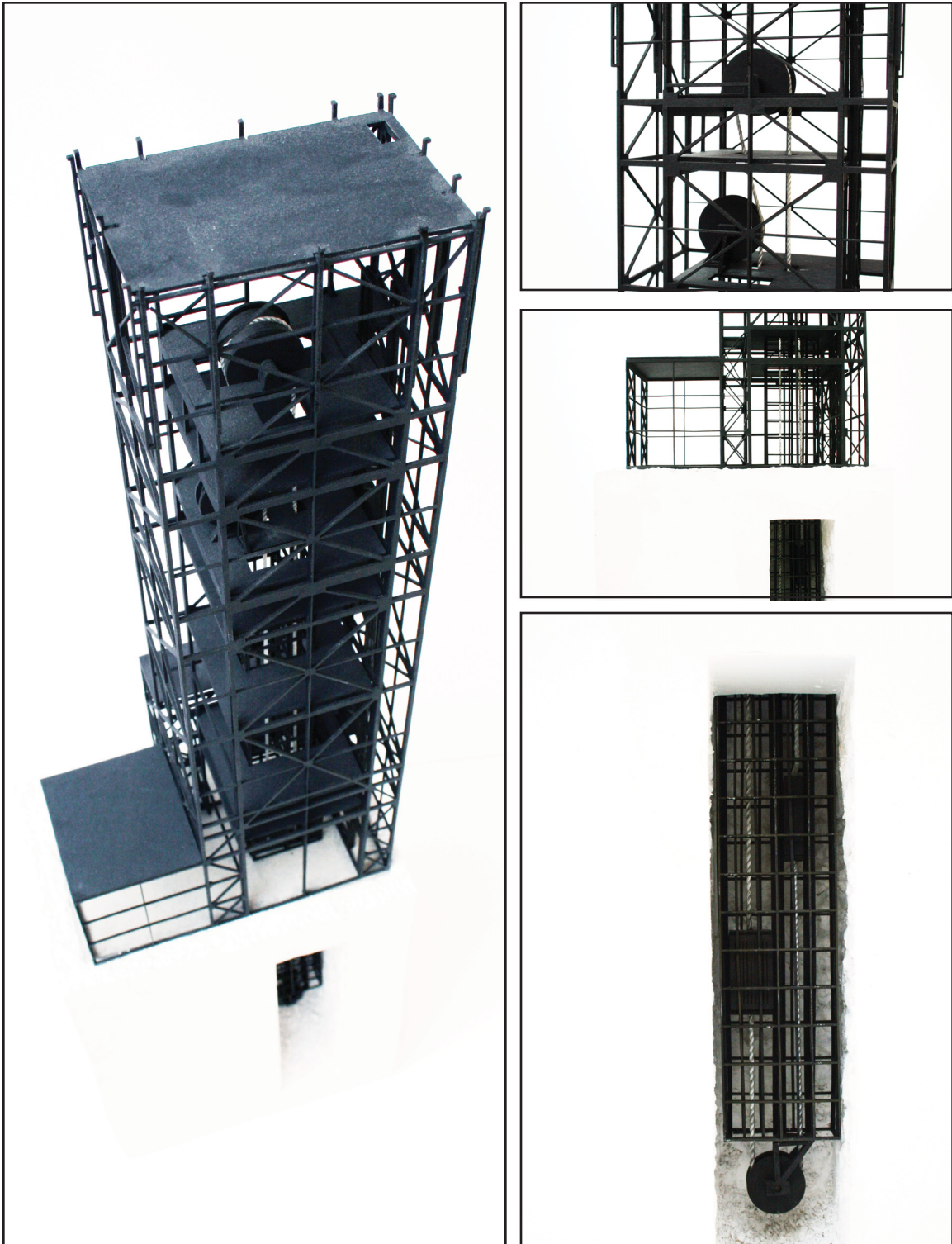
Operational analysis of the Robertson headframe. (continued)



Spatial analysis of Robertson headframe.



Physical model of the Robertson headframe and shaft with working hoist mechanism.

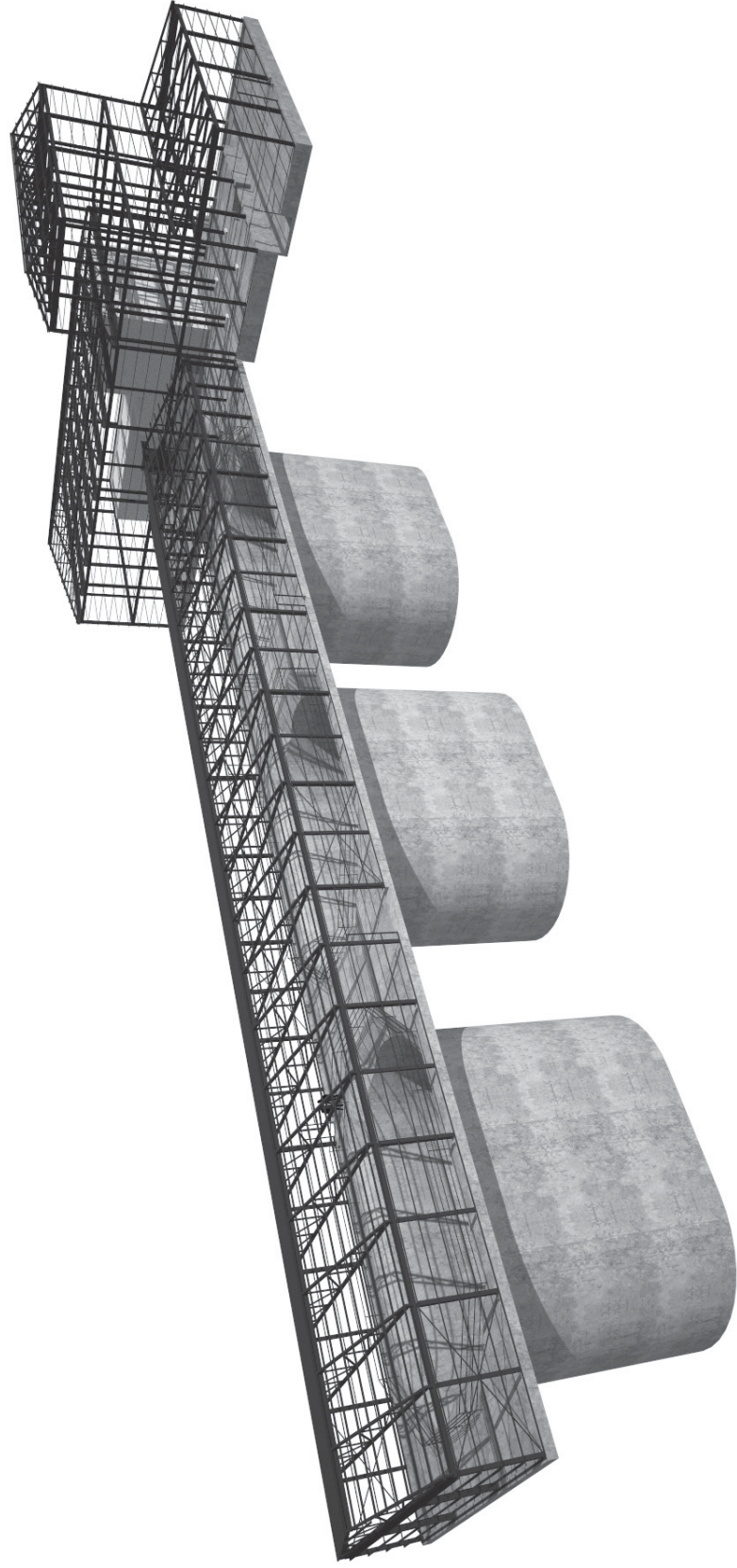


Physical model of the Robertson headframe and shaft with working hoist mechanism.

Arsenic / Blend Plant

This structure is located roughly 250 metres east of the Robertson headframe and was constructed in 1982 for the purpose of re-processing arsenic sludges from the C-1 mill complex. The initial intention of the facility was to recycle arsenic trioxide sludges from the Negus and Con ponds into high quality arsenic trioxide for use as a wood preservative in the lumber industry. After operating for six years at an economic loss, it was determined that the facility was no longer feasible to operate. Three years later, the arsenic plant was converted into a reclamation facility to assist in ongoing sequential reclamation activities. The three large pits excavated out of the bedrock and covered with shot-crete, were used to blend and settle stockpiled calcines and arsenic-contaminated sludge from over twenty years of roasting at the C-1 mill complex. The facility was used until 2007 when the last of all hazardous sludges and calcines were treated in the mill's autoclave. The structure is of light steel frame assembly with a concrete slab-on-grade foundation. A large overhead crane services the three pits, tracking back and forth through the facility to move large amounts of material between storage areas. Currently, the steel structure of the building is slated for removal and the foundation is scheduled to be filled and capped with waste rock in a similar method to that of the hazardous waste piles.³⁰

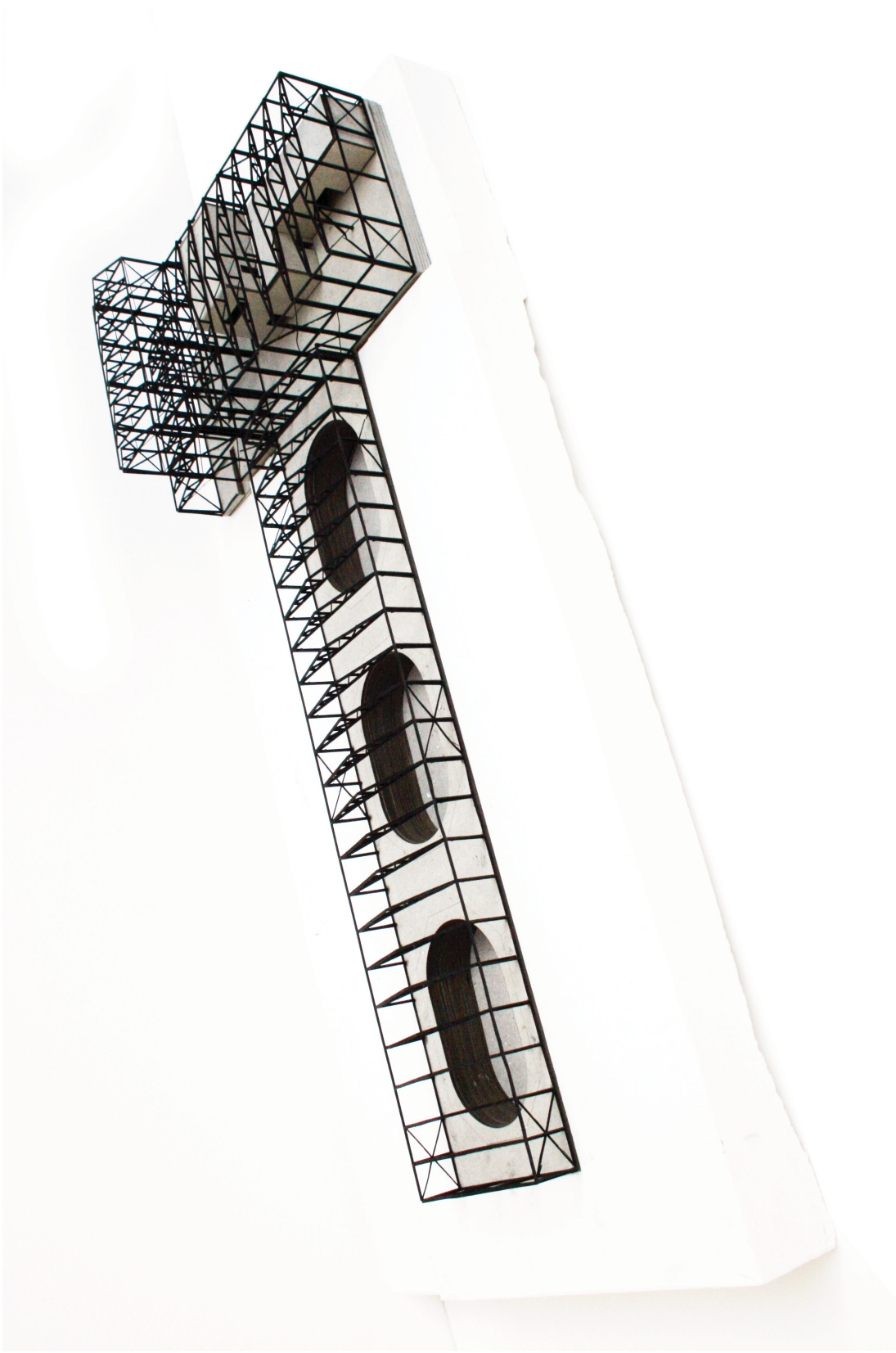
³⁰ Miramar Mining Corporation, *Final Closure and Reclamation Plan*, 53.



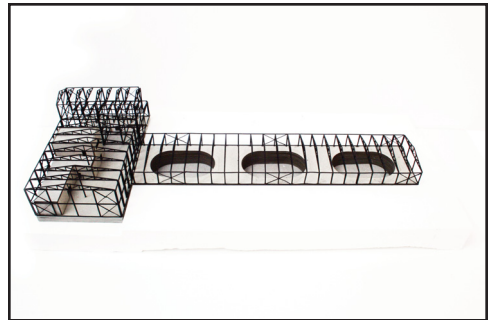
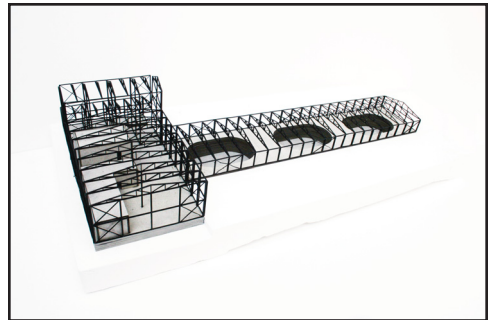
Structural rendering of existing arsenic blend plant.
(created with information from *Miramar Con Mine, Ltd: Final Closure and Reclamation Plan*)



Interior rendering of existing arsenic blend plant.
(created with information from *Miramar Con Mine, Ltd: Final Closure and Reclamation Plan*)



Physical model of existing arsenic blend plant.



Physical model of existing arsenic blend plant.

CHAPTER 2: DESIGN

A Vision for Con Mine

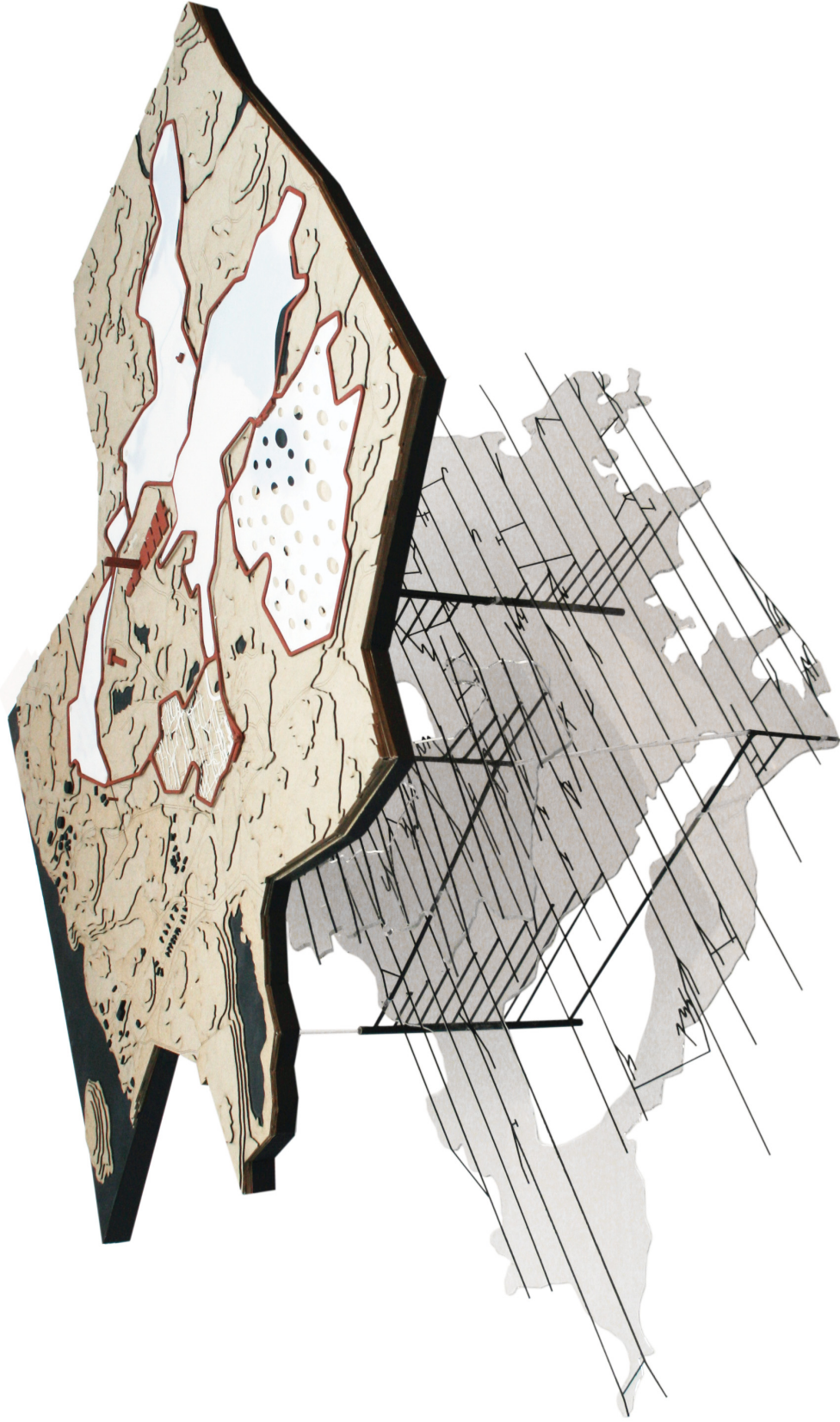
The proposed master plan for the Con Mine property is quite complex in nature, utilizing a variety of elements, buildings and programs to activate the site. This is relatively uncommon for most remediation projects, as a polarized approach is more common practice. To elaborate, there are three typical approaches to mine site reclamation; preservation, re-naturalization, and complete redevelopment. The first of these strategies is utilized to profit from heavy tourist traffic. Museums, interpretive displays, and underground tours are used to transport visitors back to past eras when mining was being commenced on the site. Though profitable during peak tourist seasons, this approach is not sustainable throughout the entire year, and only engages a small number of local residents. Secondly, re-naturalization is aimed at returning the landscape back to its former condition. Though environmentally beneficial, this approach only employs local residents for a short duration, and completely erases any cultural or historic value the site and its buildings may possess. Complete redevelopment projects take a similar approach, where by in order to make the site as economically valuable as possible, all vestiges of the past are also erased in the process. It is the intention of this project to merge all three of these approaches into one long-term, sustainable vision for the site and its neighboring city. By adapting existing buildings and infrastructure for alternate use, visitors will have an inherent connection with the history of the site; understanding how it once worked through day-to-day experiences. Furthermore, by producing heat and energy, in addition to processing waste, the site will be critically important for the operation of neighboring Yellowknife.

In general, the overall strategy is composed of 6 key phases:

1. Security and Safety
2. Research Facilities and Phytoremediation Infrastructure
3. Wetland Biofilter
4. Community Facilities
5. Renewable Energy Research Park
6. Recreational Landscapes & Miners' Memorial



Physical model of the Con mine property with proposed master plan overlaid.

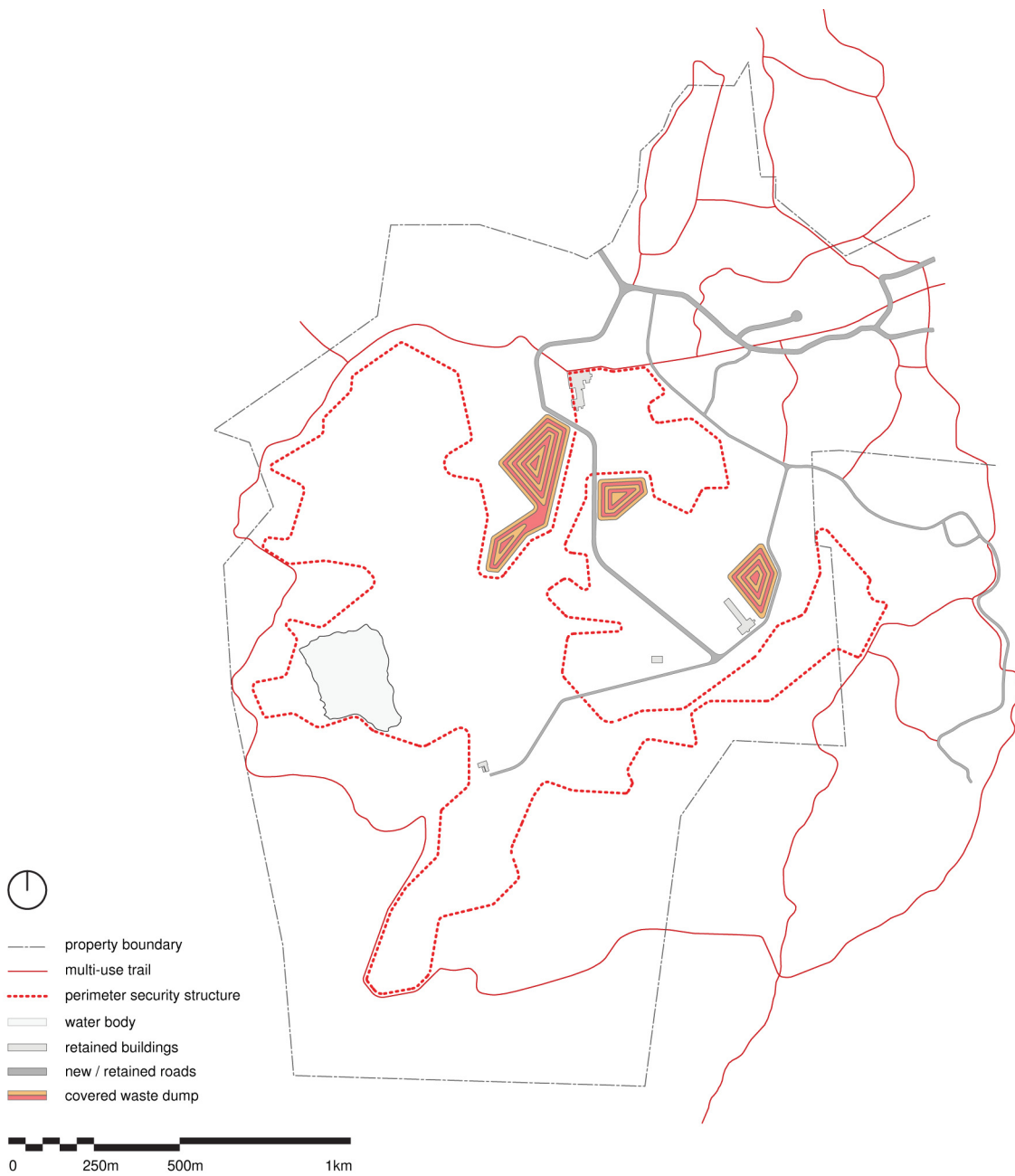


Physical model of Con mine's subterranean ore bodies, tunnels and shafts.

Project Phasing

Phase 1: Security and Safety

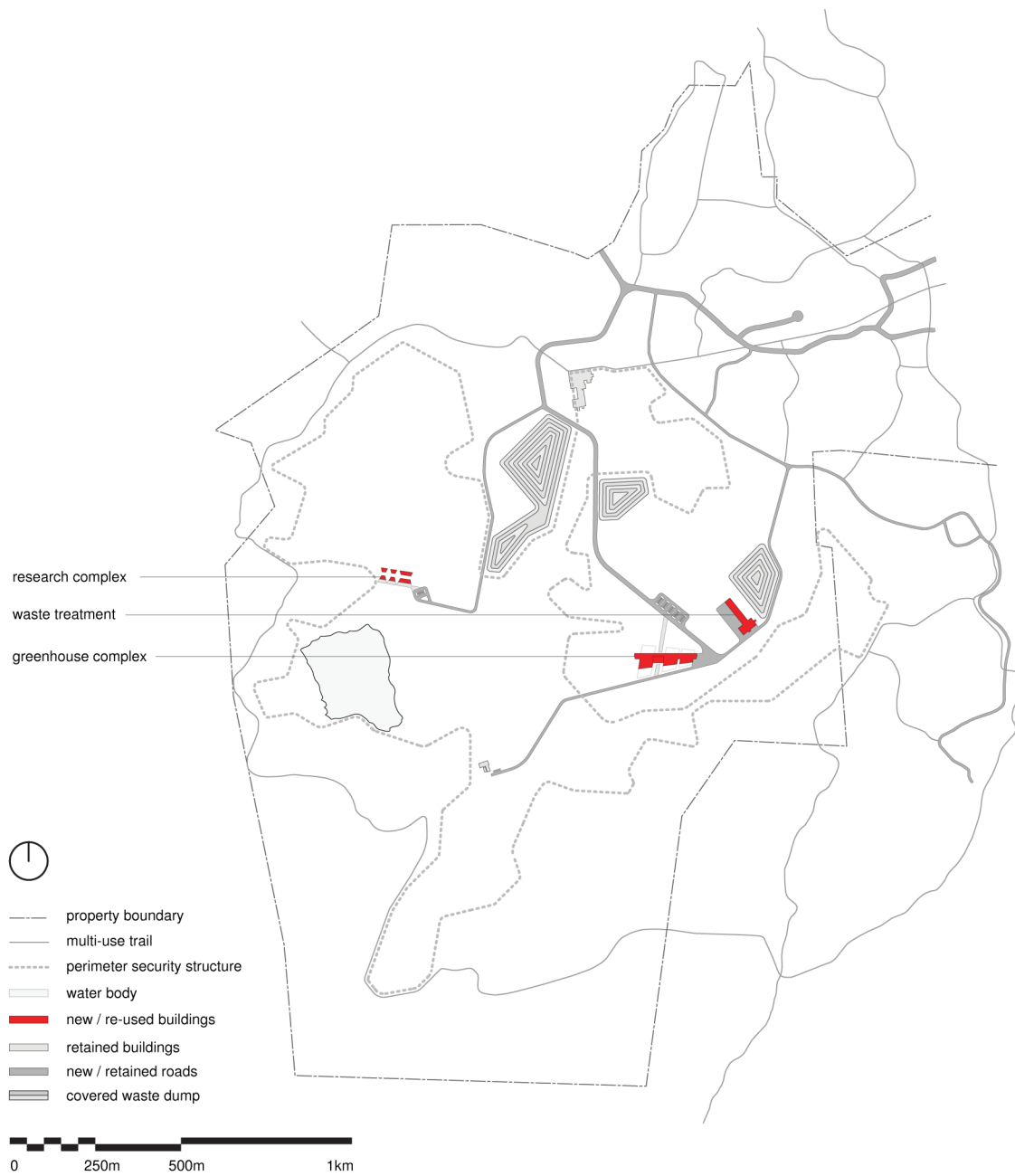
- Capping of toxic zones
- Boardwalk foundation structure installed as perimeter boundary
- Existing service roads converted to multi-use trails



Site plan showing phase 1 interventions.

Phase 2: Research Facilities and Phytoremediation Infrastructure

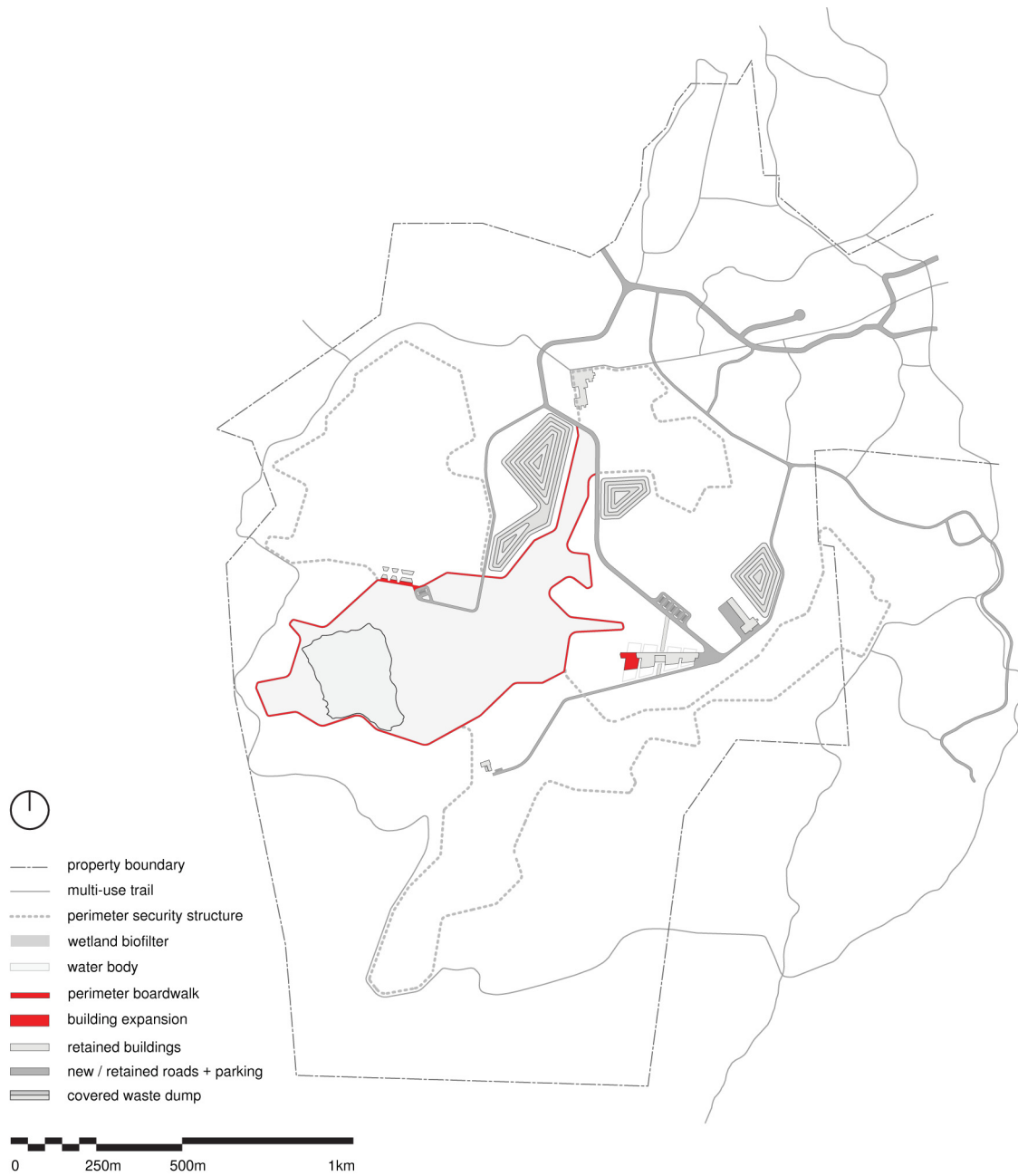
- Current environmental trailers replaced by new research stations and laboratory
- Arsenic plant converted to waste processing facility
- Greenhouse, mine water filtration plant, and geothermal energy plant installed at base of Robertson headframe



Site plan showing phase 2 interventions.

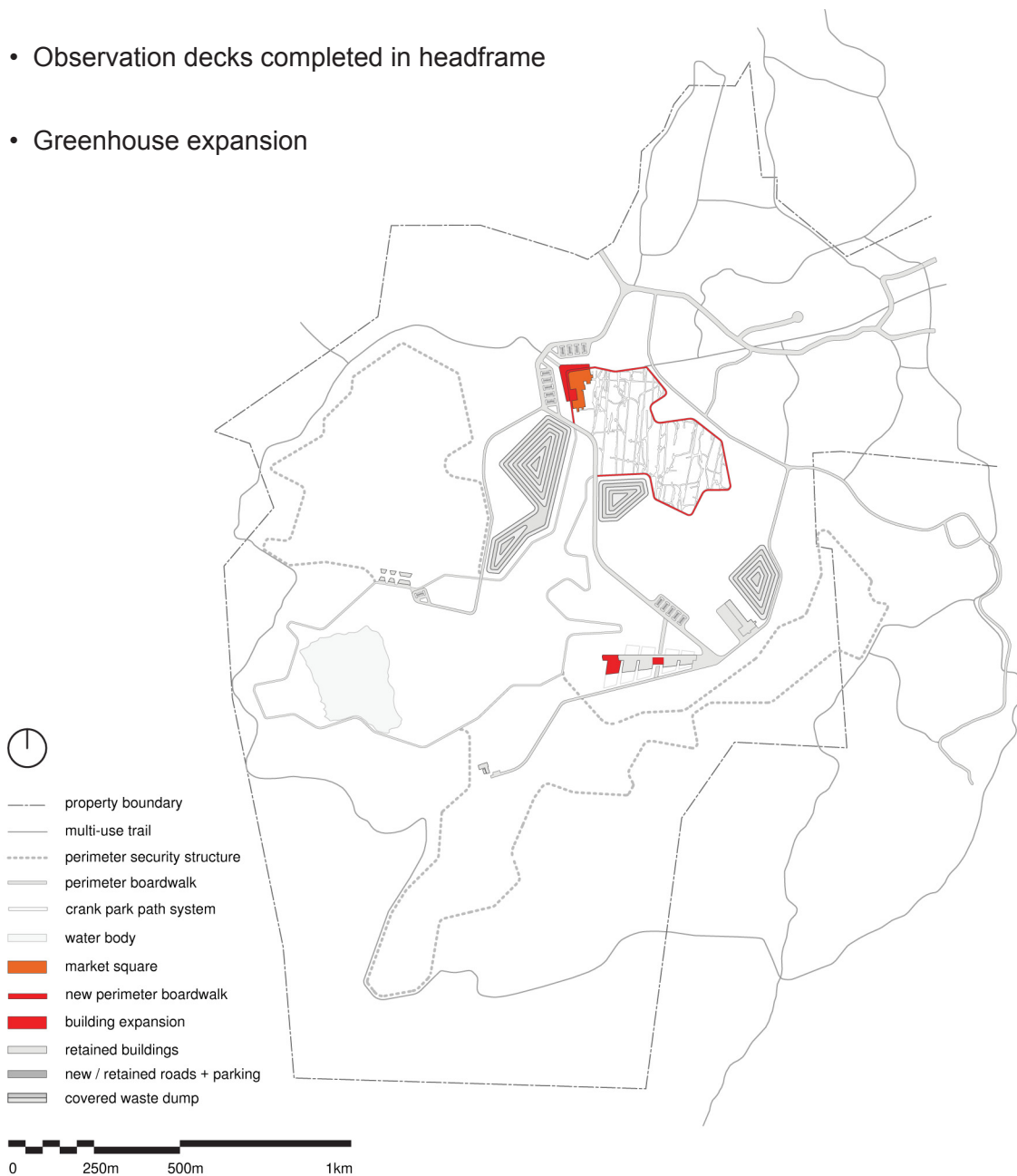
Phase 3: Wetland Biofilter

- Phytoremediation practices completed at the Middle Pud TCA
- Creation of wetland habitat for surface water run-off treatment
- Perimeter boardwalk completed around the Middle Pud TCA
- Greenhouse expansion



Phase 4: Community Facilities

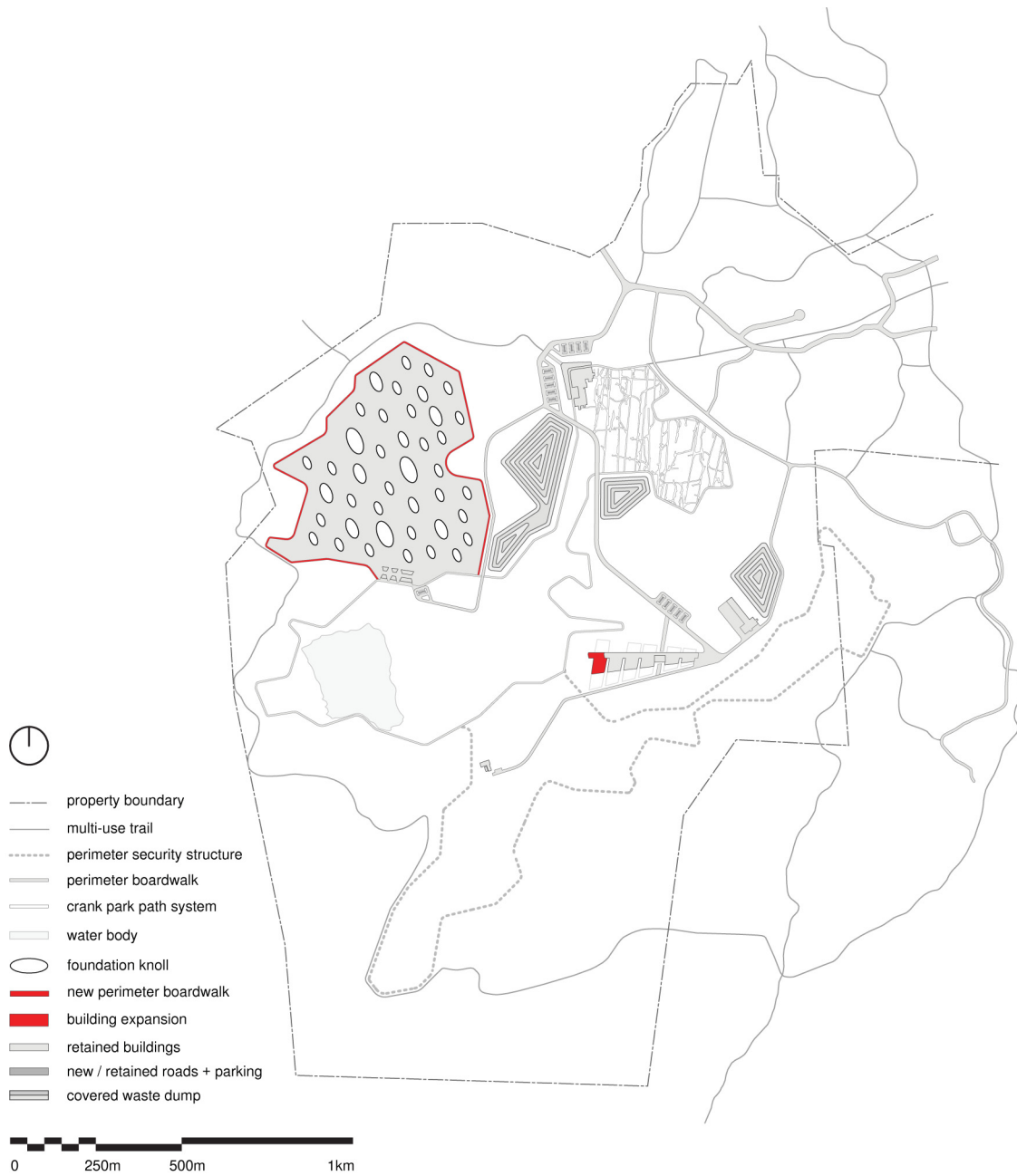
- Phytoremediation practices completed at the Crank Lake TCA
- Creation of public park with pathways representing subterranean infrastructure
- Perimeter boardwalk completed around Crank Lake TCA
- Visitor information and community centre
- Observation decks completed in headframe
- Greenhouse expansion



Site plan showing phase 4 interventions.

Phase 5: Renewable Energy Research Park

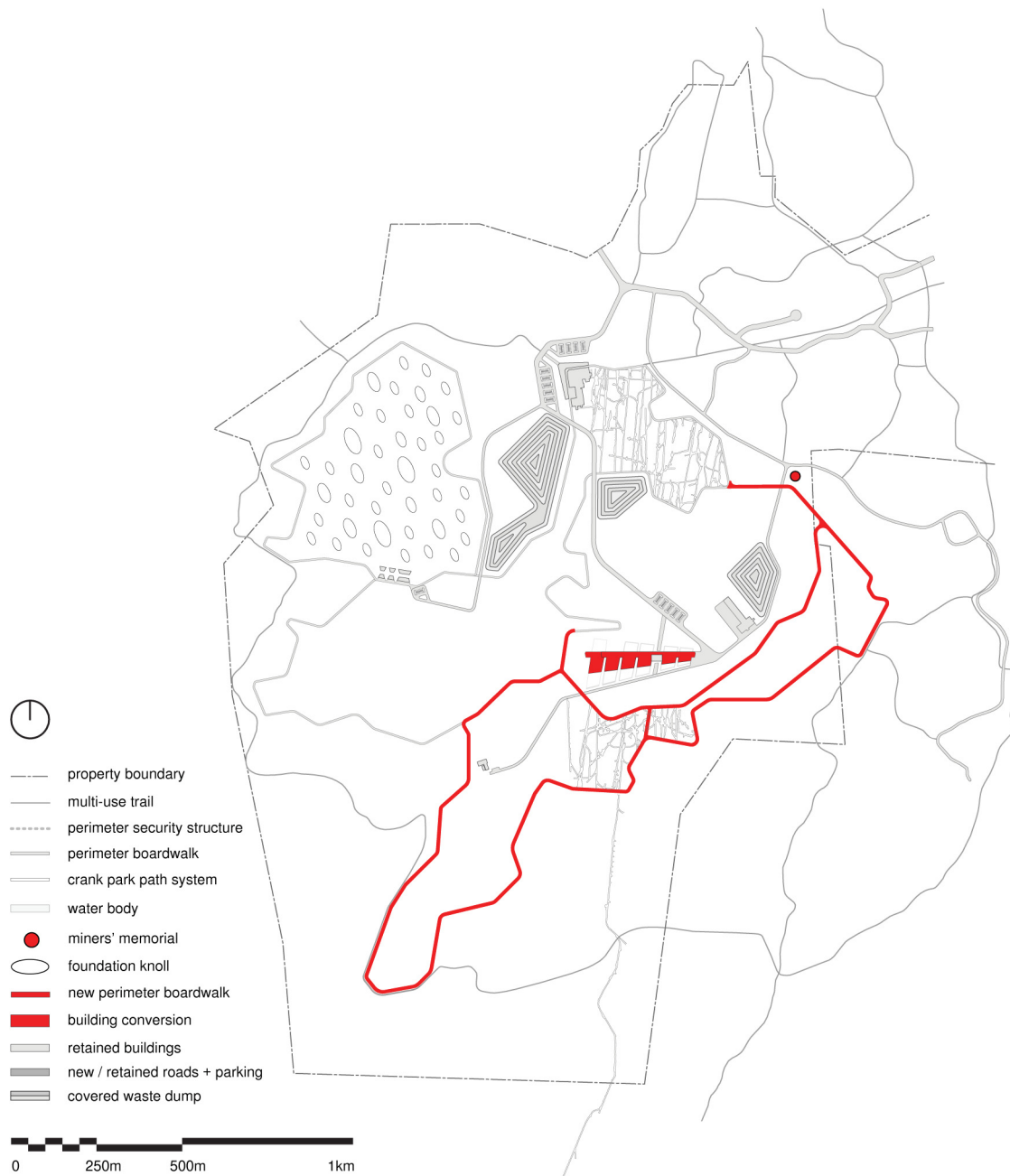
- Phytoremediation practices completed at the Upper Pud TCA
- Creation of foundation knolls for renewable energy research
- Perimeter boardwalk completed around the Upper Pud TCA
- Greenhouse expansion



Site plan showing phase 5 interventions.

Phase 6: Recreational Landscapes & Miners' Memorial

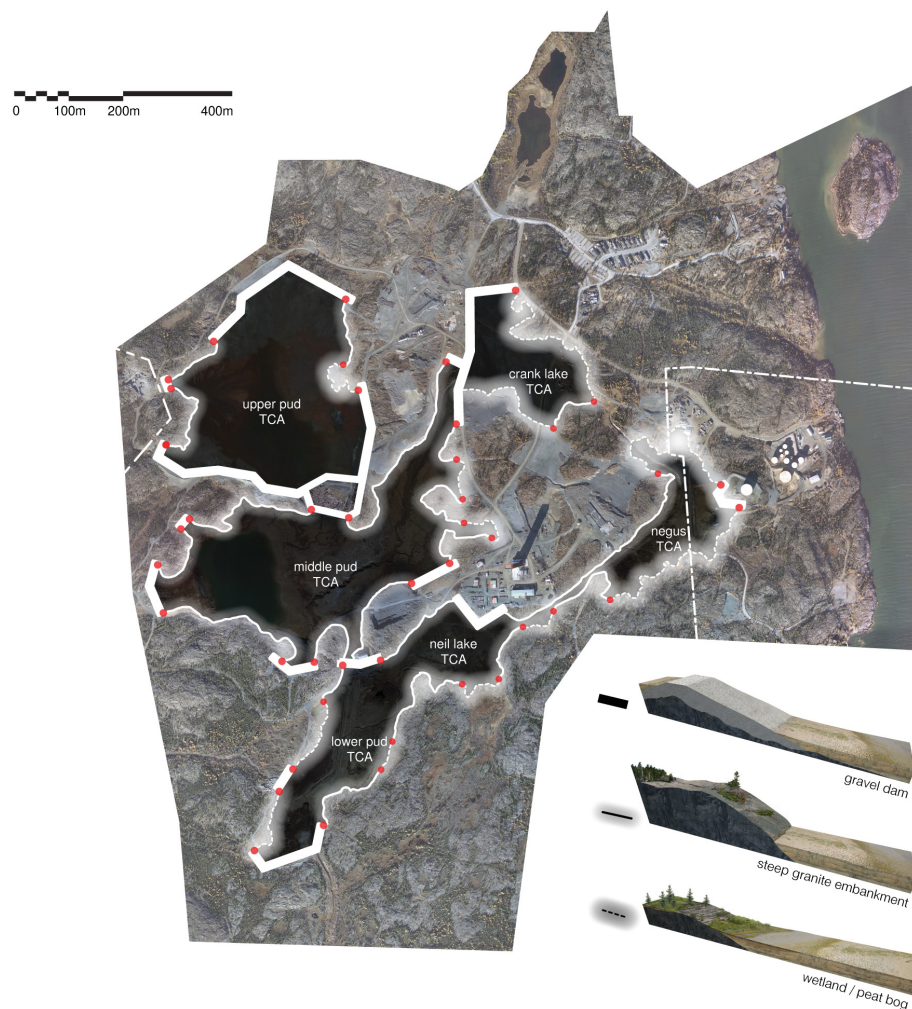
- Phytoremediation practices completed at Lower Pud, Neil Lake and Negus TCA
- Creation of trails for non-motorized recreational activities
- Conversion of phytoremediation infrastructure into agricultural operation
- Miners' memorial constructed at the Negus shaft



Site plan showing phase 6 interventions.

The Perimeter Boardwalk

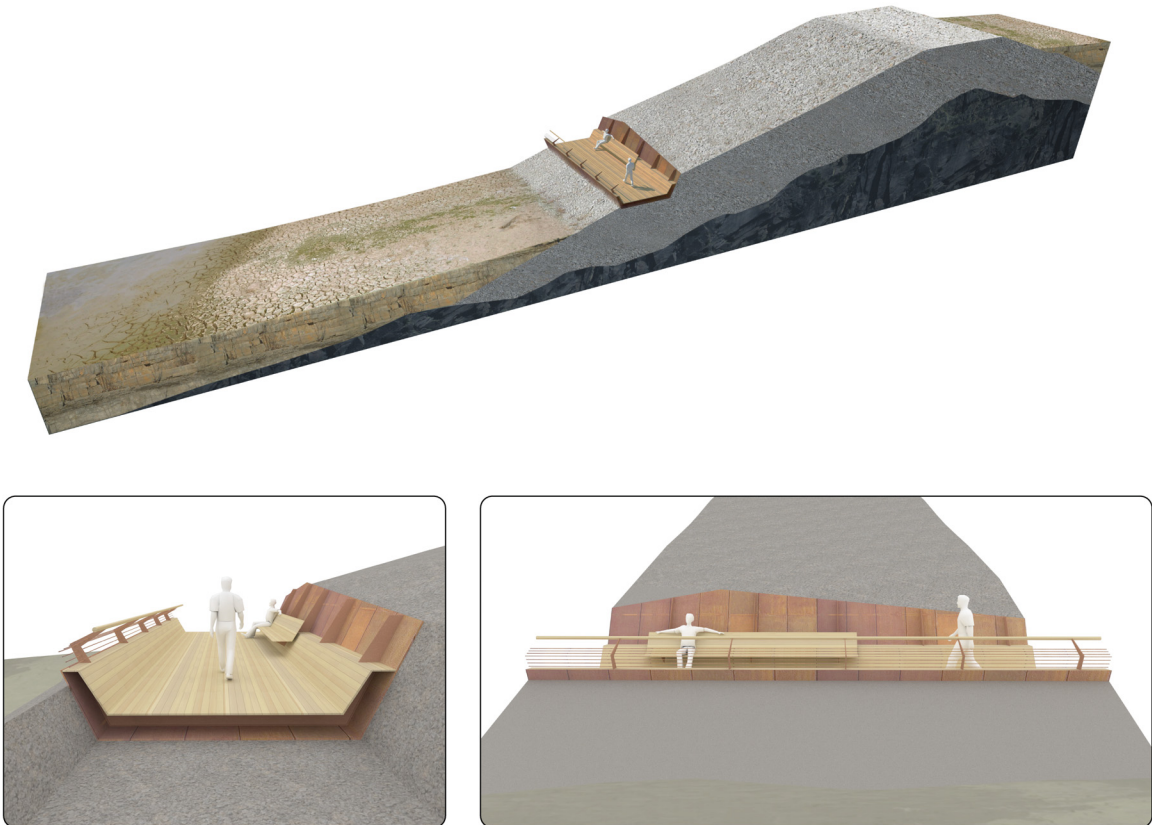
The proposed boardwalk demarcates the six historic tailings ponds present on the Con mine property. The demarcation is a way to encourage a deeper understanding of the site and its history, while at the same time, responds to the various threshold conditions around the perimeter of the tailing containment areas (TCA's). The foundation system of the boardwalk varies in each case, however the boardwalk's Cor-ten steel cladding changes more subtly in order to maintain visual continuity throughout the site. Rusted steel was chosen as the primary material for the cladding for several reasons including its durability, its reference to an industrial language, and the way in which the material can be welded in sheet-form to resemble a ribbon-like quality as it circumnavigates the site.



Site plan indicating various threshold conditions around the perimeter of the six prominent TCA's.

Tailings Dam Threshold

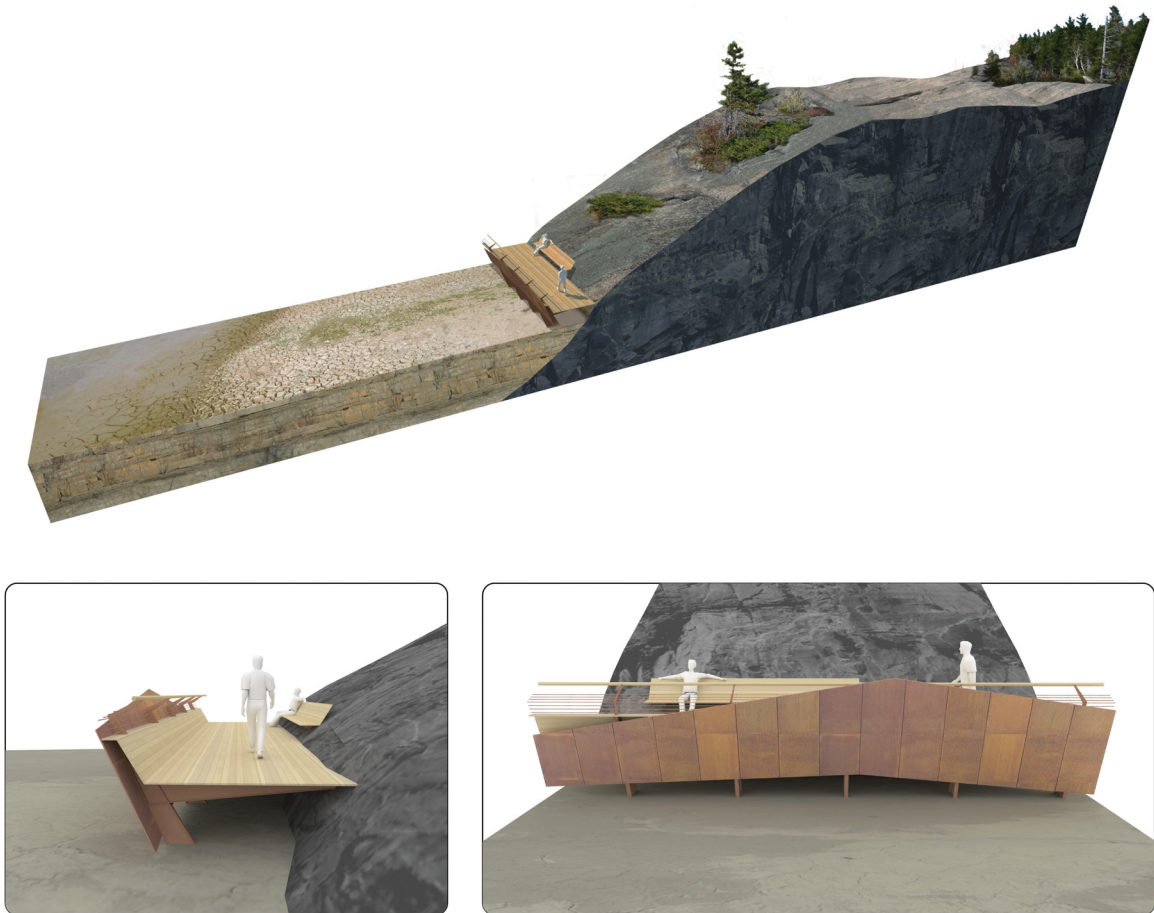
The dams around the perimeter of the TCA's were typically constructed with waste rock from early mining operations, and are generally uncontaminated. During early mining operations, a great deal of rock was excavated in order to reach gold-bearing deposits deep underground, thus an abundance of waste rock was deposited around the site. In addition to tailings dams, rock was also deposited for use as massive foundation pads for the C-1 and Robertson facility buildings. As a result, the boardwalk encounters piled waste rock around much of the Upper and Middle Pud TCA's. Here, the design of the boardwalk takes advantage of the sculptable quality of the finely-ground waste rock. The path takes shelter in these mounds, partially bermed, with the steel cladding acting as a retaining structure for pedestrians against the dam. The wooden surface of the boardwalk is supported by structural steel ribs every two metres, laid directly on-grade in this application. The ribs extend up on the tailings side of the boardwalk to support a guard, and also extend upwards on the dam side to further brace the steel retaining wall.



Aerial view and perspective section and elevation of boardwalk variant.

Rock Outcropping Threshold

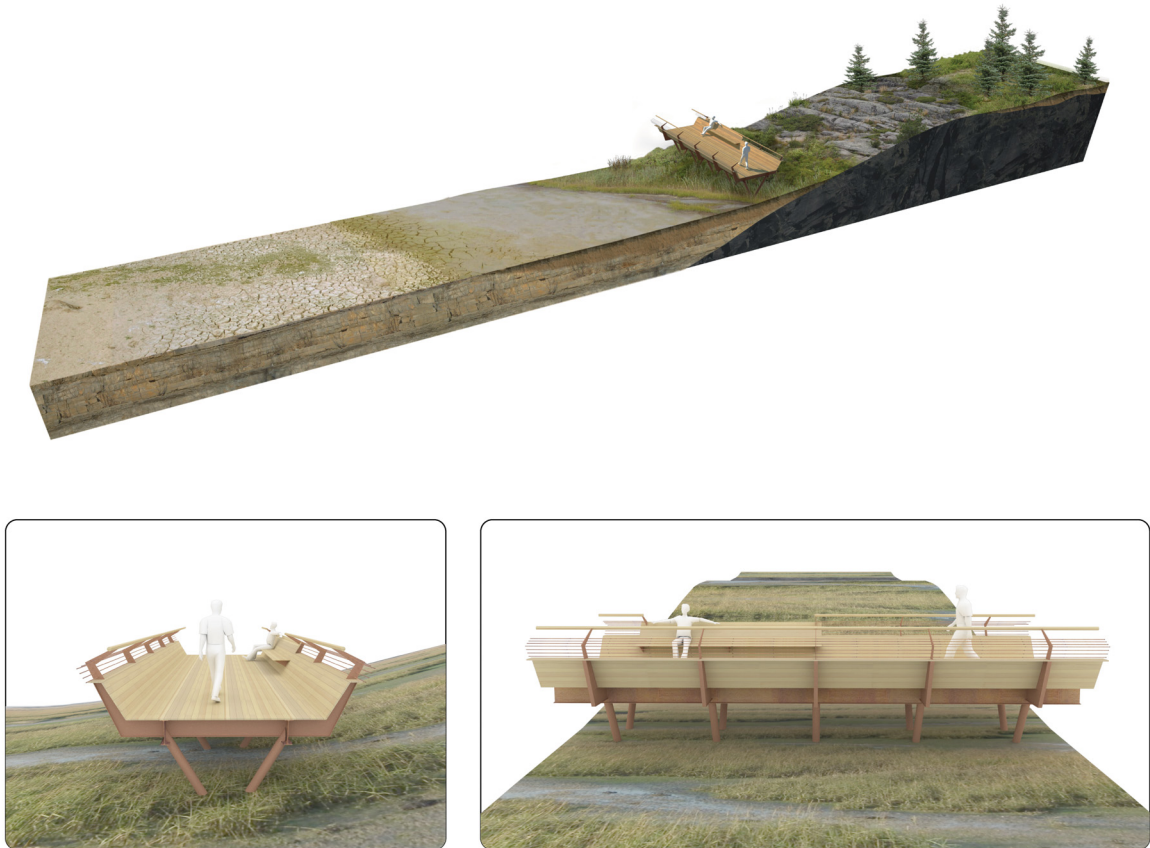
The TCA's at the Con mine are located where water bodies occurred naturally. This means that the ponds are naturally retained by the contours of the rock outcroppings in these locations. Typically these are large surfaces of exposed bedrock, many of which have steep embankments, with heights up to 10 metres in some locations. Because this rock offers excellent foundation anchoring qualities, it was decided that the boardwalk foundation in these locations would anchor to bedrock and appear to cantilever out over the tailings pond surface. At these locations, the steel cladding would sweep across to the tailings' side of the path, acting as an apparent shield against the artificial landscape beyond. In order to accentuate the natural quality of the bedrock, the wood decking would be scribed to the face of the rock, undulating the edge of the surface as one travels along the path.



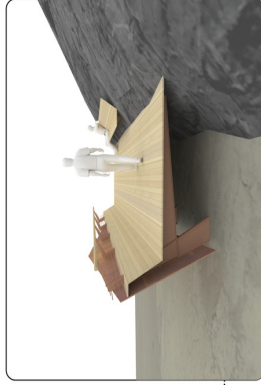
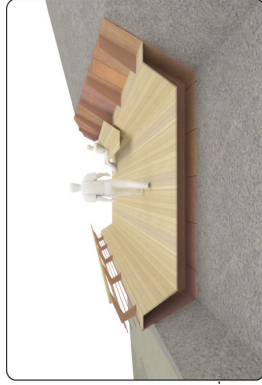
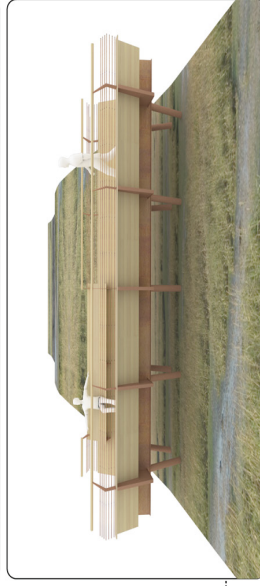
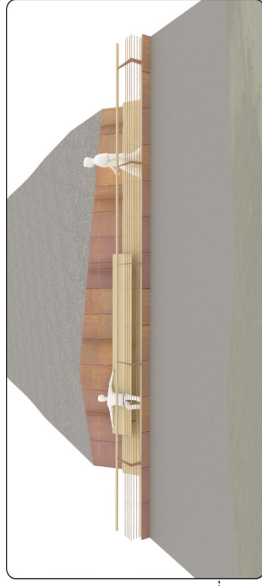
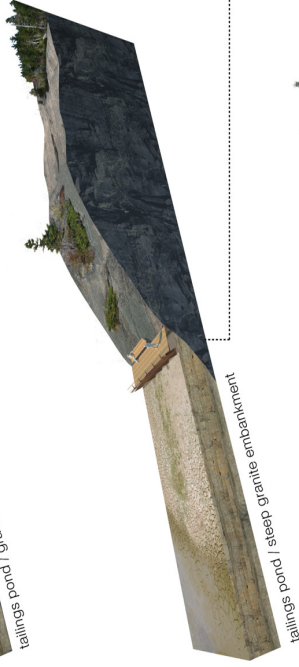
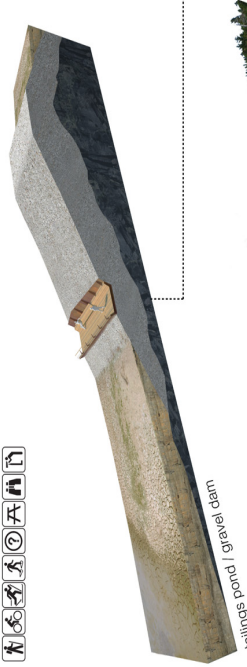
Aerial view and perspective section and elevation of boardwalk variant.

Wetland / Peat Bog Threshold

Lastly, there are a number of areas where the perimeter edges of the ponds have been blurred over time. Due to the make up of the ground in these areas, surrounding wetlands and peat bogs have begun to accumulate in the low-lying areas, encouraging re-naturalization in the process. Over time, because of these slow natural processes, the landscape will change dramatically, and the extent of the ponds will no longer be easily recognizable. In all cases, but in particularly here, the boardwalk will act as a marker to reveal the extent of deposition throughout the site. In order to allow this transformation to occur without impediment, the boardwalk is lifted off the ground altogether in these locations. Minimal diameter steel piles anchor the structure to the relatively unstable ground below with the steel cladding acting as a plane for which to travel on. This allows flora, fauna, and water to flow below the path, while creating a visual marker of historic deposition.



Aerial view and perspective section and elevation of boardwalk variant.



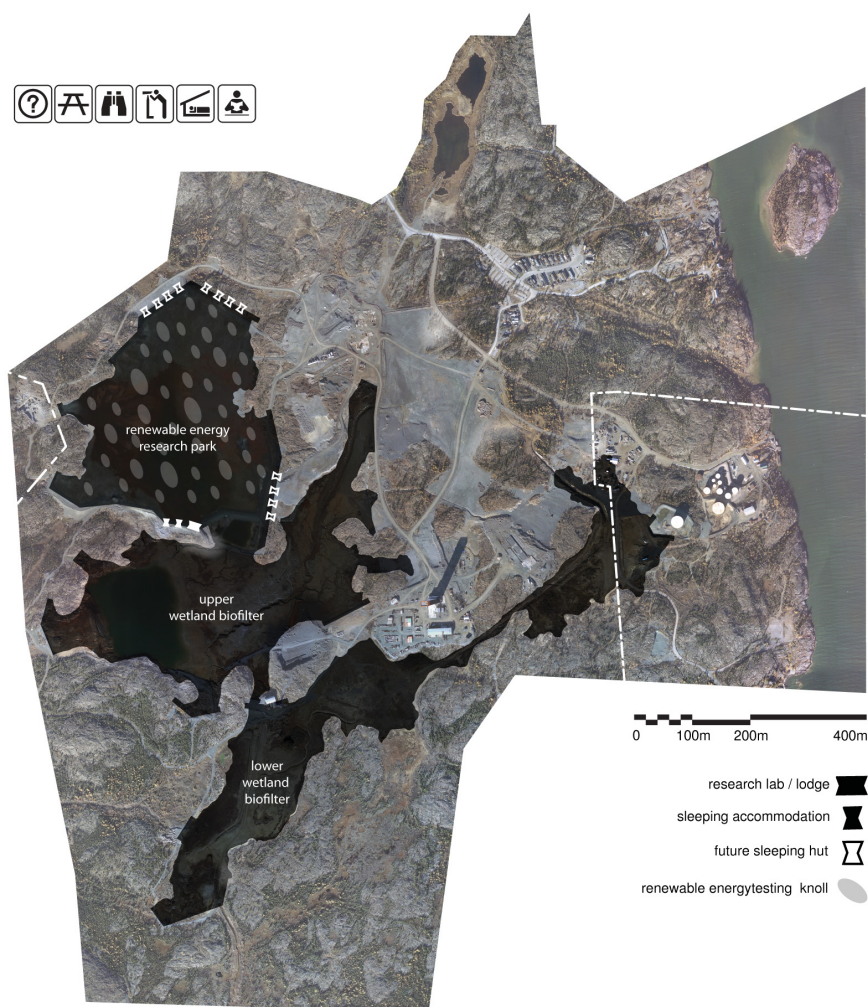
Comparison of boardwalk variants.



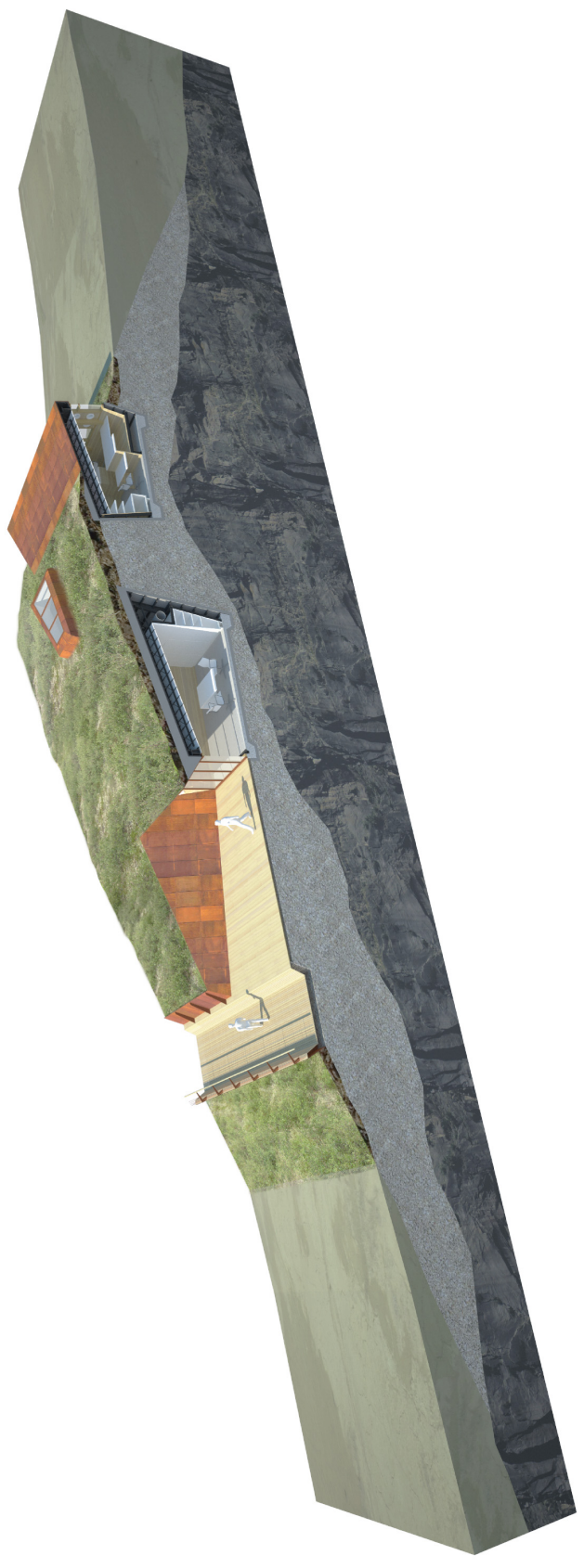
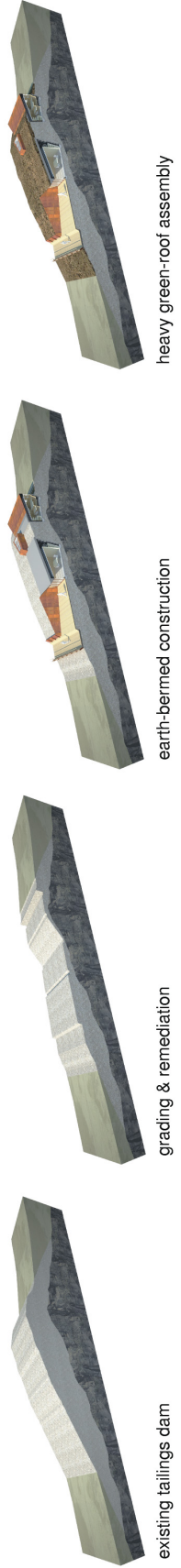
Perspective view of boardwalk intervention.

Research Stations

The primary research station complex is situated between the Upper and Middle Pud TCA's. This location was chosen because the property's largest dam is located in this area, meaning a large amount of relatively uncontaminated waste rock allows for interesting possibilities in terms of earth-berming a structure in the ground. This will provide enormous energy savings in contrast to the existing environmental lab situated in several double-wide trailers. This location is also ideal because of uninterrupted sight lines over the property's two largest tailings ponds. The Upper Pud TCA will be utilized for renewable energy technology testing, and the Middle Pud TCA will be converted into a wetland biofilter used to treat all the surface water run-off on the property. The proposed research complex will allow direct access and excellent observation capabilities for both of these landscapes.



Site plan indicating location of research stations and phased accommodations.



typical section

Construction sequencing and final sectional perspective of typical tailings dam research station.

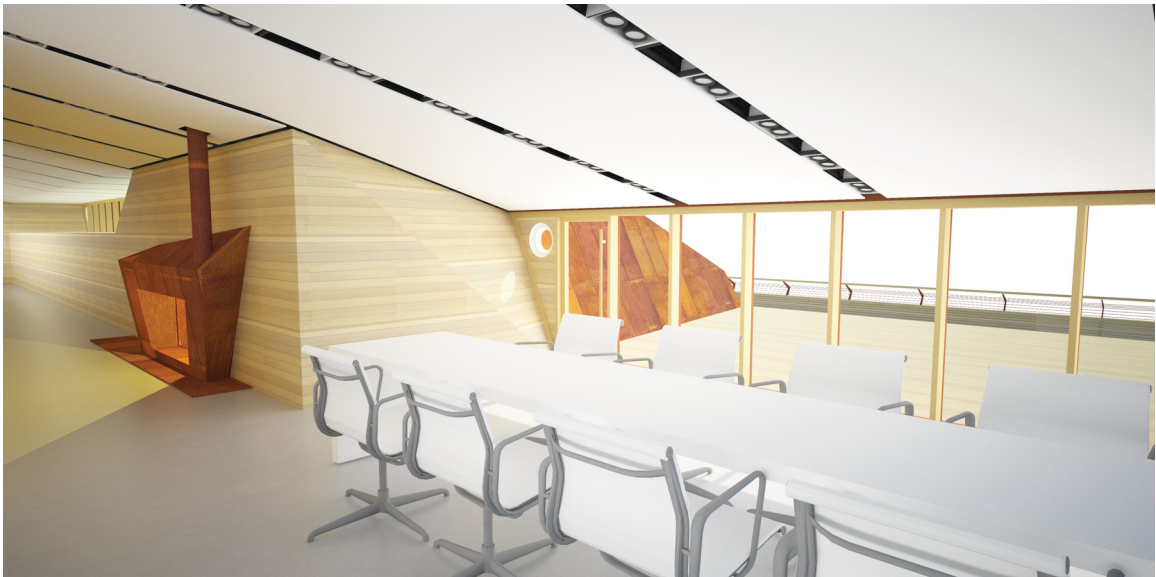
In addition to being used as locations for water and environmental testing, the tailings dams on the Con mine property provide interesting possibilities for new construction. In sub-arctic climates, particularly in the Taiga Shield ecozone, vast expanses of exposed bedrock coupled with discontinuous permafrost conditions in peat bog deposits make for difficult building conditions. Large deposits of finely-ground waste-rock however allow for alternative building typologies, the benefits of which include the possibility of earth-berming. Although it may seem ill-advised to bury a building in a dam used for retaining arsenic-laden material, the upper extent of these dams (above the historic water line) are relatively uncontaminated. Therefore, it was decided that earth-berming would achieve several key objectives in the project, the first being increased energy efficiency due to increased insulation value against the winter temperatures. Secondly, the design encourages snow scouring and limits wind turbulence for the renewable energy park beyond. Lastly, the intervention preserves the form and function of the dam itself. It is critical to this thesis that manufactured landforms maintain their artificial quality in perpetuity, and building within them is one way to achieve that objective.



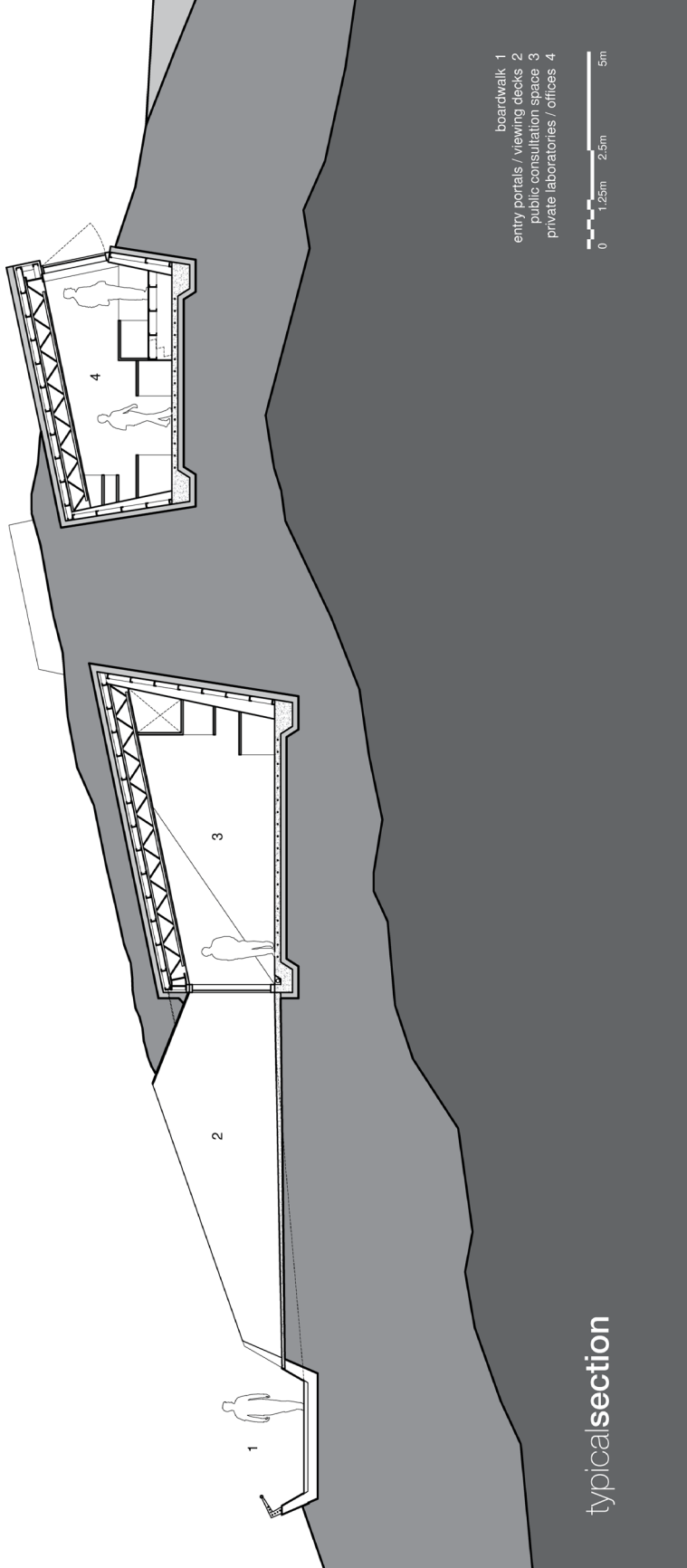
Entry portals accessed from perimeter boardwalk.



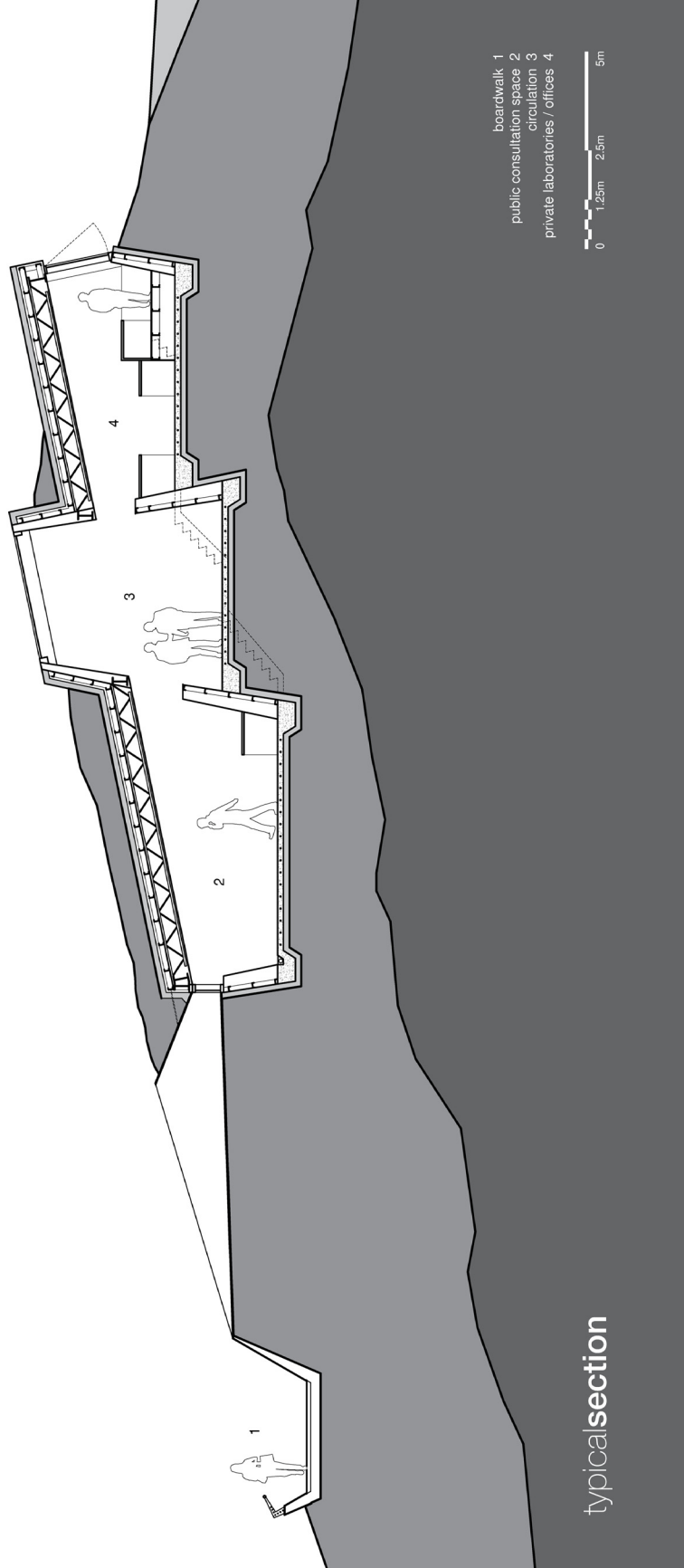
Despite the earth-bermed nature of the construction, a great deal of effort was made to ensure excellent day lighting qualities existed within the various buildings of the research station complex. The upper office and laboratory levels (or sleeping level in the accommodations) are oriented northward, hence a sloped roof line allows for diffused light to enter deep into the building's interior.



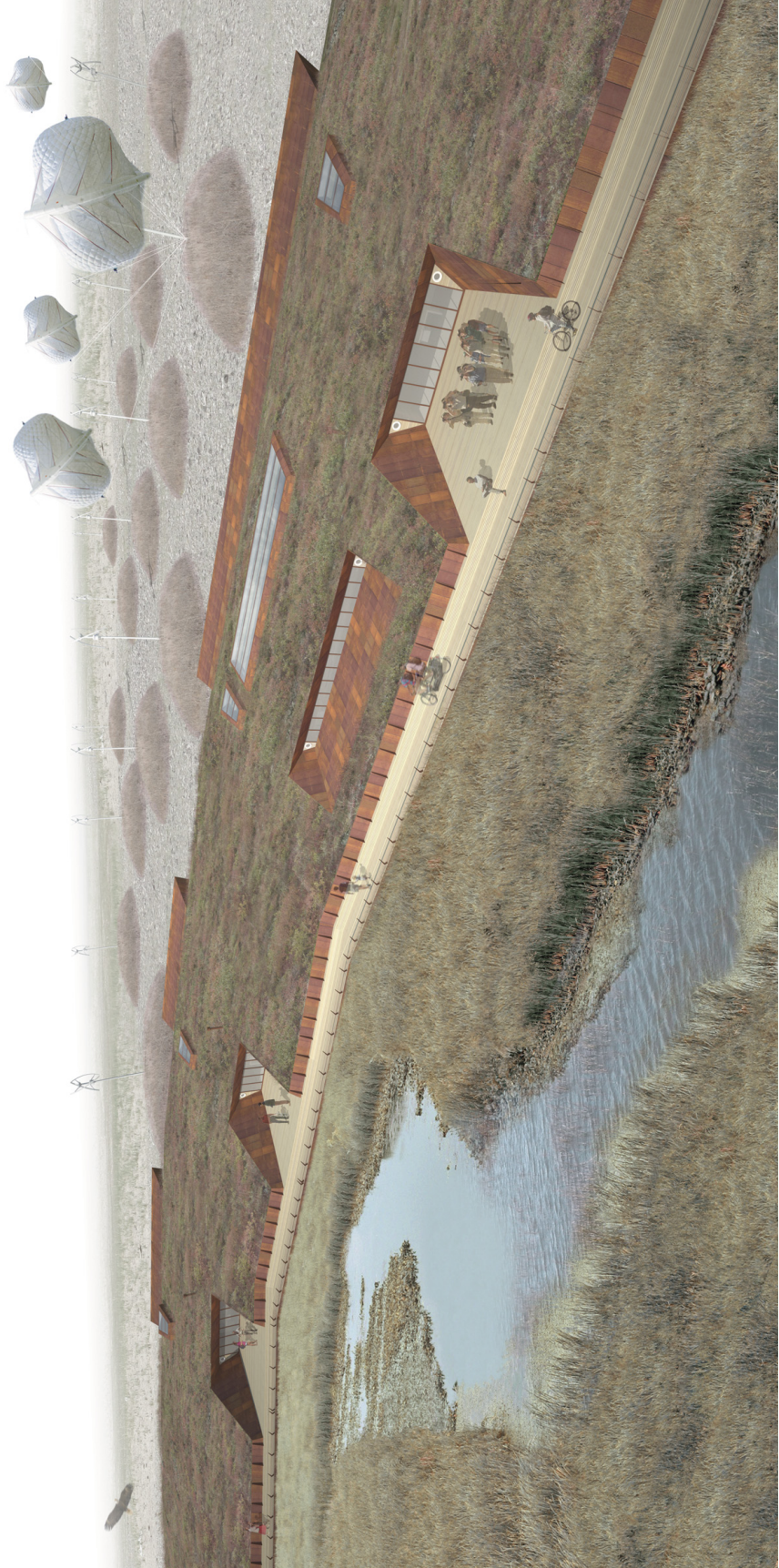
The lower levels of the complex include multi-use space for public interaction and consultation. Here, the sloped roof acts as a sun-shading device in the buildings lower south-facing elevation. Wherever the upper and lower levels of the complex join in section, skylights are provided in order to naturally light the inner depths of the building's plan.



Typical section of the research station complex.



Typical section of the research station complex.



Perspective view of tailings dam research station complex.

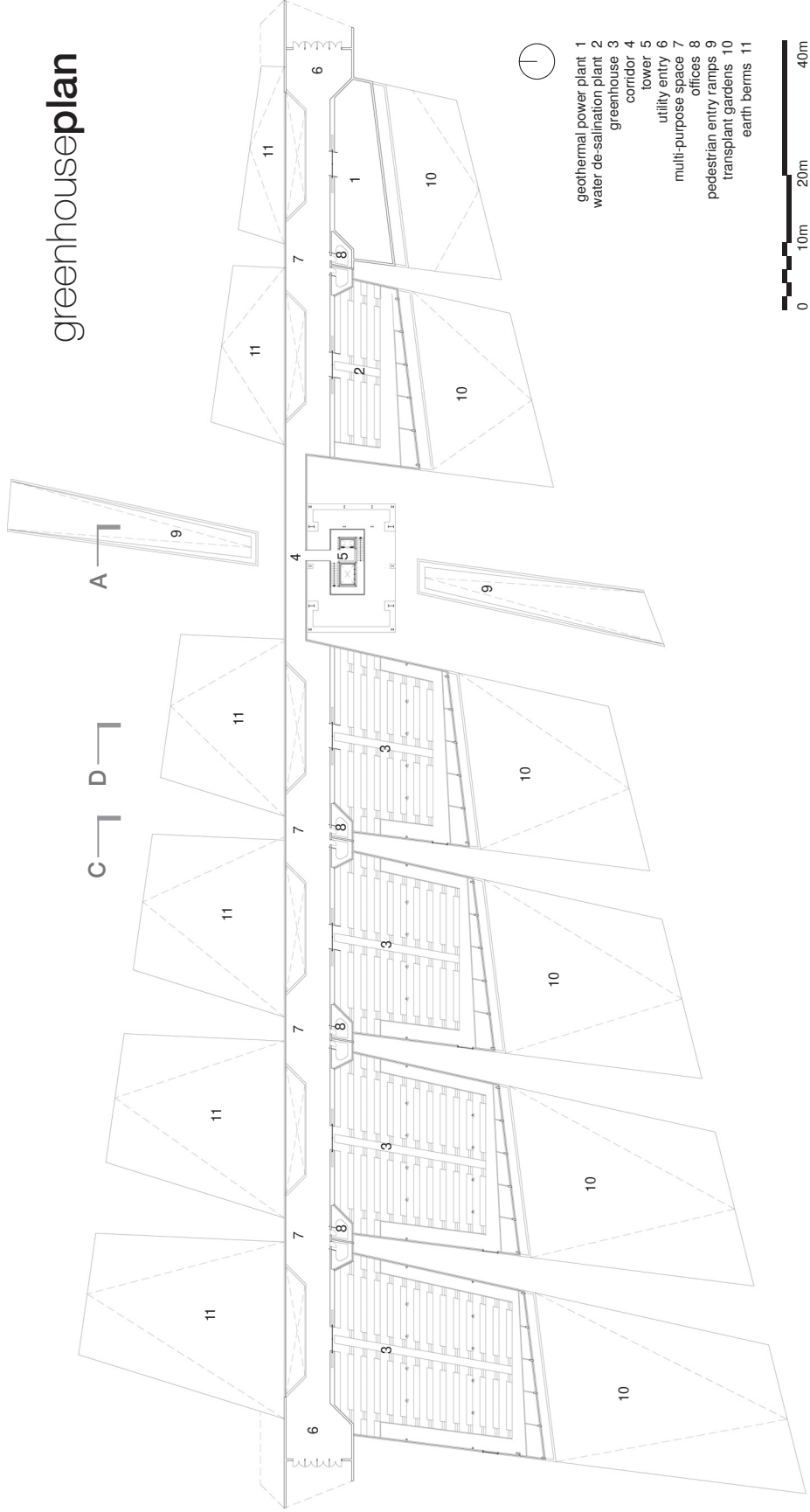
Greenhouse Complex

The portion of the Con mine property known as the Robertson complex is arguably the most important in regards to the proposed master plan from both a programmatic and economic perspective. This area includes the existing Robertson headframe and the arsenic blend plant facility. These existing structures have been incorporated into a large complex designed to facilitate phytoremediation processes in the short term, and industrial agricultural practices in the eventual future. This area was central to the mines operation, as it was the largest point of extraction for subterranean excavation. Because of this, existing road networks intersect at this location making it ideal for the transportation of planting soil and phytoremediators throughout the property's six tailings ponds. Other buildings on the site are also re-used, for example the blend plant functioned almost identically to modern day compost facilities, thus it will be used for this purpose after appropriate decontamination practices. The Robertson headframe and shaft provide critical heating and ventilation via geothermal heat exchangers and a 76 metre tall solar chimney. The tower also presents opportunities for surveying the surrounding landscape and remediation processes later in the phased development of the project.



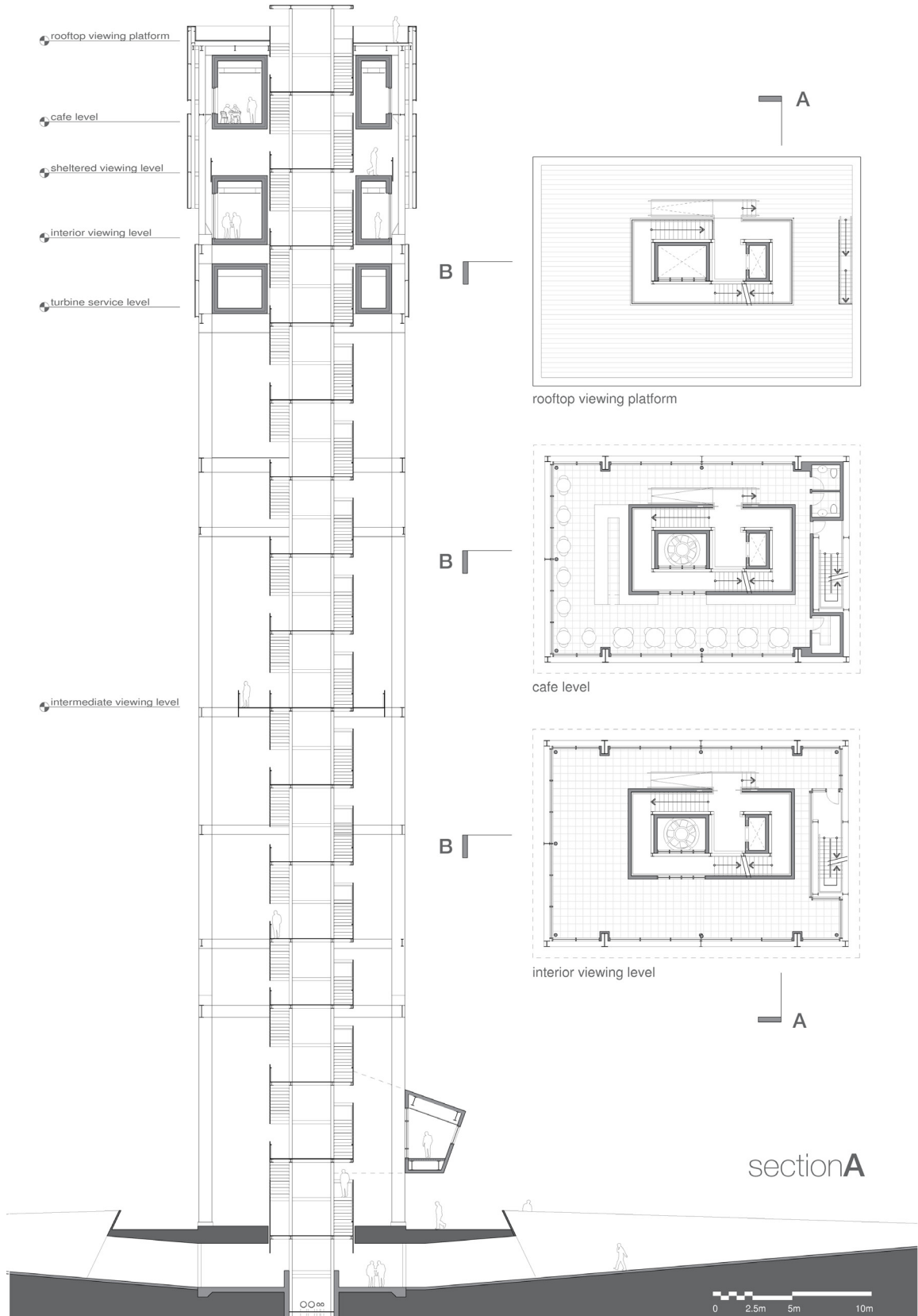
Site plan indicating location of greenhouse complex, compost facility, and water treatment plant.

For the second, third and fourth phases of the master plan, design interventions were focused on the existing Robertson headframe structure and greenhouses located at its base. Due to the low angle of the sun for the majority of the year, it is important not to obstruct the greenhouses with shadows from neighboring structures, hence the greenhouses are sited in an east-west orientation to maximize solar gains year-round. Furthermore, the greenhouses are designed to be twenty metre long modules so that additional buildings can be added as the operation expands. These individual modules are thus serviced and connected by a raised continuous corridor that also travels east-west. Because of extreme snow drifting situations, the raised configuration of the corridor allows snow scouring to occur between modules in order to keep ground level entries clear of accumulation. The greenhouses also respond to these extreme environmental conditions by berming earth on their north elevation in order to protect against bitter winter winds.

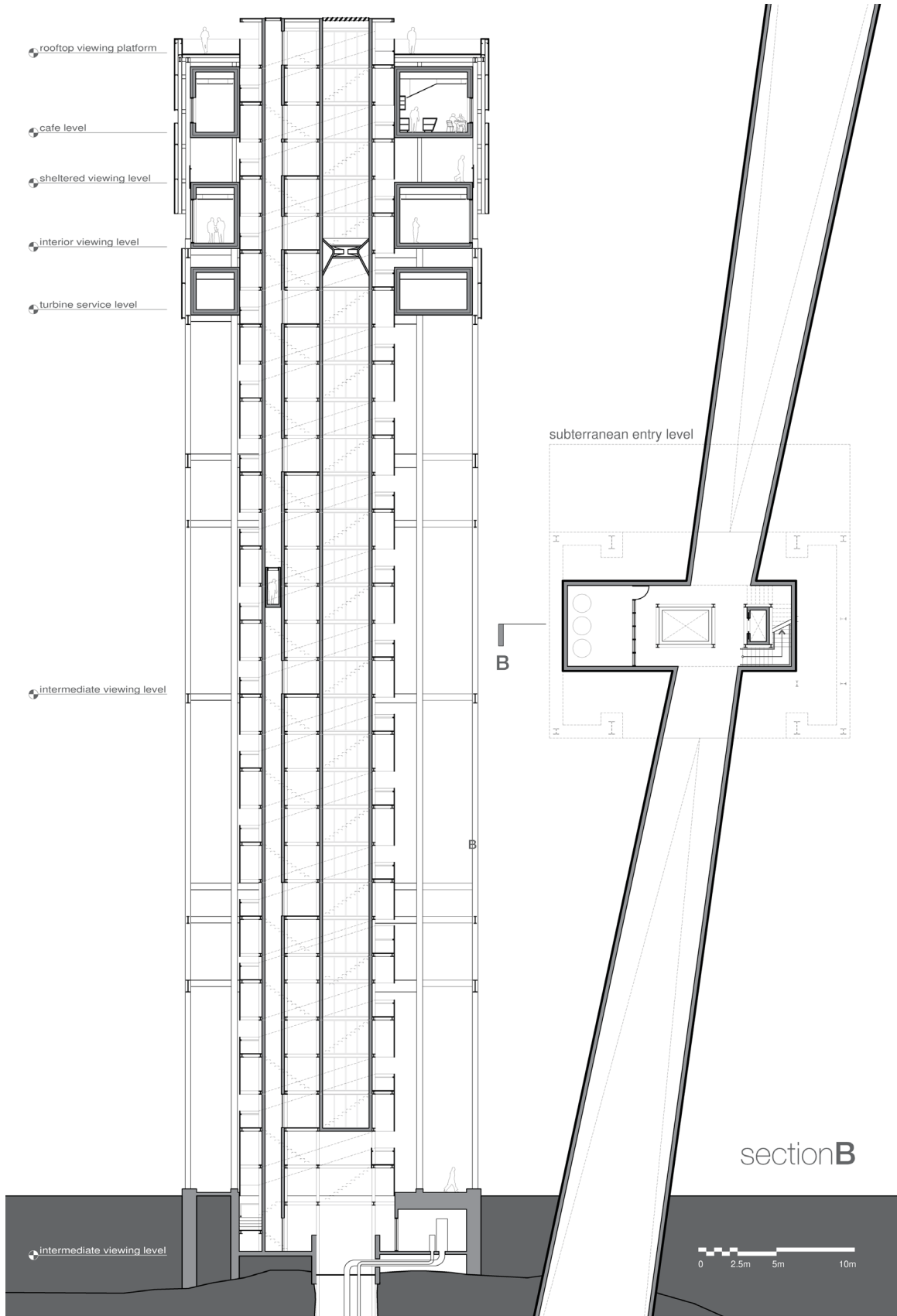


greenhouseplan

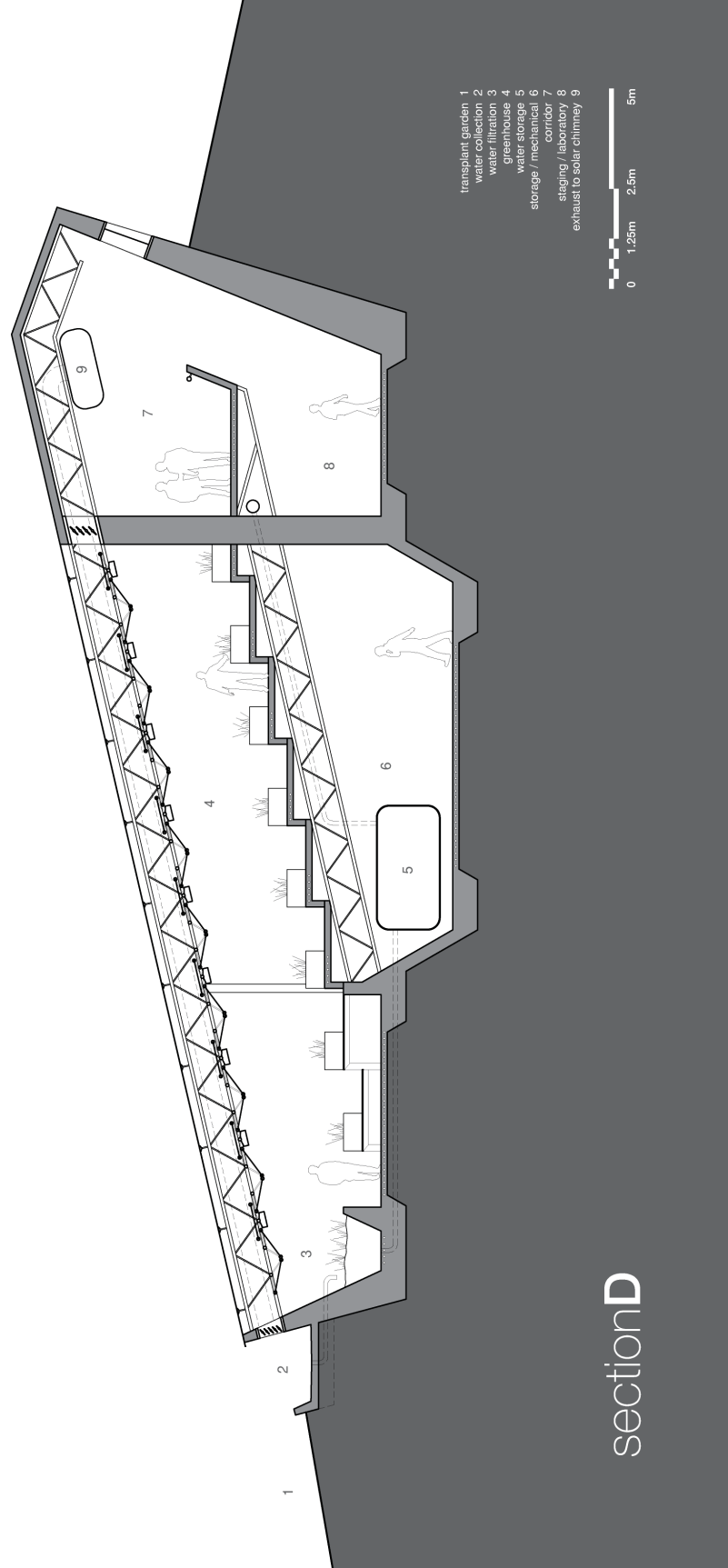
Plan of the Robertson greenhouse complex. The facility is developed over four phases, the first of which includes the construction of three modules at the tower's base. At the east side of the complex, a geothermal power plant converts heat from the depths of the Robertson shaft workings into radiant floor glycol loops and electricity for the facility's lighting. Adjacent to the power plant is a tiered desalination plant that purifies water from the mine for use in subsequent irrigation practices. Lastly, one demonstration greenhouse module is located west of the tower. Sequentially, additional greenhouse modules can be added to the facility in series, drawing from the abundant water and energy sources of the centrally located shaft. Once economic sustainability has been reached, observation decks would be constructed at the upper levels of the Robertson headframe.



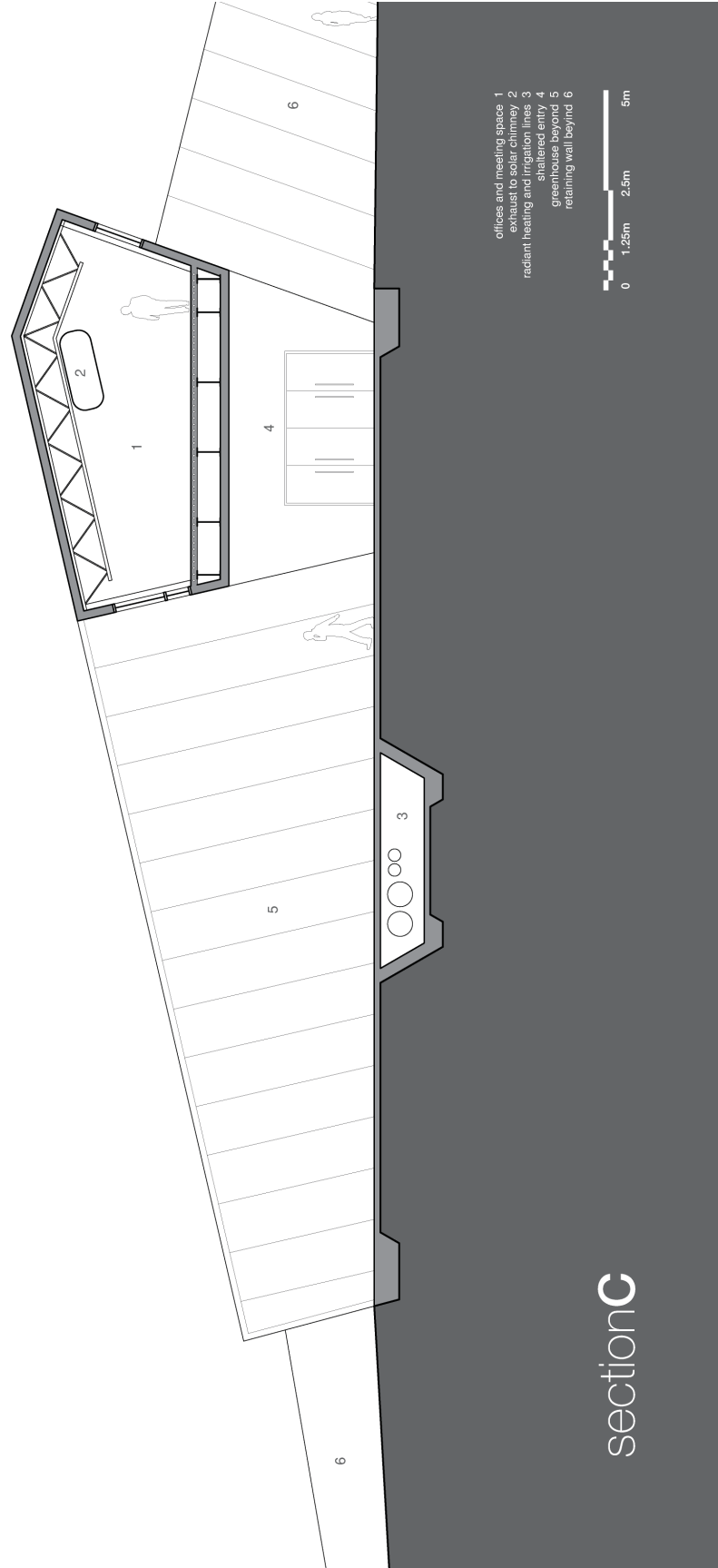
Section through observation tower / Plans of observation decks.



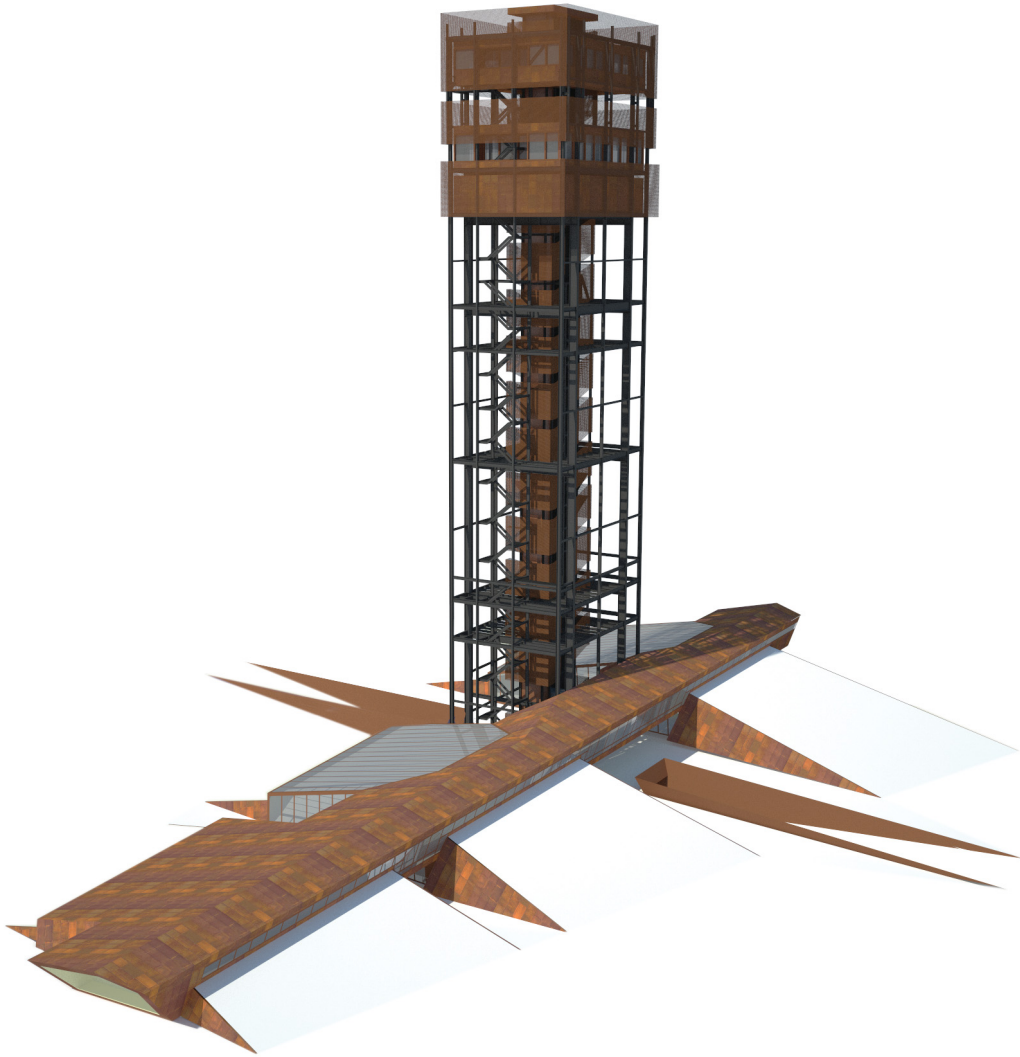
Section through central core of tower and plan of subterranean entry level.



Typical section through modular greenhouse.



Typical section through corridor that bridges between greenhouse modules.



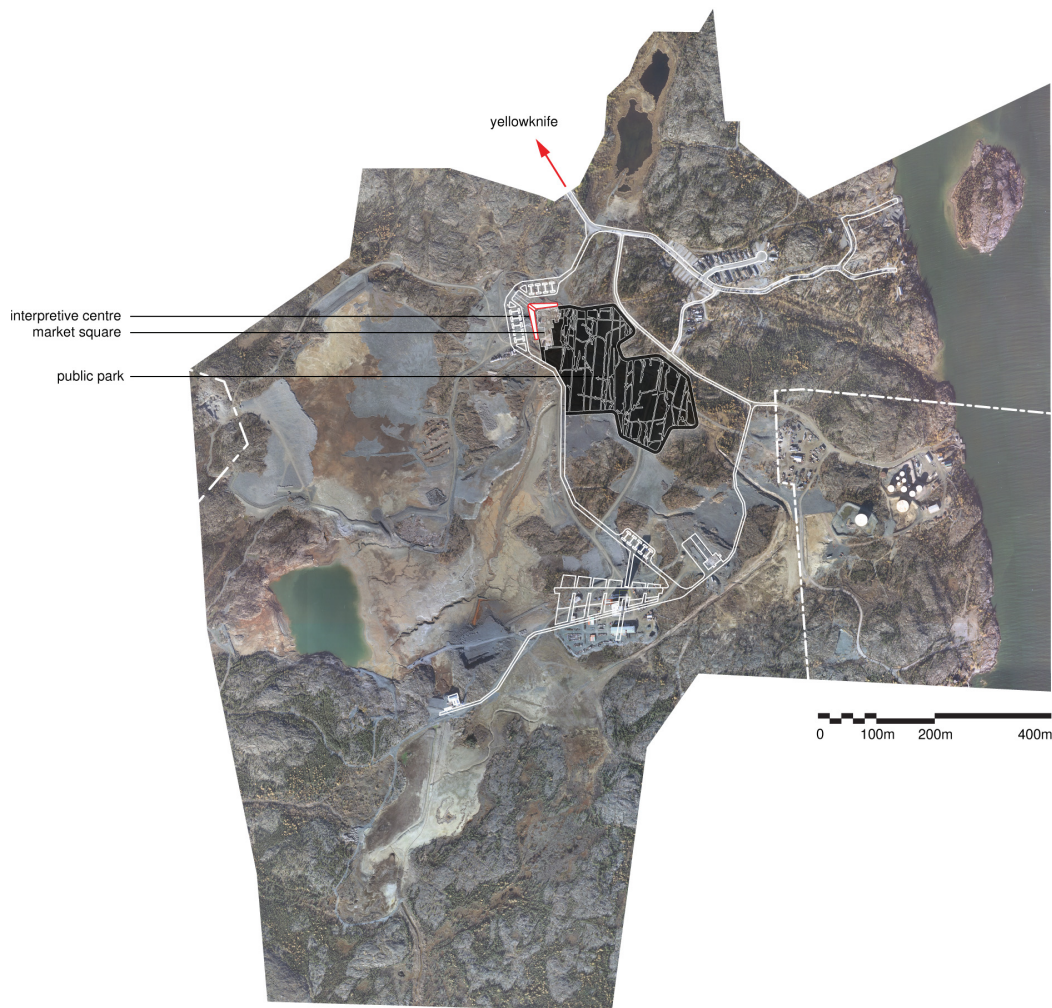
Perspective view of Robertson greenhouse complex and observation tower.



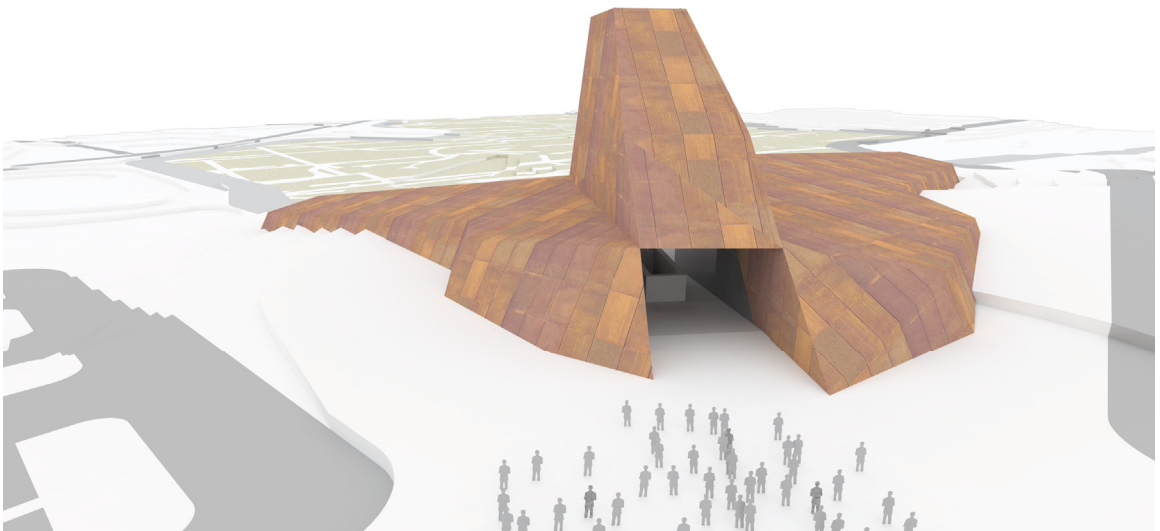
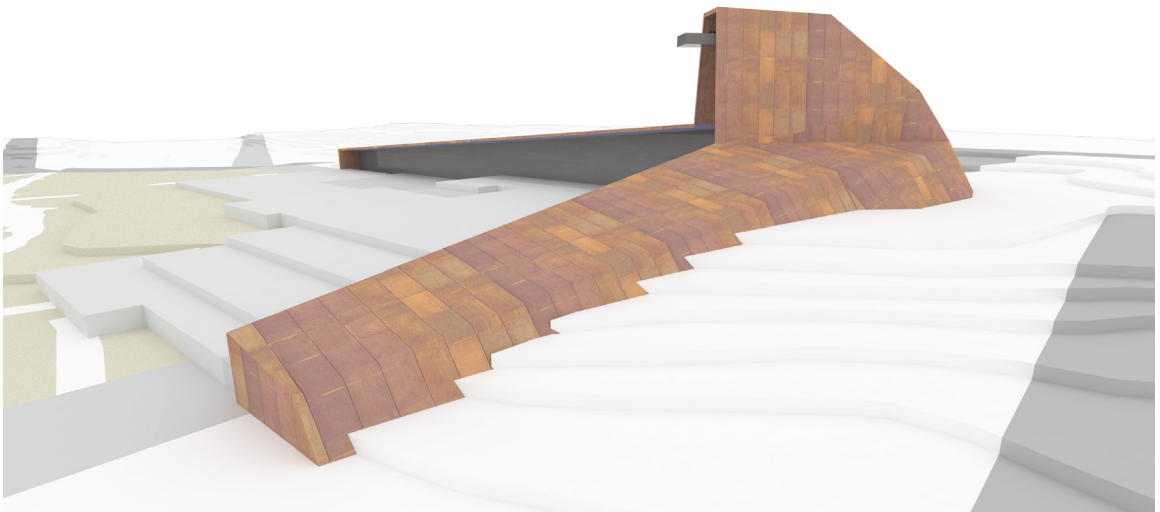
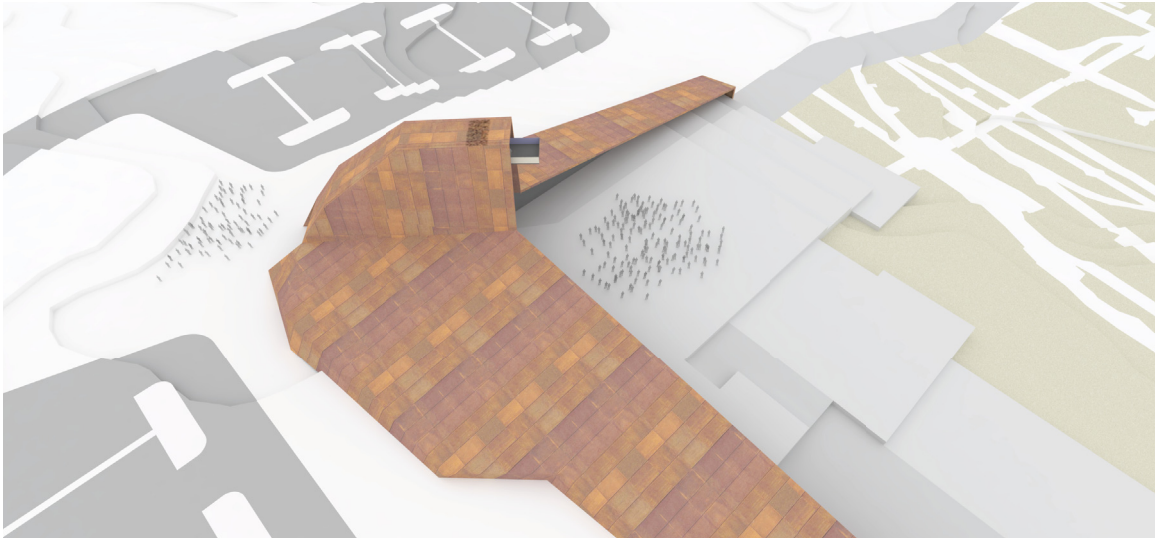
Physical model studies of the proposed solar chimney and vertical circulation shaft within the Robertson headframe.

Interpretation Centre

The interpretive centre is located at the entrance to the Con mine property. Sequentially, it will be the last of the interventions to be built, as its primary function will be to educate the community in regards to the history and current processes happening throughout the site. The building surrounds the existing foundation slab of the old C-1 headframe and processing mill, defining the extent and abstracted form of the razed buildings. The building presents a hard-edged steel exterior to the entry path and parking lot to the north-west, but opens with floor to ceiling glazing towards the courtyard and public park to its south-east. The public square utilizes the foundations labs of the old mill complex and programmatically, will facilitate a farmers market for the vegetables produced at the Robertson complex. The square also overlooks a proposed public park which is composed of pathways and trails in the configuration of the hidden tunnels hundreds of metres below the ground.



Site plan indicating location of interpretive centre and public park.



Massing studies of the interpretive centre and public square.



Perspective view of interpretive centre with public park beyond.

CHAPTER 3: CONCLUSION

Throughout Canadian history, mining centres have been notoriously predisposed to boom and bust scenarios. Physical and economic growth of these mining centres typically occurs at a seemingly unsustainable pace, and the aftermath of resource depletion or owner bankruptcy has a devastating impact on dependent communities and their inhabitants. In Canada's north, this reality is further compounded by the remoteness of these operations, made evident by countless ghost towns located throughout the Yukon and Northwest Territories. Although Yellowknife has managed to weather the economic storm of mine closure in the past, it still relies heavily on major diamond mining operations several hundred kilometres northeast of the city. What then, will become of Yellowknife, (or similar communities) when these resources are depleted?

This thesis exploration aims to answer that question, proposing a phased master plan that re-imagines the possibilities of an abandoned industrial landscape. In contrast to seasonally preserved mining towns where buildings and equipment are treated as artifact, the proposal for Con mine attempts to activate the site year-round in an economically sustainable way. With an abundance of geothermal heat, a processing plant that can easily be converted into a municipal waste treatment facility, and vast expanses of sculptable waste-rock, Con mine can contribute significantly to the long-term health and vitality of Yellowknife. The central premise of the thesis lies in the fact that considerable funding is granted to mine site remediation projects throughout the country on a yearly basis. Rather than treating the process as a band-aid solution, remediation practices can be tailored to promote long-term inhabitation of the site. By utilizing phytoremediation strategies, remediation infrastructure can be easily converted to large-scale agricultural practices once cleansing of the site is complete, thereby benefiting remote communities in perpetuity.

In summation, the proposal aims to re-activate Yellowknife's legendary mining history by adapting existing infrastructures and demarcating latent traces throughout the Con mine property. By revealing former processes of the mine in this manner, the proposal contributes significantly to the long-term sustainability of the city, preserving its rich cultural history for future generations in the process.

APPENDIX 1: LITERATURE REVIEW

For the purposes of this thesis exploration, the literature review will be divided into three separate sections dealing with various subject matter. Though these components will be inexplicably linked by the subsequent proposal, little has been written concerning the relationship between them all. The first of these subjects is "landscape", focusing on issues pertaining to contamination, remediation, recovery, and perception. The second deals with the underground, mainly the history of humankind's perception of the this realm, covering spirituality, religion, mining technology, and science fiction. Lastly, this review will cover what little research has been conducted on northern architecture and design, including issues of local vernaculars, building science, climate considerations and material culture.

Landscape Remediation

The following books are included in this review:

1. *Reclaiming the American West* by Alan Berger
2. *Drosscape: Wasting Land in Urban America* by Alan Berger
3. *Recovering Landscape: Essays in Contemporary Landscape Architecture* by James Corner
4. *Landscape: Pattern, Perception, and Process* by Simon Bell

Alan Berger is a tenured associate professor of urban design and landscape architecture at the Massachusetts Institute of Technology. He founded and directs the P-REX (Project for Reclamation Excellence) multidisciplinary research team that focuses on the design and reuse of waste landscapes worldwide. Berger's work is focused on the link between our consumption of natural resources and the resultant waste and destruction of landscape associated with it, principally how sites are cleanses, valued, and designed for adaptive reuse at local and regional scales. He studied at the University of Pennsylvania, winning numerous awards upon his graduation, and was licensed as a landscape architect in 1992. In addition to his academic work, Berger serves as a design consultant to the USEPA on Brownfield and Superfund site revitalization projects. His publications have

direct pertinence to the thesis exploration, particularly his first major work titled *Reclaiming the American West*. In it, Berger uses low-angle aerial photography, maps, and incredibly beautiful information graphics to exhibit the state of the American Mid-West landscape with its 200,000 abandoned mine sites covering hundreds of thousands of acres. Contrary to what I initially assumed, the book does not have a political agenda nor is it an editorial comment or protest, it is simply an observation, forcing one to "open their eyes and look", to think about the transformations occurring. He appears to be fascinated with the surreal, haunting, yet beautiful imagery of these vast manufactured landscapes. Although the book continually refers to these surreal landscapes as "post-technological", I believe they can be more accurately described as "post-industrial". Technically, *Reclaiming the American West* draws on the 1977 Surface Mining Control and Reclamation Act, documenting the process of reclamation that mining companies are legislated to undergo once a mine is decommissioned. His work covers the historical background and policies of mining and reclamation, presenting the challenges of working with massive, incredibly toxic sites. The resultant processes expose many physical, philosophical, technological, environmental, political, regulatory, and ethical issues and dilemmas. Further to these technical processes, Berger hints at the fact that this supports the notion that the American West continues spawning ideas of expansion and discovery, exploitation and reconnaissance, and lastly, technological domination and transformation. Essentially, these issues relate to the "technological sublime", a theme running throughout Berger's study of the possibilities and dangers of converting altered sites back to a "naturalized" state. Berger presents several key questions upon the text's conclusion, to which no answers are given, merely thoughts that the reader is left to ponder. They include the following; "Should reclaimed landscapes be made more or less productive than their pre-existing land uses?" "What are the prospective opportunities for altered landscapes to create new types and forms of landscape occupation?" "Do methods of representation play roles in the cultural judgments of altered landscapes?" These questions are pointed, yet open-ended, and encourage the reader to dwell on the possibilities presented. One section of the book I found particularly interesting was in Frederick Turner's introduction. In it, the author presents a fascinating perspective that much of what we usually count as natural is really the scar of an earlier desecration, with the further implication that perhaps it was always desecrated, and that the "sacred" landscape is actually the landscape that has learned to live with

ritual pollutions and is able to cleanse itself. Alan Berger's follow-up book published four years later is titled *Drosscape: Wasting Land in Urban America*. Like his earlier work, this text presents the raw materials for a new system of valuing the landscape, however instead of focusing on areas of natural resource extraction, Berger studies the wasted landscapes within American urban areas. Though the subject is tackled quite broadly, the book focuses on 10 urban centres throughout the US, combining geo-spatial technology with US census data to create a new "spatio-economic composite reading of each city's special waste geography." The term "drosscape" is coined by Berger, based on his root word "dross", referring to waste. By this definition, a drosscape is a waste site that has been "scaped", or resurfaced and reprogrammed for adaptive re-use. He further defines the process behind the book as being "a sort of scavenging of the regional urbanized surface for interstitial landscape remains." He further explains that these interstitial spaces are often forgotten by designers and architects, following outside of their typical scripted programming tasks. Though much of the book is analysis, Berger presents basic design strategies for working with drosscapes in it's finale. Berger describes a "bottom up advocacy process, suggesting a move away from the heroic, modernist, master-planner toward the designer who engenders inventiveness, entrepreneurialism, and long-term environmental recovery." Interestingly, the idea for Berger's second book was propagated during the aerial photography sortie's of the first. Due to the fact most mine sites are in remote locations throughout the West, Berger spent countless hours flying in and out of municipal airports, often located at the periphery of urban centres. It is typically in this threshold between the deindustrialized centre and the rapidly urbanizing periphery, or suburb, that drosscapes appear. Berger was fascinated by these sites during his many journeys to photograph mine sites from the air, hence the formulation of his companion for *Reclaiming the American West*. Though Berger's work is among the most relevant to mine, a distinct difference lies in the fact that mine sites and urban centres are often situated hundreds of miles apart in the south-western United States. What is most unique about the Yellowknife scenario, is that these two landscapes are immediately adjacent to one another, one tremendously influencing the other, and vice-versa. I hope to draw from Berger's work, combining the ideas of post-mine occupation and urban wasteland renewal.

Mining and the Underground

The following books are included in this review:

1. *Notes on the Underground* by Rosalind Williams
2. *Life Below the Ground: A Study of the Subterranean in Literature & History* by W. Lesser
3. *Living Underground: A History of Cave and Cliff Dwelling* by David Kempe
4. *A Concise History of Mining* by Cedric Errol Gregory
5. *Mining Explained* by Thomas Brockelbank & James Whyte

The original aforementioned essays by Wendy Lesser and Rosalind Williams were published three years apart, respectively. Though both deal heavily with historical literature, William's text encompasses a far broader perspective on the underground. *Life Below the Ground* on the other hand, is a comprehensive examination of largely fictitious works written between 1789 and 1958 that deal with aspects of the subterranean. Lesser's book is divided into three parts, the first of which deals with thriller novels, often depicting the underworld as a place of corruption and lawlessness. A second chapter features novels that described the advancement of science in relation to subterranean discoveries such as Jules Verne's classic novel *Journey to the Centre of the Earth*. Lastly, children's literature is featured as a classic genre that incorporates the underground, the most famous of which includes Lewis Carroll's *Alice in Wonderland*. As opposed to adult literature which usually depicts the underworld as either forbidden or perilous, children's literature often depicts it this realm as a place of personal growth, from which characters emerge "renewed". These various constructs of the underground, as manifested in literature, provide a telling glimpse into societies evolving cultural perceptions over the last two centuries.

Notes on the Underground, though heavily influenced by *Life Below the Ground*, was the result of a talk concerning "imaginary worlds" given by the author in 1986 at the annual meeting of the Society for the History of Technology. Response to the talk was so overwhelming that Rosalind Williams, Professor of history of science and technology at Massachusetts Institute of Technology, decided to publish a book on the subject several years later in 1990. The goal of the project was to explore the psychological, social, and

political implications of living in a predominantly technological environment, to which the underground is the most extreme example. Rosalind challenges the reader, asking “what are the consequences of human beings living in an environment that is predominantly built rather than given?” In addition to the underground being a technological environment however, it is also documented as a mental landscape, (in the form of myth) a social terrain (in the form of the narrative), and an ideological map. This view subsequently structures the book into sections dealing with myth, (mainly ancient), narratives, (drawing on the literary research of Lesser) and ideology, including modern perspectives on technology and the future. To begin, the book describes fascinating early human theologies as they pertained to the underground. For example, prior to the renaissance and ages of exploration, the universe was assumed to be a vertical cosmos, and journeys to the underworld were inherently sacred; regions of water, fire, or a counter-heaven, as influenced by the stars dipping below the horizon in the evening. These stories were typically oral and sacred by nature. During this time period, Earth was believed to be a nurturing mother, and minerals were living organisms that grew and gestated in the warm, dark, womb-like matrices of the subterranean world. From antiquity to the 17th century, it was thought that mineral veins were branches of an immense trunk extending to the centre of the earth – minerals could re-grow and mines could refill themselves. Mining was therefore a dubious act, akin to rape, violence, and mutilation, and as a result, the task of extracting precious minerals and metals was usually conducted by slaves, criminals, and prisoners of war. In essence, mining was a form of punishment, further enforcing the ideology of the time that the underworld was a place of sorrow, pain, and ultimately death. For example, religious ceremonies and rituals were often conducted prior to the commencement of mining in order to appease Mother Earth for the wrong being committed. Between 1500 and 1700 AD however, this perspective shifted to a written, secular tradition accounting journeys to the underworld; a place of exploration and adventure. This shift can be credited to the likes of Georgius Agricola who wrote *De Re Metallica* in 1556, a public retort to the ethical objections of mining. At about the same time in history, major advancement was being made in the fields of geology and anthropology, mainly the emergence of the belief in "deep time"; the concept that digging down into the earth's stratified cosmos reveals information about our past. This concept helped grow the human imagination, further encouraged by the major advancements throughout the scientific and industrial revolutions of the 18th and

19th centuries. As a result, fictional narratives about living underground became increasingly popular, championed by authors such as H.G. Wells, Jules Verne, Frank Baum, and E.M. Forster. It can be argued that this trend occurred because for the first time in history, technology made living in this inhospitable environment possible. To further expand on this though, Williams enlists the help of Lewis Mumford, mainly his seminal 1934 book titled *Technics and Civilization* in which the machine age is studied in a cultural context. Interestingly, much of the text is focused on the mine, as Mumford believes it was a significant promoter of early industrialization. In it, he argues that the mine was in fact the first completely inorganic and inedible environment created and lived in by man. It was a place of continuous day and night production, and a "shapeless world: a leaden landscape of perpetual winter." Mumford continues by arguing the fundamental principle of beauty is organismism, thus the underground environment devoid of life and form, is inherently hideous. Williams continues the story by discussing the industrial revolution in further detail, describing numerous major excavation projects and their metaphoric connection to the undermining of society and the abstraction of civilizations' progress. She explains how societies witnessing these projects often struggled with perception, viewing them as both cruelly disruptive to nature and wonderfully heroic for the human race. Throughout the 18th, 19th, and 20th centuries, the subterranean world became a common sight for Europeans, as new technological infrastructures were installed beneath city streets in order to support a new societal structure. By the 21st century, the underground shelter had become the new emblem of humanities ancient and honorable quest for truth, power, beauty, and security through technological achievement. Williams thus finishes the book with an in depth look at the dangers of an increasingly technological environment and its ability to become inhospitable to human life all-together. She refers to this as a new "environmental consciousness."

In 2008, a subsequent reprint of the book was issued, featuring a very interesting addition by the author discussing the evolution of her thoughts on the subject since the book was originally written 18 years earlier. In it, Rosalind Williams features an interesting reflection on the process of writing *Notes on the Underground*. She states, "In the beginning, I had a straightforward definition: it was a mine, or a pit dug into the earth, or a subway, or a tunnel. As I was writing, however, I realized that one of the most interesting aspects of the world that humans have constructed on the surface of the earth is the creation of mock or

artificial underworlds in the sense of places that are meant to exclude organic life, where everything is meant to be a creation of human artifice rather than given from the larger universe. A shopping mall, for example, can serve as a model of a technological environment (a term Mumford didn't use, but that I find useful) even if it isn't literally underground. But most of all I try to expand the concept of the underground from the earth to the sky. I end the book by comparing environmental consciousness with subterranean consciousness, pointing out that the real surface of the planet is the upper edge of the atmosphere. Our earthly home is everything below the frigid and uninhabitable realm of outer space, and so in a sense we have always lived below the surface of the planet, in a closed, finite environment."

To balance these highly theoretical outlooks on the underworld, I decided to study David Kempe's book on the history of human cave and cliff dwelling to better understand the actually underground spaces inhabited by humans throughout history. Though I looked at other texts concerning specific subterranean environments of the world, such as those below Rome, Paris, London, Toronto and New York, I found Kempe's book to be a comprehensive study of a wide variety of dwellings throughout humankind's known history. Interestingly, Kempe claims little work has been done on the subject prior to his, the first being William Boyd Dawkin's famous book *Cave Hunting* published in 1874. Subsequently, Reverend S. Baring-Gould published *Cliff Castles and Cave Dwellings of Europe* and J Walter Fewkes presented a presidential address to the Anthropological Society of Washington on the same subject, in 1910 and 1911 respectively. *Subterranea Britannica*, a journal established in 1974 also contributed a great deal to the subject matter to date. Kempe's work is also based on a paper written by J.S. Kopper in 1977 titled *Troglodytism* for the 6th International Spelaeological Conference in Prague. (Spelaeology refers to the current study of caves, originating from the Greek words for cave and study) To begin his text, Kempe explains that although cave dwelling was quite practical during the Stone Age, he is primarily interested in those peoples who opted for the Troglodytic lifestyle afterwards, through the Dark and Middle Ages and right up to the present day. The book therefore attempts to recount the history of as many underground dwellers as possible, with an emphasis on diversity, some cultures having no choice but to cave-dwell, others finding it eminently sensible. One of the earliest known written references to underground dwelling can be found in the Bible's book of Isaiah, as Isaiah himself prophesied "They

shall go into the holes of the rocks, and into the caves of the earth, for fear of the Lord, and for the glory of His majesty.” Kempe goes on to explain that this passage correlates roughly with the period in history in which troglodytism is believed to have been at its peak, sometime between 200-300 AD. The beginnings of this tradition go back much further, as caves are believed to have been the first habitation of man. The first man-made cave is dated at 3000 BC however, made evident by excavations at Gezer in Palestine. Kempe continues the timeline right up until the book's publishing date, (1988) when he claims 25,000 people were still living in cave dwellings in France. Although cave dwellings are not directly applicable to the mining subject investigated in this thesis, the last two sections of *Living Underground* are perhaps most relevant, with the chapter on tunneling referring to several interesting mine sites around the world. For example, Coober Pedy is an opal mining town in Australia's outback in which the miners themselves have carved an entire city, including restaurants, churches, and homes out of the ground in which they live. Another amazing example is Beer mine near Seaton in England, a quarry worked for centuries by subsequent populations; first the Romans, then the Saxons, later the Normans, and lastly the English until the end of WWII. Concerning underground infrastructures built for the purposes of war, Kempe describes the many abandoned bunkers and tunnels from the second world war that were converted for use as mushroom and rhubarb farms. In regards to the future, Kempe believes that the cave dwelling could be the future of English “yuppy” culture. Based on the bourgeois in France and the increasing popularity of underground wine cellars and cave restaurants, the English upper-class may one day dig extensions beneath their homes. Tourism surrounding underground space and cave dwellings is increasing around the world, and many military bunkers and abandoned mines are now being opened for tourism potential.

APPENDIX 2: PRECEDENTS

The following case study analysis features contextually relevant projects from around the world, varying greatly in scale, complexity, and program. Due to the fact the proposed project is quite unique in both its programmatic and geographical context, it was difficult to find completed work of a similar nature elsewhere in the world. Therefore, the selected projects have been categorized according to their particular theme or typology. They include;

1. Mine Site Remediation: Landscape Design
2. Mine Site Remediation: Observation
3. Mine Site Remediation: Interpretation
4. Mining Infrastructure: Alternative Uses
5. Agricultural Infrastructure: Northern Food Networks

The first section of the analysis deals purely with remediated minescapes, devoid of architecture for the most part. To elaborate, remote mine sites undergoing remediation are typically "designed" by engineers and scientists, treated as a purely scientific undertaking to return the landscape to its "natural" state or pre-industrial condition. Due to increasing global populations however, many of these once-remote sites around the world now border sprawling suburban development. As such, it is becoming increasingly common for mining companies to engage landscape architects and artists to participate in the remediation process. Spurred by increasingly negative media coverage and environmental advocacy groups, these partnerships are helping transform many mine sites in the Western world into usable public space. Secondly, the analysis covers a range of related and exemplary architectural works including mining museums, interpretive centres, observation towers, and redevelopment master plans. It is interesting to note that the majority of these examples come from Germany, where the federal government is currently investing billions of dollars in the regeneration of industrial centres that underwent considerable decline in recent decades. The Ruhr valley in particular is of considerable interest due to its rich mining legacy. Related to this, the study also features several examples of re-programmed mining infrastructure. Lastly, of programmatic relevance, the recent Prix-de-Rome proposal concerning northern food networks will be explored.

Johnson Pit #30

Location: Kent, Washington

Designer: Robert Morris

Relevance: Mine site remediation / Land art



(from Cultural Services Agency for King County, Washington / photographs by Spike Mafford)

As part of a 1979 symposium in King County Washington, artists were commissioned to “rehabilitate” lands scarred by historic surface mining and municipal waste disposal, perhaps the most successful of which was imagined by American artist Robert Morris. Morris transformed an abandoned 3.7 acre hillside quarry last mined in the 1940’s, into a contemplative landscape of stepped concentric terraces. Resembling a carefully carved crater, the public park overlooked the scenic Green River below. The eroded, overgrown slopes of the quarry were first stripped of all vegetation, and then cut and fill excavation was employed to transform the quarry into a terraced landscape delineated with sharp-edged contours. The entire earthwork was then covered with soil and planted with native rye grass, kept trim by with the use of neighboring goat herds. Stairs consisting of old railroad ties helped visitors navigate the steep slope, and a “ghost forest” of creosote-preserved stumps were positioned to demarcate the boundary of the tree line that once traversed the site. What is perhaps most interesting about this project today is the way in which it’s immediate cultural context has evolved over time. In 1979 the remote quarry was quite distant from neighbouring communities, the journey to get there envisioned as a pilgrimage for visitors. Morris felt it immensely important to maintain the manufactured quality of the landscape, so that it would continue to contrast with its natural surrounding over time.

McLeod Tailings

Location: Geraldton, Ontario

Designer: Martha Schwartz Partners Ltd

Relevance: Mine site remediation / Land art



(photographs from Martha Schwartz Partners)

This project was envisioned to be more than just a remediation or a powerful visual feature. By heavily programming the site with recreational trails, interpretive displays about its history, a golf course, and a mining museum, the site would soon become a destination rather than a gateway. Perhaps the most interesting components of the project were the many limitations and constraints experienced by the design team. Principally, the final form of the earthwork was limited by a number of important factors, the first of which included the budgetary constraint of maintaining a maximum earth-moving capacity of 150,000 cubic metres. Secondly, the forms of the earthwork were limited by available excavation equipment along with their respective turning radii and load capacities. To make matters more difficult, a leach resistant pad beneath the heap pile coupled with higher concentrations of arsenic at further depths limited the amount of excavation that could be performed. Any additional height added to the earthwork was also limited by a restriction of five metres as to not impeded sightlines for nearby vehicular traffic. Lastly, standing water and acid rock drainage prevention were major design elements employed in the final design. Altogether, these parameters made for a very complex resolution. Upon completion of the earth-moving, the disturbed areas were capped with twenty to forty centimetres of topsoil and re-vegetated with native grasses. Species that were golden in colour were specified as a subtle reference to the mineral once extracted from beneath their roots.

Landschaftspark Duisburg Nord

Location: Duisburg, Germany

Designer: Latz + Partner

Relevance: Mine site remediation / Cultural park



(from Latz and Partner / photographs by Christa Panick and Michael Latz)

Duisburg Nord is a “cultural park” inhabiting a 600 acre site that once operated as a major coal mine and steel plant. The master plan was heavily influenced by the idea that if the realms of nature and industry were combined, the experience of the place would be far richer than if traditional notions of “remediation” were employed. At the time of its design, many landscape architects, environmentalists, and conservationists, heavily criticized the designers for not eliminating the industrial relics and approaching issues of remediation in a more traditional sense. Instead, lead architect Peter Latz was fascinated by the sites industrial ruins, believing they were not only important cultural artifacts, but incredible structures in their own right. Due to heavy contamination however, this approach entailed the design of complex systems to deal with water on site. The entire property was analyzed for soil and water contamination, and strategies were determined based on the toxicity level of a particular region. Seriously hazardous soil was removed from the site entirely, and moderately contaminated soil was capped with topsoil and re-vegetated with plant species known to phytoremediate heavy metals and arsenic present in the ground. For all remaining portions of the landscape, pioneer species of birch and poplar, which are also known to bioaccumulate heavy metals, were allowed to return naturally. Old settling ponds and wastewater canals were also transformed into wetlands, filtration ponds, and reflecting pools.

Zollverein Industrial Complex

Location: Essen, Germany

Designers: OMA, Norman Foster, SANAA

Relevance: Re-programmed mining infrastructure



(from Ruhr Museum / photographs by Brigidia Gonzalez)

Throughout much of the 20th century, Zeche Zollverein was one of the largest and most modern coal mining facilities in the world. Encompassing over 100 hectares, and having employed over 5,000 Ruhr Valley miners in its hey-day, the complex, still largely intact, is considered by many Germans a shrine to industrial culture. Built in the Bauhaus tradition throughout the 1930's, the complex is considered by many to be the most beautiful collection of colliery buildings in the world. Architects Fritz Schupp and Martic Kremmer embraced functionality and flexibility, fusing buildings and machines into inseparable entities. Closed and abandoned in 1986, the site received considerable attention as to its future, and a master plan by Rem Koolhaas of OMA in 2001 resulted in the UNESCO World Heritage designation the site still obtains. Principally, the proposal enforced the historical memory of the Ruhr area, while transforming into an innovative "creative centre." Today, the site is envisioned as a cultural terrain of museums, restaurants, design studios, creative businesses, and venues for conferences, recreation, exhibition, dance, and music. Visitors follow a series of giant canary sculptures from a nearby rail station into the park, at which point an encircling path or "coal route" follows the mining sequence from extraction and processing, to loading and shipping. A skating rink, swimming pool, ferris wheel, and series of recreational trails and pavilions activate the exterior components of the complex. In 2010, over a million visitors entered the grounds, and currently 40 million euros are being invested in new buildings and repairs.

Don Valley Brickworks

Location: Toronto, Ontario

Designers: DSAI, DTAH & ERA

Relevance: Remediated quarry site / Cultural park



(drawings from Diamond & Schmitt Architects)

The Evergreen Brickworks project in Toronto is an excellent example of the restoration and re-appropriation of a former industrial building complex on a contaminated site. The project, near completion, will be Canada's first large-scale community environmental centre, and entailed the renovation of existing buildings, and the addition of a new building totalling more than 9,300 m². The project includes a visitor's welcome centre, event spaces, children's programming facilities, NGO administrative offices and work spaces, a museum, farmer's market pavilion, retail space, restaurant, culinary institute, and a public skating facility. The \$35 million project will be built to LEED platinum standards, and will utilize green roofs, solar chimneys, rainwater harvesting, digital lighting control systems, and natural gas-fired high efficiency boilers. The 4.9 hectare site is susceptible to heavy annual flooding, so storm water management ponds were carefully constructed to deal with this issue. Furthermore, vegetated greenways carve carefully through the site to help navigate and cleanse storm water run-off before flowing into the adjacent Don River. In the winter months, a heat recovery system will help ensure the skating rink remains frozen, and in so doing, will heat an adjacent space.

Jøssingfjord Mining Museum

Location: Jøssingfjord, Norway

Designer: HultmanMagnusson

Relevance: Historical interpretation / climate



(from ArchDaily / drawings by HultmanMagnusson)

Jøssingfjord is a remote, scenic fjord located within the municipality of Sokndal in southwestern Norway, famous for its long history of mining. The site is situated in a valley straddled between two mountains of titanium powder mined for its use as a white colour pigment. Hultmanmagnusson's building was the winning proposal in a design competition for a new mining museum to be placed on the property. Programmatically, the brief included an area for the exhibition of historical, geological, and technological information, in addition to a cafe and temporary exhibition space. The building is envisioned as a central focal point in a new culturally focused "geo-park" landscape. Unlike the other competition entries, this design enforces the linear qualities of the spectacular fjord, and by acting as an extension of an existing power plant structure, further strengthens the existing qualities of the site. In terms of materiality, the exterior envelope is comprised of a gabion wall structure stacked with local stone. This is reflected in the proposals title, "Varde", a vernacular Norwegian term for a man-made pile of stones. Openings in this envelope of stone are carefully articulated to create interesting direct and indirect relationships between the program and the spectacular landscape outside, revealing and concealing. Exhibition spaces are organized vertically around a central mine elevator, with ramps acting as meandering paths, connecting and weaving all levels in the process. Visitors begin their journey on the highest level, ending at a cafe on the lowest level with a dramatic view of the ocean beyond.

German Mining Museum

Location: Bochum, Germany

Designer: Benthem Crouwel Architekten

Relevance: Historical interpretation



(from ArchDaily / drawing by Benthem Crouwel and photographs by Udo Kowalski)

The Deutsches Bergbau-Museum, as it is called in German, is situated in the city of Bochum in the heart of the Ruhr Valley. Utilizing a series of abandoned mine buildings, the main museum complex consists of over 12,000m² of exhibition space and receives over 400,000 visitors annually. The project shown here is a recent 1,800m² addition to the museum, three levels in height and freestanding from historic buildings, though linked by two bridges on its upper two levels. Programmatically, the building contains temporary exhibition space, and an area for the permanent collection dedicated to Saint Barbara, the patron saint of mining. Aesthetically the building draws from the symbolism of the underground mine quite literally. The building is envisioned as a cube of coal extracted from the ground, exposing the sectional quality of the mines strata, tunnel, and shafts. The facade is course and very dark in colour, mimicking the qualities of the coal found below. The tunnels and shaft are reflected in the glazed circulation route that winds its way around the exterior of the building. Lighting in these “voids” transitions from white, to orange, and finally to red, reflecting the temperature gradient experienced while descending into the earth at great depths. A generous meandering skylight over the otherwise enclosed third floor level symbolizes a crack in the earth, exposing the intense contrast of the daylight above.

Legacy Park Environmental Education Centre

Location: Calgary, Alberta

Designer: Simpson Roberts Architecture

Relevance: Remediation interpretation



(from Wood WORKS! / photographs by Steve Nagy)

The Ralph Klein Legacy Park Environmental Education Centre is located on the outskirts of Calgary in a newly created constructed wetland aimed at alleviating the city's untreated stormwater run-off. Initially, the wetland was a project undertaken by the Water Resources department in the 1990's, though subsequent funding from a parks improvement fund in 2003 interested the Parks department in a joint venture vision for the area. The 230 hectare five-cell wetland treats water from a 6,000 hectare surrounding area, and is currently the largest in Canada. With the involvement of the Parks department, the site now includes a 30 hectare recreational area anchored by an environmental education centre. The 1,930m², \$14.4M facility includes flexible educational programming, multi-purpose space for corporate functions, an artist-in-residence studio, administrative offices, and offices for the non-for-profit Ducks Unlimited. The educational spaces are designed to be as flexible as possible to allow for evolved uses over time, and many are designed to open up to the exterior if weather permits. The part of the building, as described by the architects, is a jungle gym that can be explored from all angles. The building emerges from a grassy mound, clad in heavy gabion baskets, and transitions to a light-framed structure that gently perches over marshland. Catwalks are suspended beneath the building at its end, allowing users to engage with the wetland at an intimate distance.

Svalbard Science Centre

Location: Svalbard, Norway

Designer: Jarmund / Vigsnaes Architects MNAL

Relevance: Environmental interpretation / climate



(from ArchDaily / drawing by JVA Architects and photographs by Nils Petter Dale)

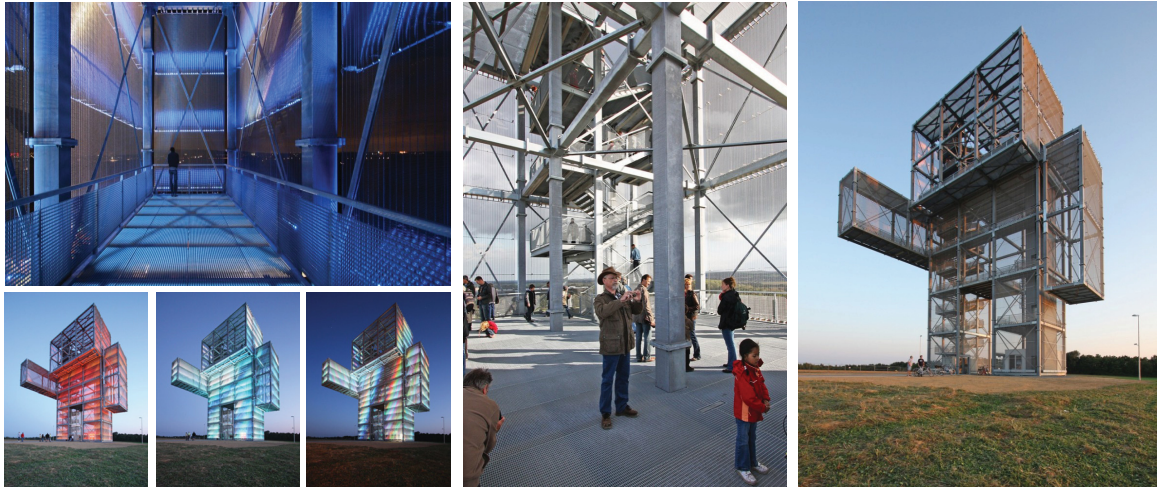
The Svalbard Science Centre is located on a remote Norwegian archipelago in the arctic ocean. The building is the result of an architectural competition and entailed a large 9,000m² addition to an existing university research facility. As a result, the new introverted campus became the largest building on the system of islands and incorporated additional program elements such as facilities for the Svalbard museum. Formally, the buildings massing was entirely driven by exhaustive studies relating to wind action and resultant snow accumulation. By carefully siting the building and deliberately accelerating wind beneath and around the envelope, snow scouring prevents accumulation in front of entries, principal window openings, and mechanical components. Flexibility was also a major design consideration, both climatically and programmatically. Due to its remoteness, the building utilizes an almost entirely wooden structure so that future alterations, renovations, and additions can be made easily on-site with limited skill labour involved. This wooden structure and heavily clad wooden interior also act as further insulation for the building, eliminating the thermal breaks associated with concrete and steel. The building also utilizes a copper clad exterior skin which remains malleable and workable at extremely cold temperatures, thus allowing for a lengthened construction season. Lastly, the building is raised off the ground on steel piles in order to maintain permafrost conditions below.

Indemann Observation Tower

Location: Inden, Germany

Designer: Maurer United Architects

Relevance: Remediation observation



(from ArchDaily / photographs by Maurer United Architects)

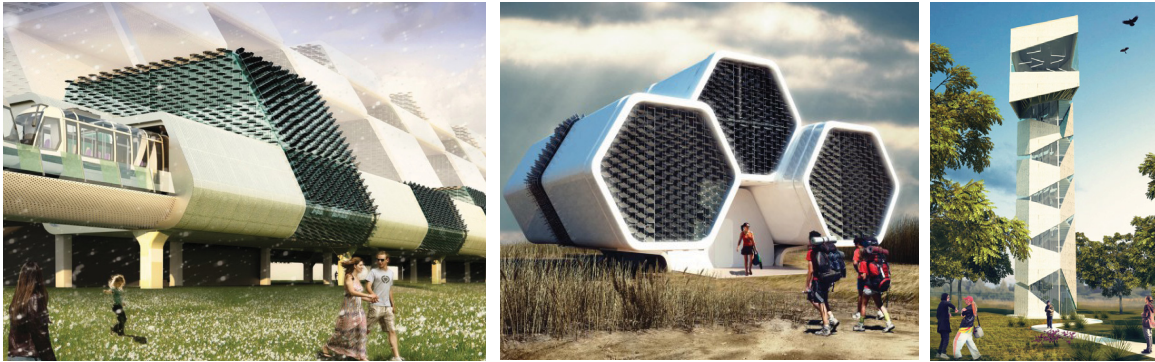
Within the municipality of Inden, Germany, large scale open-pit coal mining operations have recently displaced several entire villages. The expanding 4,500 hectare site is immediately adjacent to the city, and is bordered on one side by the A4 expressway, one of Europe's busiest transportation networks. The mine will continue operating until 2030, at which point the heavily manipulated landscape will transform into a recreational park anchored by a large marine environment to be programmed for various water sports. In 2004, the municipality decided to erect a monument on the site, a symbol of the structural-political evolutions that will occur on the site as heavy industry makes way for a media-based economy. With this symbolism in mind, the architects proposed a 36m tall observation tower in the form of a robot nicknamed the "Indemann." The robot acts as a sentinel for the digital age, and for environmental stewards, observing the evolving landscape and its responsible remediation over the coming decades, pointing towards the future with its outstretched arm. The tower's skin of semitransparent stainless steel mesh provides remarkable transparency during the day, and a surface for digital projections at night. The nearly 1,470m² of mesh are also embedded with over 40,000 LED lights, allowing for incredible computer-controlled light shows throughout the evening. The building has become a landmark for the Maas-Rhine region, attracting over 10,000 visitors at its opening. The structure has been quoted as uniting Dutch design with German efficiency.

Chernobyl Tourism Redevelopment Plan

Location: Chernobyl, Ukraine

Designer: ZA Architects

Relevance: Remediation / Observation



(from ArchDaily / drawings by ZA Architects)

The Chernobyl Tourism Redevelopment Plan is a theoretical proposal focused on the exclusion zone surrounding the radioactive Chernobyl disaster site. This is an area of low to no radiation what-so-ever, however negative and inaccurate perceptions have resulted in the abandonment of the area. Apart from a few studying scientists and elderly residents who refuse to leave the area, human absence has resulted in an incredible abundance of flora and fauna in the zone. For example, a rare horse breed at the brink of extinction during the nuclear disaster, is currently thriving with a growing population of 40. Curious tourists have been visiting the site in increased numbers recently however, so ZA Architects is proposing a sustainable tourism network to take advantage of this trend, and help stimulate responsible redevelopment of the area surrounding Chernobyl. The plan is anchored by a mono-rail network with 4 stations that will allow tourists to safely experience more contaminated portions of the site. The rail is lifted off the ground, allowing for minimal disturbance, and the uninterrupted movement of animals below. Upon entering the stations, trains pass through a decontamination “wash.” The proposal also incorporates look-out towers, a wind farm to stimulate a sustainable energy market, and residential “pods” for the overnight accommodation of tourists. The pods are particularly interesting as they deal with inhabiting contaminated areas. The modular, prefabricated units have interchangeable parts, and metal window-screening elements to reflect radiation from both the environment and the sun.

Roman Quarry

Location: St. Margarethen, Austria

Designer: AllesWirdGut Architektur

Relevance: Re-programmed mining infrastructure



(from ArchDaily / photographs by Hertha Hurnaus)

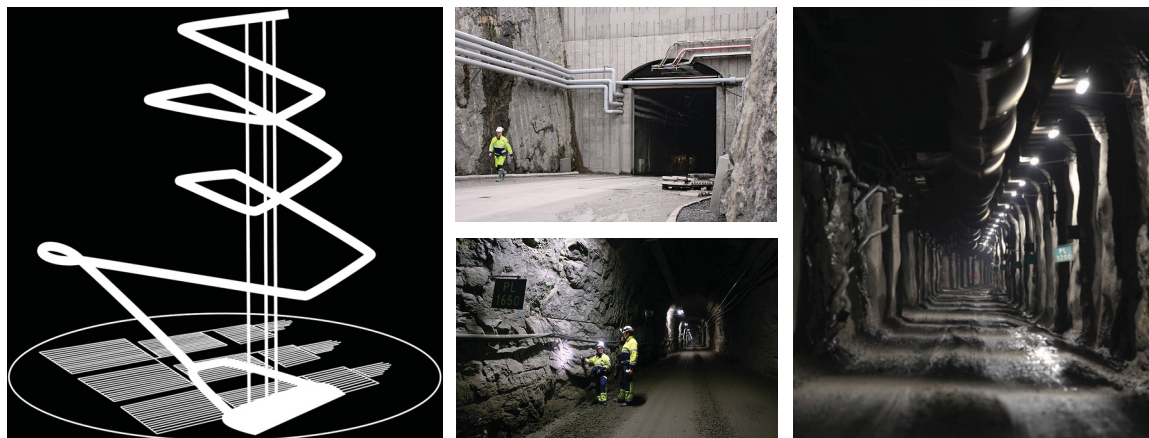
This project is an example of innovative programming within an abandoned mine site. Originally a Roman rock quarry, the landscape has been utilized in recent decades for outdoor performances, mainly opera and passion plays which benefit from the incredible acoustics qualities of the rock walls. In 2006, construction began on a series of ticket booths, administrative buildings, and amenity structures linked by a dramatic circulation path that weaves it's way through the site, up and over jagged rock outcropping into deep open-pit quarries below. The ramp itself is the centrepiece of the intervention, inspired by the actual mining methods of Roman quarriers. The ramp sits lightly on the landscape, lifted gently off the ground by steel columns, and it's Corten steel cladding contrasts dramatically with the light stone of the quarry. The new circulation path aims to heighten the dramatic effect of entering the performance spaces, replacing the old direct circulation route that was merely a functional access way.

Onkalo Nuclear Waste Repository

Location: Eurajoki, Finland

Designer: Posiva Oy

Relevance: Adaptable mining infrastructure / climate



(drawing and photographs from Posiva Oy)

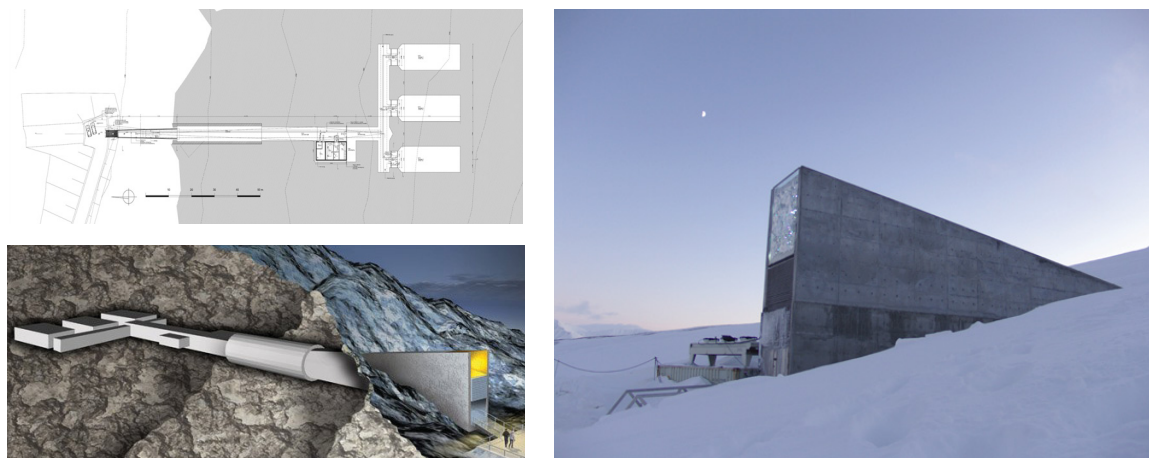
Onkalo is an awe-inspiring facility under construction in a remote area of Finland, 300 kilometres northwest of Helsinki. The result of the country's 1994 Nuclear Energy Act, the \$4.1 billion facility will be the first permanent nuclear-waste repository in the world. Situated near the Olkiluoto nuclear power plant, construction of the subterranean facility began in 2004. Onkalo, meaning "cavity" in Finnish, is being built to exacting standards: the need to last a minimum of 100,000 years without surveillance or management by future generations. Currently, a tunnel has been dug through solid bedrock to the final disposal level, spiraling 420 metres below the surface of the Earth. The construction of the repository is projected to be complete in 2020, allow for nuclear fuel-rod storage to commence at that point. Subsequently, the facility will be used for a century, at which point the chambers will be capped, and the tunnels and shafts backfilled. As for the storage method of the nuclear waste, spent fuel-rods will be deposited in corrosion resistant copper canisters with five centimetre-thick walls. The copper canisters will then be buried in a bed of bentonite clay, due to its ability to absorb water and prevent damage by geological movement. The debate over the significance of a semantic warning to future generations at the tunnels entrance, was the subject of an award winning documentary by Danish director Michael Madsen entitled "Into Eternity." The film's philosophical and ethical questions concerning the controversial construction brought global attention to Onkalo.

Svalbard Seed Vault

Location: Spitsbergen, Norway

Designer: Peter W. Sodermann

Relevance: Adaptable mining infrastructure / climate



(from Global Crop Diversity Trust / photograph by Mari Tefre)

The Svalbard Global Seed Vault is an innovative subterranean structure built to preserve the genomes of the world's plant supply. The project, having been termed the "modern day Noah's Ark", will secure the global diversity of crop species for future generations in the event of political, economic, or environmental catastrophes. The remote location was chosen due to its consistently cold, dry climate, a critical component to ensure the indefinite survival of the nearly 2.25 billion seeds that will be stored within. With an average underground temperature of -3°C in the hillside where the facility resides, minimal energy will need to be consumed in order to ensure the required -18°C storage temperature. The facility, buried deep in a remote permafrost hillside 1,125km's south of the north pole has four main components: an illuminated entrance portal, a lengthy concrete tunnel, a small set of administrative offices, and a transverse tunnel deep in the hillside linking three identical storage vaults. The entrance portal, being the only visible portion of the facility, was given special attention in the design process. As a result, the portal is a sharp, angular wedge designed to contrast with the gentle wind-swept hillside from which it protrudes. Furthermore, designer Peter Sodermann commissioned artist Dyveke Sanne to illuminate the portal with innovative fibre-optic-lit cladding. The orientation was carefully chosen to ensure the scouring of snow if maintenance wasn't possible for an extended period of time.

Emergent North

Location: Canadian Territories

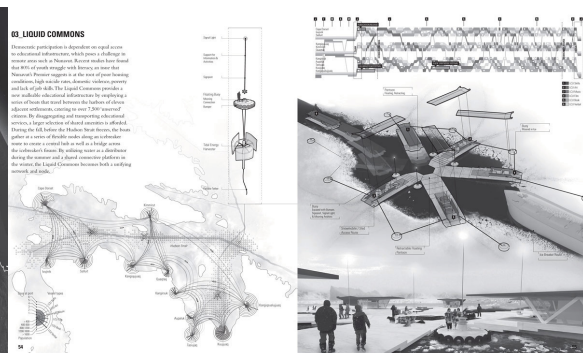
Designer: Lateral Office

Relevance: Remote agricultural infrastructure / climate & culture

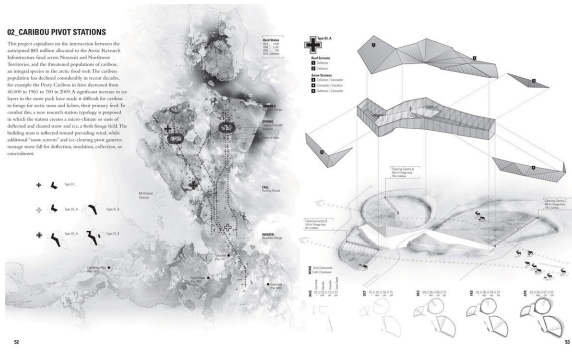
This work titled "Emergent North", developed as result of the 2010 Prix de Rome grant for travel and research. The project attempts to address the challenges and opportunities of social and ecological empowerment in Canada's unique northern geography. The work, though not directly related to this thesis subject, provides an interesting contextual analysis of the north. As stated by Lateral office, "with an estimated quarter of the world's undiscovered energy resources and opening navigation trade routes, the Arctic is under threat of environmental change and development pressure... ..throughout the 20th century, Canada's Far North has a sordid and unfortunate history of colonial enterprises, political manoeuvrings, and non-integrated development proposals that perpetuate an exclusively militaristic and economic approach to development. The time to envision, plan, and act in this fragile context is urgent."



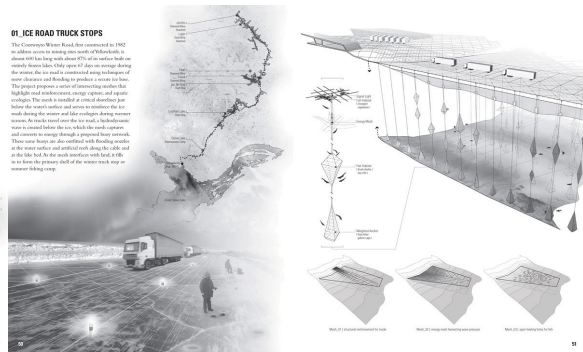
Context map



Liquid commons: ice bridging



Caribou calving ground pivot stations

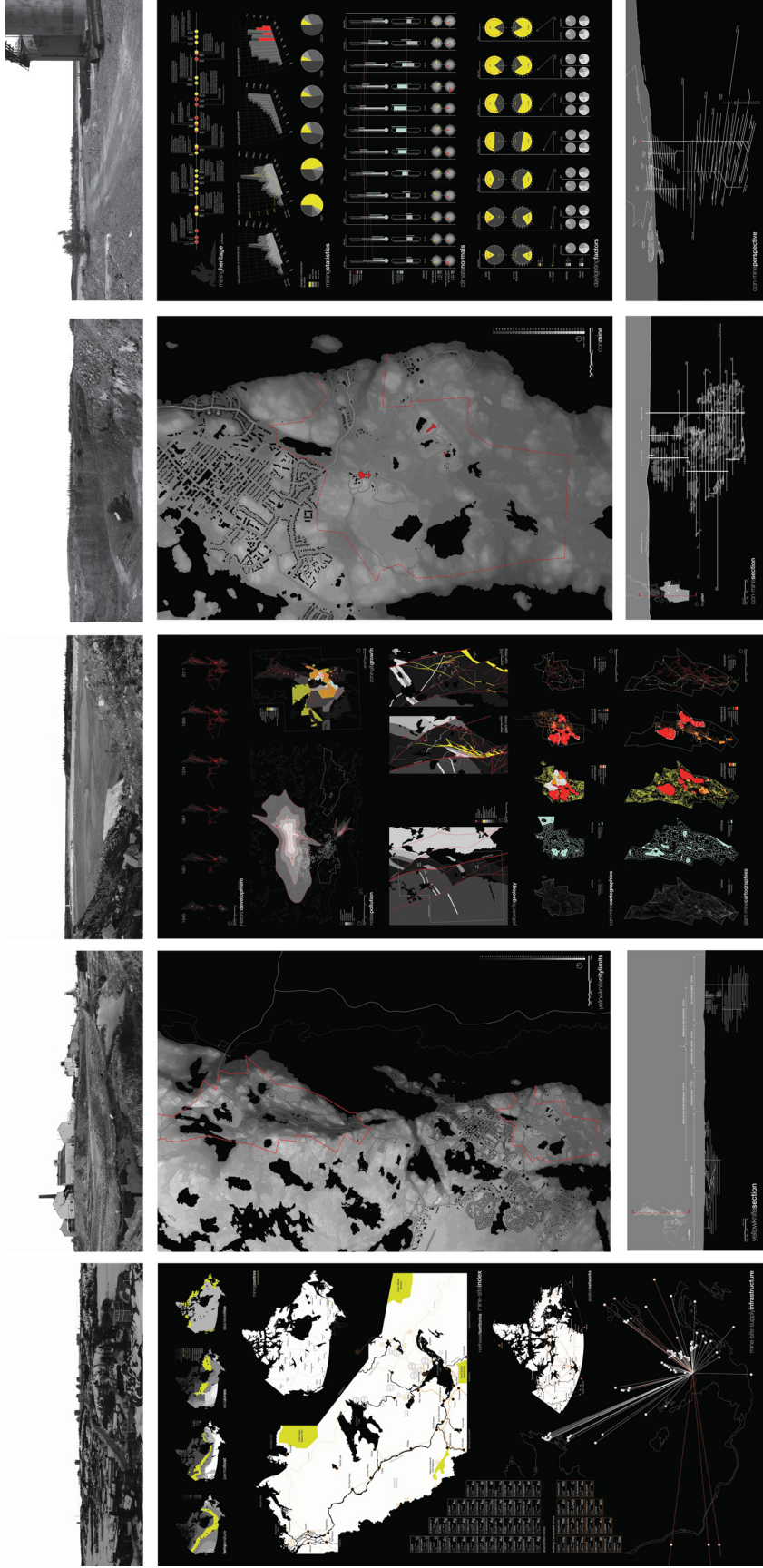


Ice highway infrastructure: truck stops

(from Canada Council for the Arts / drawings by Lateral Office)

APPENDIX 3: PRESENTATION





Final presentation boards for preliminary research and analysis

APPENDIX 4: GLOSSARY

(definitions from *The Operational History of Mines in the Northwest Territories, Canada*)

Autoclave: A high pressure and temperature vessel for oxidizing refractory ore. Ore or concentrate is fed into the strong vessel and placed under high pressure and temperature conditions with elevated oxygen levels to liberate the gold or base metals.

Agitation: Tanks in a milling plant which stirs a solution to aid in the separation of minerals from waste, usually with the introduction of compressed air.

Anticline: An upward fold or arch of rock strata.

Assay: A chemical test performed on a sample of ore to determine its mineral content.

Backfill: Mine waste rock or tailing sands used to support the stope roof after ore removal.

Ball Mill: A steel cylinder filled with steel balls that is rotated at great speeds. Mine ore is added into the mill and the balls are used as a crushing and grinding medium.

Bullion: Metal (gold, silver, lead, zinc, copper) which has been formed into refined bars or ingots.

Bunkhouse: Crew quarters for the employees of a mine when private accommodations are not available (usually in an isolated mining camp).

Byproduct: Other minerals which are produced from an ore and are not the primary mineral of interest.

Cage: In a mine shaft, the device, similar to an elevator car, that is used for hoisting personnel and materials.

Calcine: Concentrate that is ready for smelting (typically arseno ores which have had arsenic and sulphur minerals roasted off)

Claim: A portion of land held by a prospector or mining company under the authority of Federal or provincial laws.

Clarification: Process of clearing dirty water from gold-bearing solution by removing suspended material.

Classification: Process of separating minerals and ore material according to size and density.

Collar: A timber or concrete structure built around the top of a mine shaft for structural support.

Concentrate: A rich mixture of minerals (in the form of a fine powder) that is produced from the milling process. This material requires further processing in the form of smelting or roasting to recover the desired mineral content.

Crosscut: A horizontal mine tunnel that is driven perpendicular to the strike of a vein or deposit. Crosscuts are typically driven to cut across to another deposit.

Cut-and-Fill (Stoping): A method of stope mining where ore is mined in slices, or lifts. The ore is then removed completely from the stope. In order to reach the next slice in the stope, the excavation is filled with waste rock or backfill and formed with a cement floor to support heavy machinery. The next slice is mined and the process is repeated until the stope is completely mined to the above level.

Cyanidation: A method of extracting gold grains from crushed ores by dissolving it in a weak cyanide solution.

Decline: An underground ramp that spirals down to a depth, usually with a –10% grade. Declines are a cheaper method to developing an underground deposit than vertical shafts.

Deposit: A mineralized body which has been intersected by sufficient closely spaced drill holes and/or sampling to support sufficient tonnage and average grade of metal(s) to warrant further exploration-development work.

Diabase: A common basic igneous rock usually occurring as dykes or sills.

Dip: The inclination of a geologic structure (bed, vein, fault, etc.) from the horizontal; dip is always measured downwards at right angles to the strike.

Drift: A horizontal mine tunnel that follows the strike of a vein or deposit.

Dry: The mine facility where workers change into work clothes. Clothes are hanged up on hooks and baskets to dry.

Dyke: A long and thin body of igneous rock that intruded a fissure in older rock. Can contain pegmatite minerals or kimberlite (diamond bearing) ore.

Flotation: A milling process in which valuable mineral particles are induced to become attached to bubbles and float, and others sink.

Flowsheet: An illustration or description which outlines the sequence of operations, step by step, by which ore is treated in a milling plant.

Free-Milling: Ores of gold and silver from which the metals can be recovered by concentrating or cyanidation methods without resorting to pressure leaching or roasting treatment.

Headframe: A structure built over-top of a shaft that functions as part of the hoisting system.

Hoist: An item of machinery that is used primarily to service a mine shaft with an elevator type of function for man-cage and skip handling.

Igneous Rock: Rocks formed by the solidification of molten material from far below the Earth's surface.

Kimberlite: A volcanic rock that hosts diamonds.

Level: A horizontal opening underground consisting of drifts and crosscuts. They are driven off of shafts or decline ramps and are spaced at regular intervals.

Mill (Processing Plant): A processing plant that uses a variety of chemical and mechanical techniques to breakdown ore from a mine and recover its mineral content. Products from a mill usually require further treatment (refining or smelting) to fully recover the desired metals. Mills produce concentrates or precipitates, and tailing wastes.

Orebody: A natural concentration of valuable material that can be extracted and sold at a profit.

Ore Reserves: The calculated tonnage and grade of mineralization which can be extracted profitably; classified as Drill Indicated Reserves, Possible/Inferred Reserves, Probable/Indicated Reserves, and Proven/Measured Reserves according to the level of confidence that can be placed in the data.

Outcrop: An exposure of rock that can be seen on surface and is not covered by soil or water.

Pillar: A block of solid ore or other rock left in place to structurally support the shaft, walls or roof of a mine.

Portal: A mine tunnel opening that identifies the start of an adit or a decline.

Raise: A vertical or incline mine tunnel that is driven up from a mine working to tap into a deposit in preparation for certain types of stope mining. Raises are commonly driven to connect mine levels, to break-through to the surface for ventilation, or as escape-routes, man-ways, or ore passes.

Rake: The trend of an orebody along the direction of its strike.

Rare Earth Elements: Scarce minerals such as niobium and yttrium.

Refinery: The plant in which precipitate or concentrates from the gold milling process are smelted and poured into the form of rough gold dore bars.

Refractory Ore: Ore that resists the action of chemical reagents in the normal treatment processes and which may require pressure leaching or other means to effect the full recovery of the valuable minerals.

Reclamation: The restoration of a mining site after mining or exploration activity has ceased. To return the site to a natural state as it was before mining disturbance.

Roaster: A plant designed to heat a refractory ore to drive off volatile substances or oxidize the ore. The oxidation of the ore liberates the gold. Typically produces poisonous gases and arsenical wastes that must be disposed of properly or treated.

Sedimentary Rocks: Rocks formed from material derived from other rocks and laid down under water and cemented over time.

Shaft: A vertical or inclined mine opening that is used as a hoisting compartment to service the underground workings of a mine. Headframes

Shear Zone: A zone in which shearing has occurred on a large scale.

Sheave Wheel: A large, grooved wheel in the top of a headframe over which the hoisting rope passes.

Skip: A self-dumping bucket used in a shaft for the hoisting of ore.

Stope: An excavation in a mine from which ore is extracted.

Strike: The direction or bearing (measured by angle on the horizontal surface from true north) of a vein or rock formation.

Tailings Pond (Tailing Containment Area or TCA): Material rejected from a mill after most of the recoverable minerals have been collected. These wastes are impounded in protective ponds, which are blocked off by dams and dikes to prevent the (sometimes) hazardous material from entering the natural watershed. Sometimes tailings will contain a small mineral content that may be economical to re-process and recover the previously un-recovered metals.

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