DESIGN MEMORANDUM / ECONOMIC EVALUATION

FOR

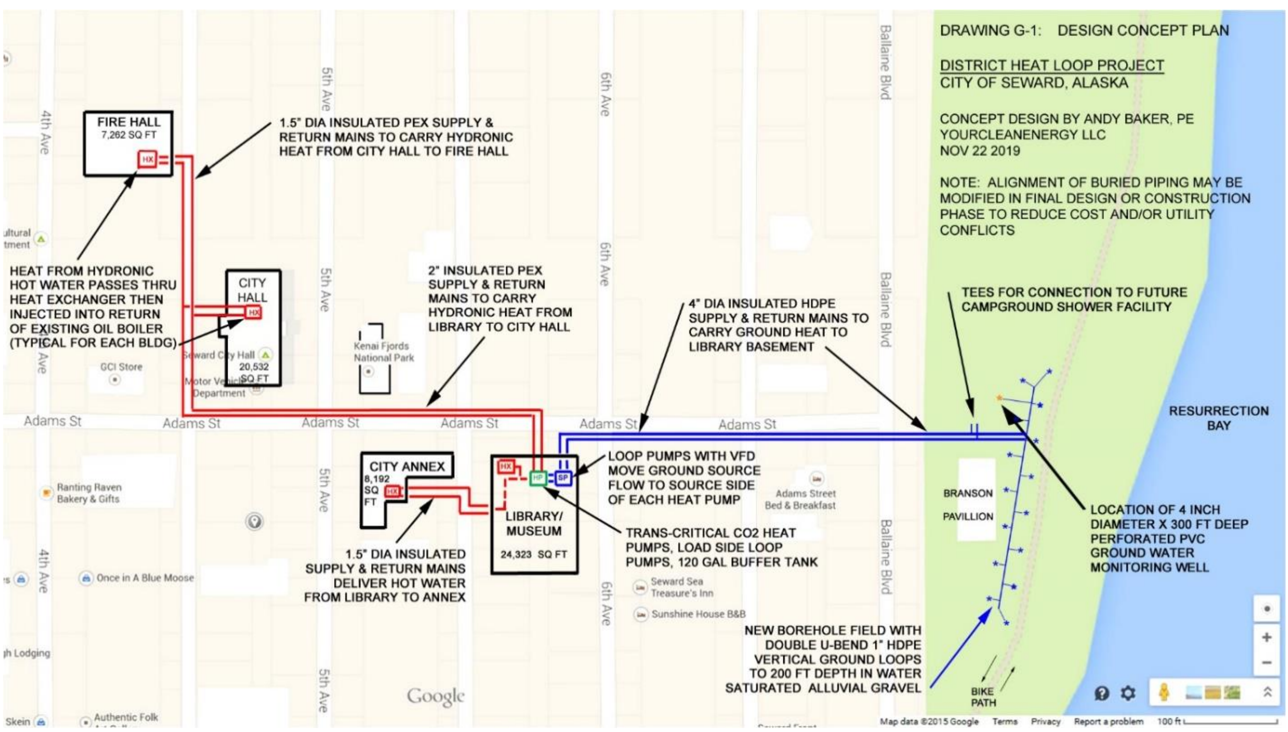
GROUND SOURCE HEAT PUMP / DISTRICT HEAT SYSTEM

TO PROVIDE PRIMARY HEAT FOR

CITY LIBRARY & MUSEUM
CITY HALL ANNEX
CITY HALL
FIRE HALL

FOR

CITY OF SEWARD, ALASKA



UPDATED OCTOBER 28, 2022 BY ANDY BAKER, PE
TO SUPPORT DOE/EERE GRANT APPLICATION DE-FOA-0002632

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TABLE OF CONTENTS

EXECUTIVE SUMMARY – DISTRICT HEAT LOOP PROJECT OPTIONS 3

SCOPE ADJUSTMENT AND FINAL RECOMMENDATION IN VIEW OF INCREASED COSTS 4

INTRODUCTION 5

EXAMPLE OF A SUCCESSFUL OCEAN SOURCE CO2 HEAT PUMP SYSTEM IN SEWARD 6

A SUMMARY OF THE FOUR CITY BUILDINGS INCLUDED IN THIS EVALUATION 7

RECENT HISTORY OF ELECTRICITY COSTS FOR CITY OF SEWARD LIBRARY / MUSEUM 8

RECENT HISTORY OF GRID ELECTRICITY USAGE BY CITY LIBRARY / MUSEUM 9

RECENT HISTORY OF HEATING OIL COST FOR CITY BUILDINGS IN SEWARD 10

RECENT HISTORY OF HEATING OIL USAGE BY CITY BUILDINGS 11

RECENT AND PROJECTED HEATING FUEL COSTS FOR THE CITY OF SEWARD 12

ESTIMATED SAVINGS OF HEAT PUMP SYSTEM OVER ELECTRIC BOILER AND OIL BOILERS 12

SUMMARY OF EXISTING BOILERS AND ESTIMATE OF PEAK HOURLY & ANNUAL HEAT LOADS 13

SOLAR HEATING OF THE OCEAN ALONG THE EQUATOR IS MOVED BY GYRES TO ALASKA 14

SEA WATER TEMPERATURE IN RESURRECTION BAY PEAKS EACH YEAR AFTER FALL STORMS 15

GEOLOGY AND SUB-SURFACE WATER RESOURCE BELOW WATER FRONT PARK 16

DRILLING, CONSTRUCTION, AND TESTING OF TEST BOREHOLE NEAR BIKE PATH – AUG 2015 17

PROPOSED DESIGN OF VERTICAL GROUND LOOPS TO EXTRACT OCEAN HEAT 18

EXAMPLE PROJECT USING DOUBLE U-BEND VERTICAL LOOPS WITH SEPARATOR CLIPS 19

TRENCHING OF SUPPLY & RETURN MAINS ALONG AND UNDER CITY STREETS AND ALLEYS 20

GROUND SOURCE HEAT PUMP OPERATION AND COEFFICIENT OF PERFORMANCE (COP) 21

PRELIMINARY DESIGN OF GROUND SOURCE DISTRICT HEATING SYSTEM 22

EXECUTIVE SUMMARY – DISTRICT HEAT LOOP PROJECT – FOUR BUILDING OPTION

50 Year Present Worth Financial Analysis:	**Four Building Option:**
	Library, Annex, City Hall & Fire Hall
	18 Boreholes - Five CO_2 Heat Pumps
Description Of Financial Component	
Total Installed Project Cost Opinion (October 2022)	**-$4,522,850**
Less AEA Grant Amount In Hand	**$725,000**
Additional Grant Funds Required To Build (2022 Dollars)	**-$3,797,850**
Electricity use by source pumps - Year 1 = 26,810 KWH	-$6,560
Present worth of electricity use by	
source pumps - over 50 year project life*	**-$339,700**
Electricty use by heat pumps - Year 1 = 289,470 KWH	-$70,750
Present Worth of electricity use by	
heat pumps - over 50 year project life*	**-$3,667,240**
Maintenance Cost - District Heat System - Year 1	-$16,000
Present Worth of Maintenance Cost For	
District Heat System - over 50 year project life**	**-$991,160**
#1 Heating Oil Saved By Heat Pumps - Year 1 = 21,300 gallons	$107,990
Present Worth of #1 Heating Oil Saved By	
Heat Pump System - Over 50 year project life***	**$13,451,810**
Net Carbon Offset By Using Heat Pumps - Year 1 = 113 Tons CO_2	$5,630
Present Worth of Carbon Offsets Produced By	
Heat Pump System - Over 50 year project life****	**$241,560**
Net Annual Savings At End Of Year 1	$20,310
Net Present Worth Of Project Over 50 Years	**$4,897,420**
Benefit To Cost Ratio - Total Project Cost $4,522,850	**1.44**
Benefit To Cost Ratio - Additional Grant Funds $3,797,850	**1.56**
Payback On Additional Grant Funds	**36.3 years**

Notes:

* Grid electricity at Large General Service rate of $0.26/KWH, 2.75%/year escalation; 25KW Solar PV Array to provide 23,000 KWH/yr, equivalent to approximately 6% of annual electricity for heat pump system, 25 KW PV array will reduce the cost of electricity for the project to $0.2444/KWH

** Maintenance labor costs escalating at 3% per year; includes CO_2 Heat Pump compressor replacement every 12.5 yrs

*** Unit cost of #1 heating oil escalating at 6% per year with $5.07/gallon price in 2022; heating oil usage includes connection to future sidewalk snow melt systems that will offset approximately 3,900 gallons/yr heating oil at the Library, and 2,814 gallons/yr heating oil at City Hall

**** Carbon offset = 22.4 lbs CO_2 / gallon heating oil not burned; carbon footprint of grid electricity from CEA = 0.7959 lbs CO_2 / KWH; estimated revenue from sale of carbon offset is $50/ton in 2022, $60/ton in 2023, $70/ton in 2032, $80/ton in 2042, $90/ton in 2052, $100/ton in 2062

SCOPE ADJUSTMENT / RECOMMENDATIONS IN VIEW OF INCREASED COSTS SINCE 2015

As the design process advanced thru 2019 and 2020, it became evident that adjustments in the original 2015 concept and scope were needed to keep the District Heat Project within reasonable budget limits for a project to be built in 2022. An independent cost estimate provided by HMS Inc. of Anchorage in October of 2022 further reinforced this case by illustrating how much construction costs had escalated in Seward over the past seven years. While the 2015 grant allocation of $725,000 from AEA has remained fixed, the matching contribution required from the City of Seward to build the project in 2022 has increased well above the $157,497 identified in the 2015 grant request. The primary factors that have increased project cost:

- Material and labor costs from 2015 YCE cost opinion have escalated by 4% to 12% per year to 2022 costs. Covid 19, supply chain issues, and historically high inflation have made significant impacts in recent years to construction costs in Seward, Alaska.

- Heat pump equipment was changed from units using synthetic refrigerant R-134a to units using CO_2 refrigerant. This change was to improve performance and achieve higher temperature output, based on lessons learned from the four CO_2 heat pumps operating at the Alaska SeaLife Center since early 2016. For the four-building project (Library, Annex, City Hall, Fire Hall), CO_2 heat pumps will deliver hydronic heat up to 194F, while R-134A heat pumps are limited to 130F. CO_2 heat pumps operate without the high greenhouse gas liability of synthetic refrigerants (the 20-year GWP of R-134a is 3810 while GWP of CO_2 is 1). However, the CO_2 heat pump units are still considered emerging technology in the US market and hence are currently more expensive per ton of heating capacity. Each heat pump unit alone has a 2022 landed cost in Seward of approximately $70,000. At the time this project may be funded for final design in 2023, it is likely that increased competition of both rack mount and unitary cabinet CO_2 heat pump suppliers will take interest and provide bids that may equal or exceed the Mayekawa Unimo units currently specified.

- The 2015 project cost opinion was developed assuming that some equipment and materials would be directly procured by the City, and with trench excavations and backfill performed by the City at force account rate. The 2015 project cost opinion also assumed that the City would have a project manager available in-house to oversee the various contractors required. The 2022 cost opinion present herein is based on an outside project manager with the entire project bid out.

In early 2022, a committee of citizens from Seward dedicated to advancing this district heat project formed what is known as the Heat Loop Project (HLP) Committee. This committee is organized under the Port and Commerce Advisory Board (PACAB). The HLP Committee identified the opportunity to apply for a grant through the US Department of Energy (DOE) EERE's Community Geothermal Heating and Cooling Design and Deployment (DE-FOA-0002632). In August 2022, the City of Seward secured the services of YCE and R&M, and assistance from NREL staff, to develop and complete the grant application for the DOE community geothermal grant for a four-building project that includes the Library, City Annex, City Hall and the Fire Hall. This grant application presents a project with a total of five 20-ton CO_2 heat pumps located in the Library basement. Source heat will be derived from a total of 36 vertical ground loops that intersect the subsurface tidal zone in the City's Waterfront Park. The completed grant application was submitted to DOE on October 7, 2022. This Design Memo was then updated to reflect the current four-building project.

The four-building project anticipates future sidewalk snowmelt at the Library and City Hall, and future 25 KW Solar PV array, and will afford an annual heating oil offset of approximately 21,300 gallons/yr. At the current heating oil price of $5.07/gallon, and Large General Service electricity price of $0.26/KWH, the project is estimated to produce an annual savings over heating oil boilers of approximately $20,310. Prepared by HMS of Anchorage, the opinion of probable total cost in 2022 dollars for the four-building project option is $4,522,847. The AEA grant amount allocated by the state legislature for this project is $725,000. The estimated amount of matching funds required from a grant agency and/or the City of Seward to build the project in 2022 is estimated to be $3,797,84. As shown in the Executive Summary of this report, this match investment will generate a Net Present Worth over 50-year project life estimated to be $4,897,420, a Benefit To Cost Ratio of 1.44, and an estimated payback on investment of 36.3 years.

INTRODUCTION AND BACKGROUND

In March of 2019, the City of Seward secured the engineering services of YourCleanEnergy (YCE) in association with mechanical / electrical designers EDC, Inc., for the design of a Ground Source Heat Pump / District Heat System to serve the existing City Library, City Annex, City Hall, and Fire Hall buildings. Design Drawings and Design Memo for the project were completed by YCE/EDC in November 2020. In May of 2022 the citizen led Heat Loop Project Committee identified a DOE grant opportunity suitable for the four-building version of this project. The Design Memo presented herein has costs updated to 2022 dollars to reflect the four-building project for the DOE grant application submitted by the City in October 2022.

The City Library is heated with a modern two-stage oil-fired boiler and has a standby 135 KW seven stage electric boiler. The City Hall and Fire Hall both have two oil fired boilers in them. The Annex is currently heated with a single oil-fired boiler. The concept of this evaluation is based on converting the primary source of heat for all four city buildings from existing heating oil and electric boiler heat systems to a ground source CO_2 heat pump system. The ground source loops will derive ocean tidal heat from a closed loop vertical borehole field located in the City owned Waterfront Park immediately adjacent to Resurrection Bay.

Attractive operational savings are anticipated over time by offsetting heating oil boilers in the four city buildings with an ocean source CO_2 heat pump system. The anticipated savings are based on results of the ocean source CO_2 heat pump system at the Alaska SeaLife Center in Seward that has been operating since 2016 at lower cost than heating oil or straight electric heat systems. The Waterfront Park along Resurrection Bay lies above a water saturated deep alluvial deposit that is ideal for installation of a field of 240 ft deep vertical ground loops. The vertical ground loops will supply source heat via a closed glycol loop to a bank of heat pumps located in the Library basement. The heat pumps will use CO_2 as a refrigerant to extract heat from the source glycol. The same heat pumps will warm a main building hydronic loop up to 180F as heat supply for the four city buildings. Hydronic heat will be distributed from the main heating loop to the mechanical rooms of the City Hall and Fire Hall. A secondary hydronic loop from the heat pumps will distribute heat to the mechanical room of the Annex; a heating fan coil unit in the Library basement; and then finally to a low temperature radiant heat system in the Library.

Of the four City buildings, the City Library is the most amenable for conversion to heat pumps due to its new construction with well insulated envelope, low temperature radiant floors, and modern hydronic system. The City Hall and Fire Hall are older multi-use buildings that would benefit significantly from both a comprehensive energy audit and fundamental energy efficiency improvements. The Fire Hall can benefit from insulation of exterior walls in basement. The Annex is adjacent to the Library and has had envelope improvements that make this building capable of receiving hydronic heat at 160F. As more energy efficiency improvements are made over time to the City Hall and Fire Hall, the heat production required from the CO_2 heat pumps in winter will reduce. This will in turn free up heat pump system capacity for outdoor sidewalk snowmelt systems that can be installed at the Library and at City Hall when old sidewalks are replaced.

Acknowledgements. YCE would like to thank the citizen Heat L:oop Project Committee, PACAB, City Council and City Administration for moving forward on a grant application for this district energy project that taps the immense natural heat resource that is Resurrection Bay. Appreciation is also expressed to Darryl Schaefermeyer for sharing his valuable experience with ASLC heat pump projects.

EXAMPLE OF A SUCCESSFUL OCEAN SOURCE CO_2 HEAT PUMP SYSTEM IN SEWARD

Alaska SeaLife Center, Seward. In 2009, an Economic Evaluation comparing the installation and use of sea water heat pumps to replace existing oil boilers was completed by YourCleanEnergy. In 2010, the 120,000 square foot Alaska SeaLife Center received grant funds from the Denali Commission and Alaska Energy Authority to design and install two 90 ton heat pumps that utilize sea water from ice free Resurrection Bay to provide heat for indoor spaces, outdoor sidewalks, and domestic hot water. In December 2012, the two existing oil boilers were turned off and the sea water heat pump system performance was monitored continuously through December 2013. Throughout 2013, the heat pump system displaced 48,104 gallons of heating oil, producing a net savings of $120,000 and a net CO_2 emission reduction of 420,000 lbs. The average system COP (coefficient of performance) for the year was 2.77; this represents an efficiency of 277% over heating oil or straight electric heat.

In 2014, AEA provided an Emerging Energy Technology grant award to the Alaska SeaLife Center to design and install four additional heat pumps to offset their existing electric boiler load. These high quality, reliable, and safe heat pumps utilize CO_2 as the refrigerant and lift from sea water temperatures (40 degrees F) up to 194 degrees F for baseboard heat in the offices and labs; domestic hot water heating; and outdoor habitat slab snow melt heating. This project was designed by YourCleanEnergy in 2015 and the new heat pump system was commissioned in early 2016. The four CO_2 heat pumps are Mayekawa Unimo 20-ton units manufactured by Mayekawa of Japan. These units are currently the only packaged CO_2 heat pump available at this size in the US market for water and space heating. The heat pumps make use of the unique and valuable CO_2 trans-critical vapor compression cycle. First, heat from 45F seawater is used to turn CO_2 from liquid into vapor. Then the CO_2 vapor is compressed to nearly 2000 psi which adds significant heat to the vapor. Then the hot vapor circulates thru a gas cooler that transfers much of its heat into a 100F hydronic loop that is heated up to 194F. The 194F hydronic water leaving the heat pumps is blended into a large building loop that is kept at 140F to 160F, depending on outside air temperature. Hydronic water from the large building loop is first used to supply medium temperature baseboards; then to top up the 600 gallon domestic hot water tank; then to supply a duct coil in air handler AHU-4 to heat the wet side of the basement; and finally to supply heat to outdoor habitat slabs for snow melting in the winter months. For the period 2016-2018, the Center's four Mayekawa 20-ton seawater source heat pumps have achieved net energy savings of $135,000 while avoiding 1.3 million pounds of CO_2.

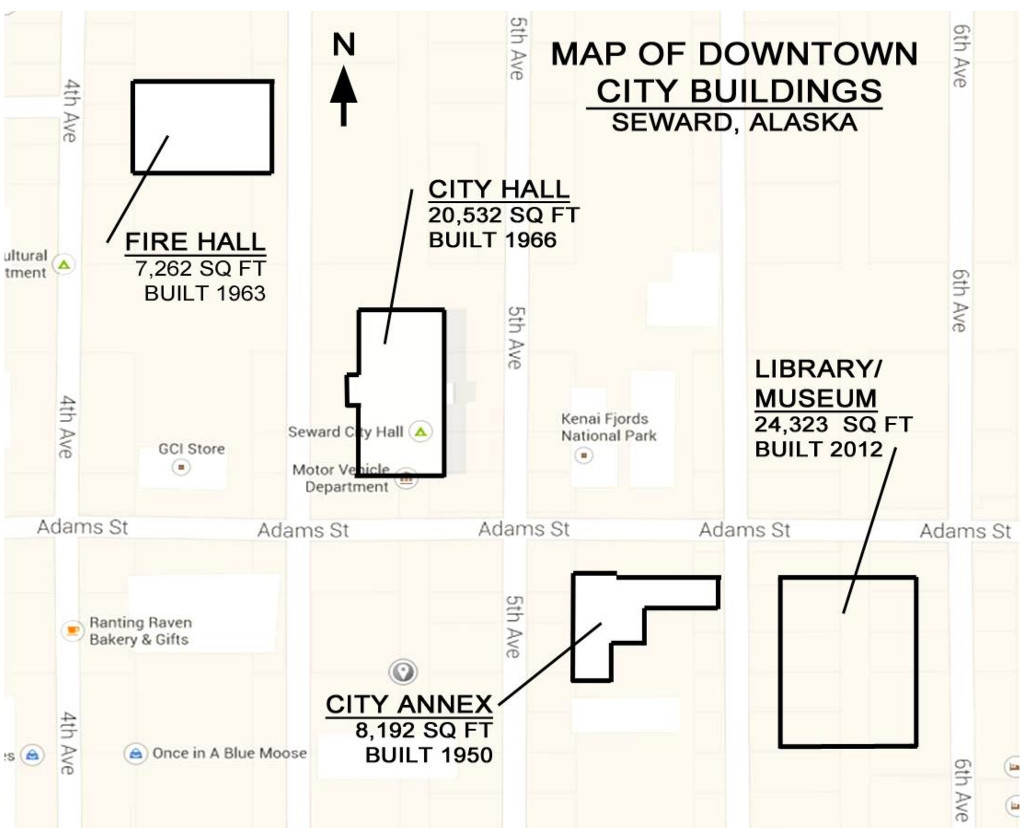
A SUMMARY OF THE FOUR CITY BUILDINGS INCLUDED IN THIS EVALUATION

A summary of basic information regarding the four city buildings included in this evaluation is given below:

Building Name	Sq Ft	Date Built	Type Of Use
Fire Hall	7,262	1963	Emergency Response, Bldg Inspector
City Annex	8,192	1950	Elect Dept, Planning Offices
City Hall	20,532	1966	City Admin, State & Federal Offices
Library/Museum	24,323	2012	Public Library & Historical Museum

Building Name	# of Boilers	Boiler Type	Liquid Fuel Type	Fuel Tank Size
Fire Hall	Two	Oil Fired	#1 Heating Oil	2000 Gallons*
City Annex	One	Oil Fired	#1 Heating Oil	500 Gallons
City Hall	Two	Oil Fired	#1 Heating Oil	2000 Gallons*
Library/Museum	Two	(Oil Fired + Electric)	#1 Heating Oil	2000 Gallons

**Fire Hall and City Hall share a single tank located adjacent to the Fire Hall*

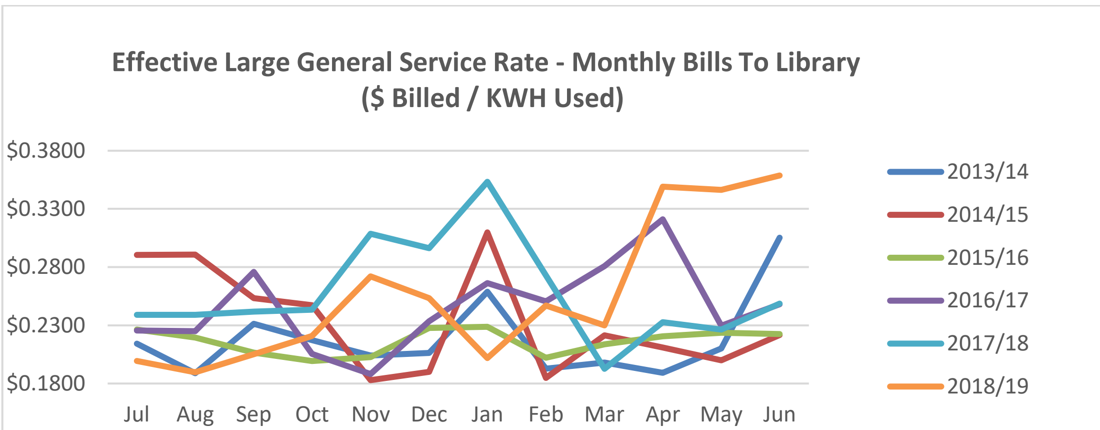


RECENT HISTORY OF ELECTRICITY COSTS FOR CITY OF SEWARD LIBRARY / MUSEUM

The primary location of electricity use for this project will be in the basement of the Library/Museum. The Library/museum is currently charged by the Seward Electric Utility at the Large General Service rate. Seward Electric Utility purchases power at wholesale from Chugach Electric Association (CEA) with the exception of local standby diesel generation when grid power is interrupted by avalanches or other events. The Large General Service electric rate consist of the following price components:

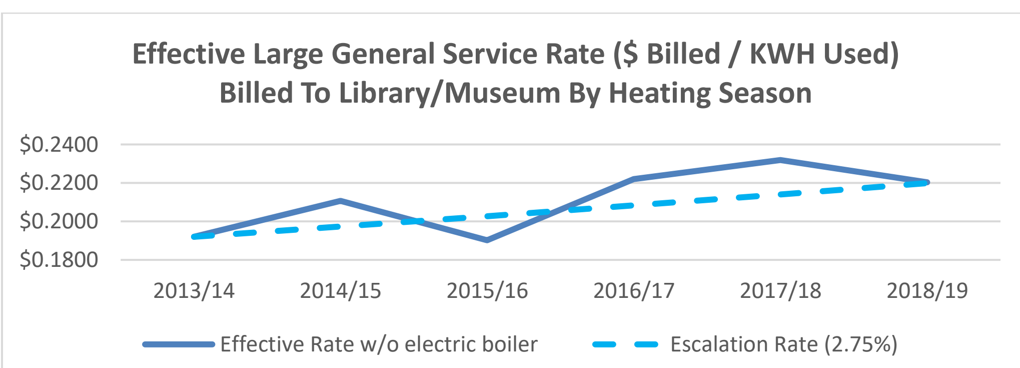
Primary Charge ($/KWH) + Additional Charge ($/KWH) + Peak Demand Charge ($/KW) + CEA Fuel Charge ($/KWH) + Monthly Charge ($/Month) = Total Monthly Charge

For simplicity, an Effective Electricity Rate ($/KWH) is used in this evaluation report to estimate future costs for loop pumps and heat pumps in the Library/Museum. The Effective Electricity Rate ($/KWH) is express as the Total Monthly Charge ($) divided by Total Monthly Energy (KWH) used. This is seen below for the Library for the six most recent heating seasons from 2013/14 thru 2018/19:



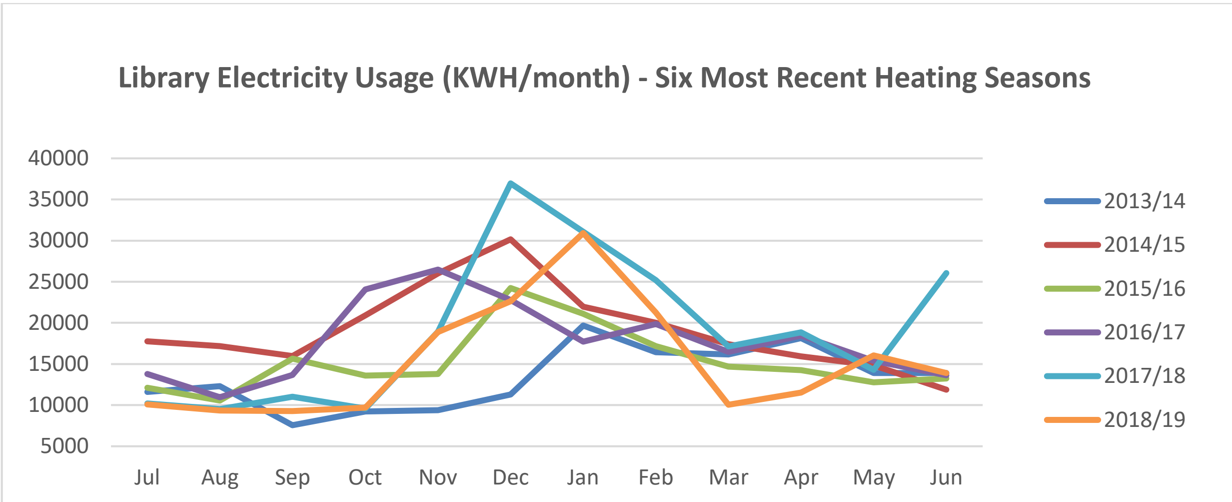
In 2022, the Large General Service (LGS) effective rate charged to the Library is averaging close to **$0.26/KWH** when the electric boiler is not used. The electric boiler imposes a large demand charge when running; this electric boiler will be kept off-line when the new heat pump system is operating. The Library basement will house all heat pumps and the primary loop pumps included in the proposed Ground Source Heat Pump / District Heat Project. The Seward Electric Utility is not presently considering a “bulk user” rate which can include the heat pump project with a dedicated 480 volt 3-phase service at the Library. It would be advantageous if there were an effective “bulk user” rate (including demand charge, fuel surcharge, and all other charges) that would allow the District Heat Project to purchase electricity at a rate lower than LGS.

The effective rate of grid electricity provided to the Library from City of Seward has been escalating at an average rate of approximately 2.75% per year for the following recent six years.

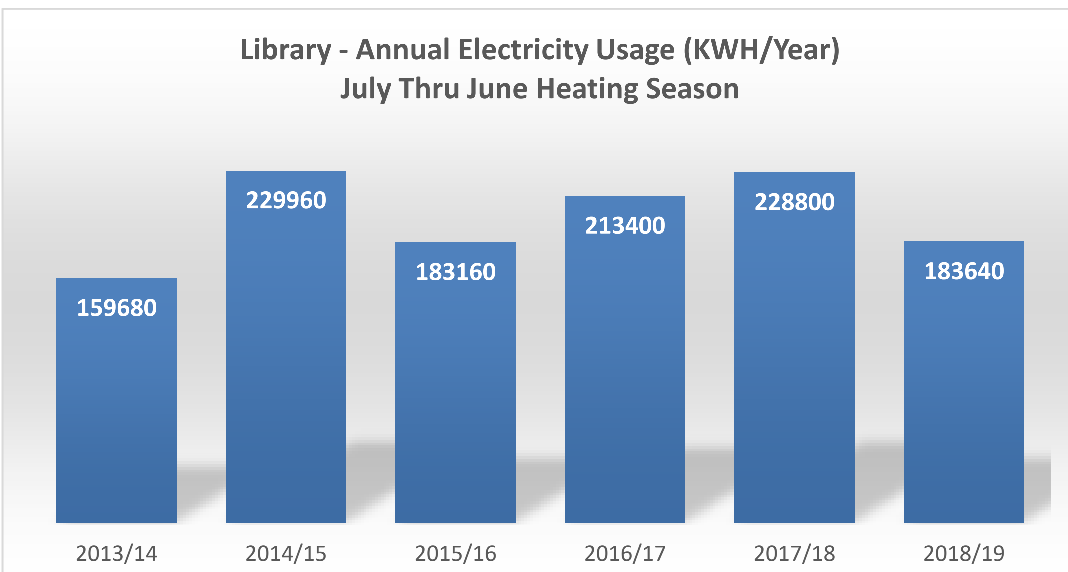


RECENT HISTORY OF GRID ELECTRICITY USAGE BY CITY LIBRARY / MUSEUM

For the most recent heating season of 2018/19, the total cost of electricity for the Library / Museum was **$47,075** for the purchase of **183,640 KWH**. The electricity usage increased significantly in the months of November, December, January and February due to usage of the 135 KW Lattner electric boiler located in the mechanical room of the Library. This boiler employs seven stages of electric resistance heating that activate quickly when heat is called for. Using an electric boiler for space heating with the current cost of power in Seward adds significant usage and cost to the Library operating budget. This fact alone makes using heat pumps with 260% efficiency very attractive when ocean source heat is nearby.



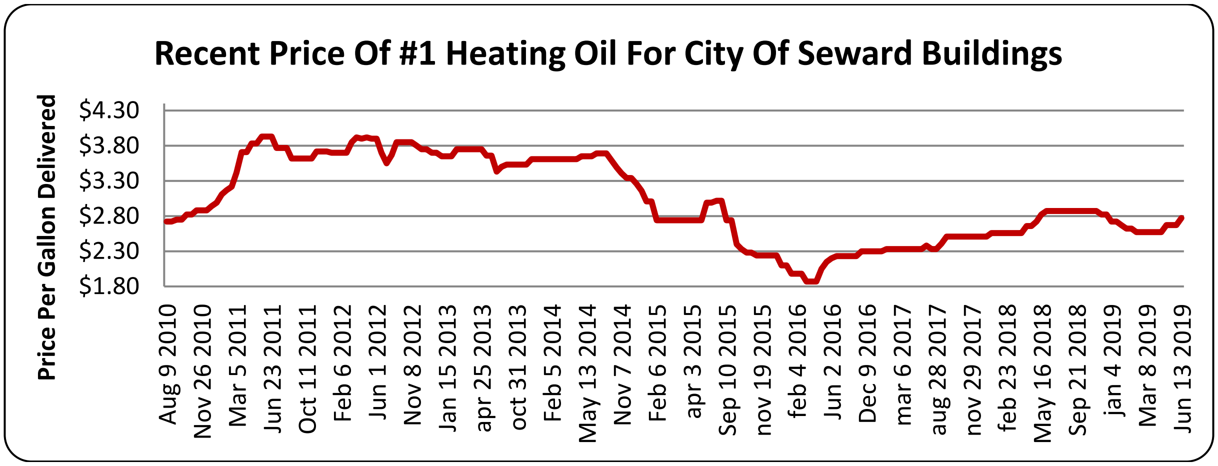
Annual electricity usage in KWH by the Library / Museum over the past six heating seasons is shown below.



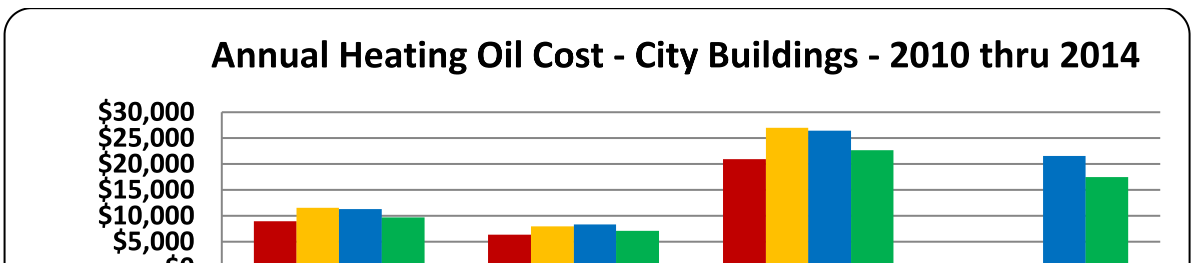
The Library/Museum was built in 2012. The average annual electricity usage over the past six heating seasons is **199,733 KWH/year**. The variation in usage between these heating seasons was due in part to short term utilization of the 135 KW electric boiler that imposes both increased current draw and additional demand charges from the utility. The proposed heat pump system, when operating at design capacity, will effectively offset the need for the electric boiler and afford cost savings to the Library.

RECENT HISTORY OF HEATING OIL COST FOR CITY BUILDINGS IN SEWARD

In order to plan for energy efficiency and district heat projects for buildings in Seward, it is useful to review the trend of heating oil cost ($/gallon delivered) from the past ten heating seasons (July 2010 thru June 2019). The City of Seward purchases #1 heating oil from Shoreside Petroleum for their buildings.



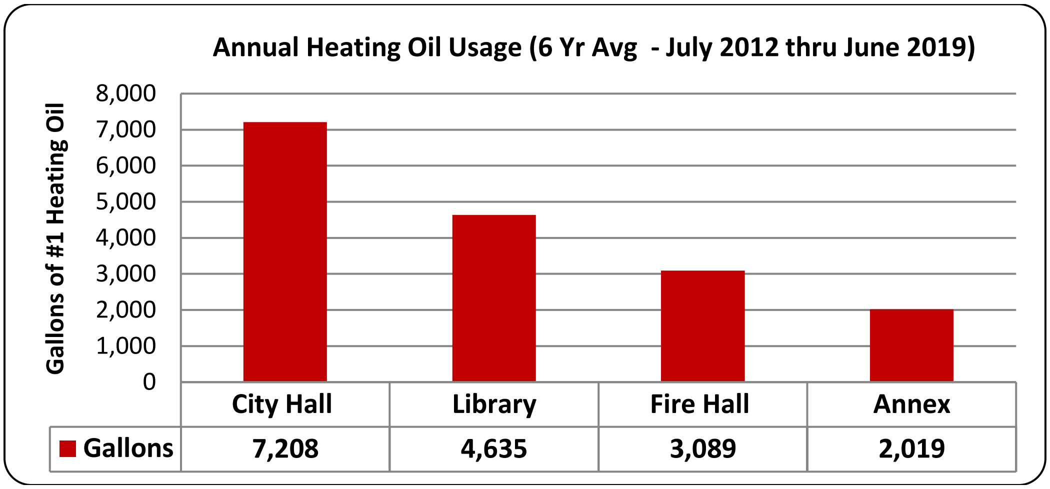
In recent years, the price of heating oil in Seward has varied greatly, as can be seen in the graph above of heating oil bill fuel prices from 2010 to 2019. A large spike occurred in the summer of 2022, with prices escalating to $5.07/gallon. Following the 2011 spike, prices remained in the range of $3.60/gallon through August of 2014. Military conflict in the Ukraine and Russia initiated a shortage of oil supply in the global market starting in February of 2022; this has driven prices for heating oil across the USA to over $6/gallon in some cases by late summer of 2022. It is anticipated that global supply will remain restricted into the near future, and that the market price for heating oil in Seward may remain in the range of $5/gallon. The financial analysis of the proposed district heat loop system is evaluated with heating oil at $5.07/gallon.

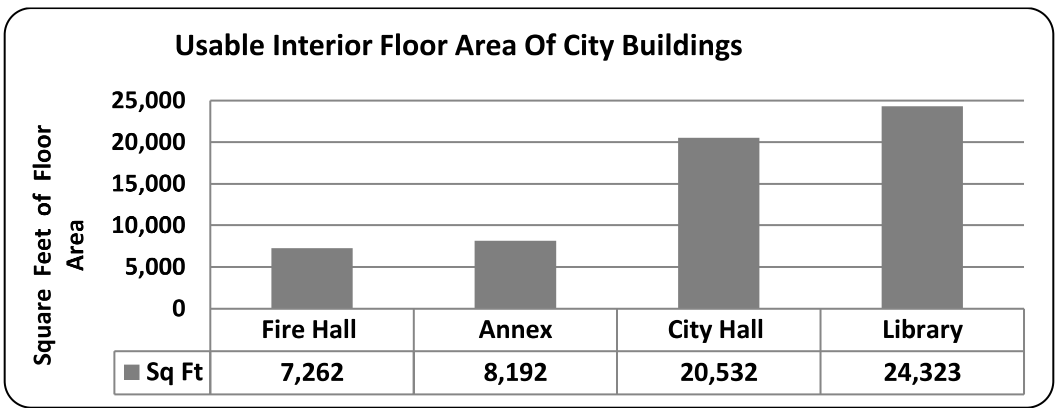


	Fire Hall	Annex	City Hall	Library
2010/2011	$8,973	$6,347	$20,937	$0.00
2011/2012	$11,563	$7,940	$26,979	$0.00
2012/2013	$11,318	$8,322	$26,408	$21,557.51
2013/2014	$9,723	$7,133	$22,688	$17,487.00

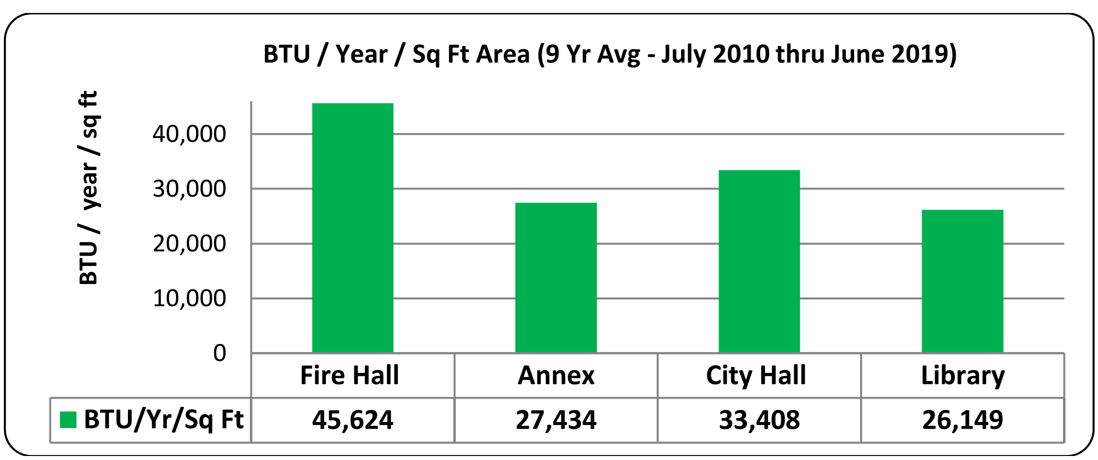
The total amount of City budget spent on heating oil for the four city buildings reached **$67,605** for the 2012/2013 heating season due to a cold winter and moderately high oil prices. While it is not the largest of the four buildings, City Hall consumes the greatest amount of heating oil by a noticeable margin. The Fire Hall has by far the greatest heat loss thru walls, doors and roof of the four buildings. Insulating the inside of the concrete exterior walls of the Fire Hall basement would significantly reduce heat loss from this building. Waste heat from boilers and hot piping in the Fire Hall mechanical room could then migrate up thru ceiling to the truck bay concrete floor, and offices on the first floor where heat is needed most.

RECENT HISTORY OF HEATING OIL USAGE BY CITY BUILDINGS





The overall efficiency of heating oil boilers and envelope insulation value in the four City buildings can be compared to each other by dividing the total amount of heating oil used each year in the building by the total usable floor area. While the Fire Hall is the smallest of the buildings, it consumes by far the greatest amount of heating oil per unit floor area. This is attributed in part to poor insulation in portions of the building envelope, in particular the basement exterior walls and the roof; and to the regular opening of large overhead doors in the ground floor truck bay for vehicles during the heating season.



RECENT AND PROJECTED HEATING FUEL COSTS FOR THE CITY OF SEWARD

For the past twenty years or more, the City of Seward has utilized heating oil as the primary fuel source for space heating boilers and standby power generation. In recent years, the City has purchased large quantities of #1 heating oil at bulk rate from Shoreside Petroleum. While there have been fluctuations in the unit cost of crude oil products in the past twelve years, the overall price escalation has been on a baseline of approximately 6% per year from August 2010 ($2.60/gallon) through July 2022 ($5.07/gallon).

The surplus of crude in the global market pushed down heating oil price beginning in September of 2014; however, this was a short-term effect. Healthy economic growth in the USA is expected in coming years, along with some reduction in crude oil demand in the USA due to efficiency increase. The long-term global shortage of crude oil supplies and growing global demand, especially that of China and India, may increase the escalation rate, as well as regional military conflicts. The use of a 6% per year escalation for heating oil in Seward is reasonable and realistic given the past and projected history of crude oil prices.

An electric boiler was installed in the new Library/Museum as an alternate heating method to burning heating oil. When the oil boiler is operating properly, the electric boiler is not used often due the fact that the recent price of oil has made operation of the two stage (low and high fire) oil boiler far more cost effective than the electric resistance heat elements that draw significant current and introduce demand charges into the monthly Library electric bill.

ESTIMATED SAVINGS OF HEAT PUMP SYSTEM OVER ELECTRIC BOILER AND OIL BOILERS

The heat pump system proposed for this district heat project will be powered by grid electricity purchased at the Library under the Large General Service rate which is currently close to $0.26/KWH. This electricity will be consumed by the heat pump compressors, and the various circulation pumps required to make the system functional and reliable. The Seward electric utility has the option to consider a “bulk user” or “industrial rate” which could include the new heat pump system to be located in the Library. As presented in the summary recommendations on Page 3 of this evaluation, an effective bulk electricity rate of less than $0.26/KWH in 2022 would make the project economics more attractive for investment by the City. A vote of City Council is required to establish such a bulk electricity rate.

The proposed CO_2 heat pump system has an estimated annual average coefficient of performance of 3.0, meaning that for every element of electrical energy consumed, the system will produce three elements of equivalent heat energy. Using the estimated 3.0 COP and current electricity and heating oil costs, it is possible to predict the potential savings in operating cost of the heat pump system in comparison to the existing electric boiler and the existing oil boilers:

- Cost of making 1,000,000 BTU with <u>#1 heating oil</u> (using 80% eff boiler, $5.07/gal) = **$47.29**
- Cost of making 1,000,000 BTU with <u>electric boiler</u> (@ LGS Rate of $0.26/KWH) = **$76.18**
- Cost of making 1,000,000 BTU with <u>CO_2 heat pump system</u> (COP 3.0, $0.26/KWH) = **$25.41**

Using a ground source CO_2 heat pump system with electricity priced at the Large General Service (LGS) rate of $0.26/KWH will reduce heating costs for the city buildings by approximately 46% in comparison to using existing oil boilers with heating oil price of $5.07/gallon.

Using a ground source CO_2 heat pump system with electricity priced at the Large General Service (LGS) rate of $0.26/KWH will reduce heating costs for the Library by approximately 67% in comparison to using the existing electric boiler.

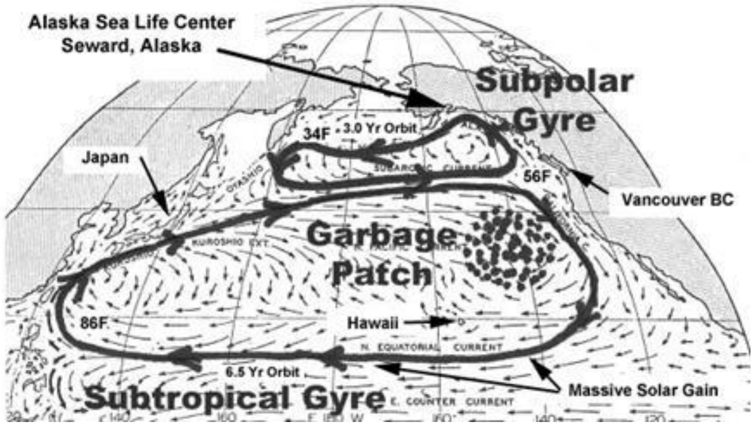
SUMMARY OF EXISTING BOILERS AND ESTIMATE OF PEAK HOURLY & ANNUAL HEAT LOADS

In January 2015, the City of Seward performed field testing of the existing oil-fired boilers in City Hall, Annex and the Fire Hall. While the boilers were running hot, an analysis of combustion flue gas temperature and composition was performed. Additionally, run time data loggers were installed on these oil boilers for the entire month to determine how often the boilers were running on the coldest days. From these field measurements and equipment data, the peak hourly heat load (Btu/hour) of the buildings was estimated for the design winter outside air temperature of 5F. It was then possible to estimate the size of new hi-efficiency water source heat pumps that could effectively replace the heating capacity of the existing boilers:

Site	**Library / Museum**	**Library / Museum**	**City Hall**	**City Hall**	**Fire Hall**	**Fire Hall**	**Annex Bldg.**
Boiler	Burnham V904A Lead boiler	Lattner Electric S135LW Lag boiler	System 2000 EK-3F Lead boiler	Weil McLain V600 Lag boiler	System 2000 EK-1 #1	System 2000 EK-1 #2	Weil McLain P-768-WT
Stack Temp.	370*		360*	440*	400*	350*	480*
CO2	11.60%		3.20%	2.20%	8.20%	7.70%	7.50%
CO	37 ppm		18 ppm	84 ppm	0.0 ppm	0.0 ppm	17 ppm
2	4.90%		16.50%	19.20%	9.60%	9.50%	10.60%
Extra Air	28.20%		34.50%	51.90%	78.30%	53.80%	93.10%
Nozzle	2.1 low fire 4.3 high fire		2.00-60A	250-60A	.75-70A	.75-70A	1.25-60A
Nozzle Flow Rate	2.1		2.6 gal/hour		1 gal/hour		N/A
Gross Output BTU/Hour	281,400 on low fire	460,000	348,400		134,000		248,000
Field Measured Efficiency	86.20% on low fire	No Data	73.20%	68.20%	82.50%	85.00%	78.60%
Net BTU/Hour	242,567	No Data	255,029		110,550		194,928
Run Time @5F	95.00%	No Data	95.00%		90.00%		45.00%
Peak Hourly Heat Load @5F BTU/Hour	**230,438**	No Data	**242,277**		**99,495**		**87,718**
Heat Pump Cap (Tons) Req'd To Offset Boilers	**19**		**21**		**9**		**8**
Design Annual Heat Load (MMBTU)	**700**		**734**		**368**		**261**
Design Annual Oil Usage (Gallons)	**6,064**		**7,480**		**3,325**		**2,475**
Site	**Library / Museum**	**Library / Museum**	**City Hall**	**City Hall**	**Fire Hall**	**Fire Hall**	**Annex Bldg.**

Data from the run time loggers was used to create heat load graphs for each building that are based the typical winter outside air temperatures measured in recent years in Seward. These graphs are shown in the Appendix of this report. From the simulation software associated with the data loggers, the design annual heat load and heating oil usage was estimated. These design heat loads are then used in the economic evaluation to establish how much heating oil will be displaced by heat pumps, how much electrical energy is required for loop pumps and heat pumps, and what annual savings that will produce.

SOLAR HEATING OF THE OCEAN ALONG THE EQUATOR IS MOVED BY GYRES TO ALASKA



The natural delivery of warm sea water to Resurrection Bay is part of the global heat engine. Large amounts of solar energy are absorbed by the ocean and atmosphere and are transported poleward. A simple example is that winds and currents from the south are generally warmer than those from the north. In the North Atlantic Ocean, the Gulf Stream carries warm water from the tropics to high latitudes along the East Coast of the U.S. It then moves across the North Atlantic and warms Europe. This clockwise gyre or circular pattern fills the North Atlantic.

The North Pacific is also warmed by a similar ocean circulation with the Kuroshio Current bringing water from the tropics northward along Japan and then eastward across the North Pacific. This current hits North America offshore of Seattle where it splits into the southward flowing California Current and the northward flowing Alaska Current. The Alaska Current brings warm water into the Gulf of Alaska. However, high amounts of rainfall over the gulf and along the coast put a low density "lid" on this relatively warm, salty tropical water. This lid overlies the subsurface source of warm water in the Alaska Current. The Alaska Current flows around the Gulf of Alaska in a counterclockwise direction along the shelf break which is about 100 miles offshore near Seward.

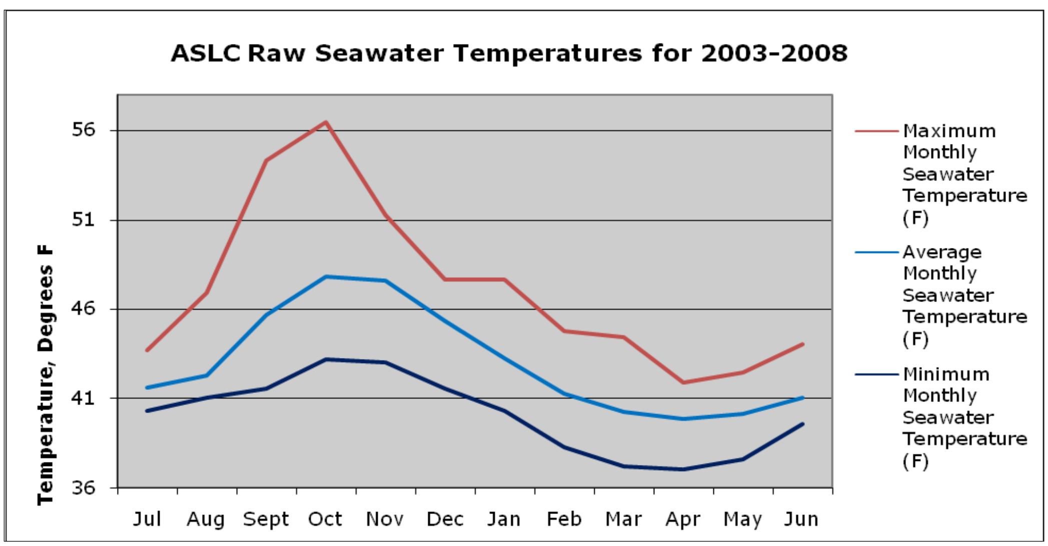
As the rains increase in autumn, a lot of freshwater enters the ocean from the coast. As it piles up along the coast, it begins to move offshore. The water beneath this upper layer of freshwater is mixed a little and is also carried offshore. It is replaced with water from below. This upper layer offshore moving layer allows deeper water to move to the coast. This deep layer of warm water supplies the heat from the tropics that warms Resurrection Bay each fall. This same heat has been successfully tapped to heat the Alaska SeaLife Center through long sub-arctic winters since 2011 using high efficiency ocean source heat pumps.

The Seward Line is a line of reference to obtain the oceanographic properties across the shelf and into the deep Gulf of Alaska. The GAK1 monitoring station and Seward Line was established in December 1970. In recent decades it was expanded to include biology and it continues to be sampled.

SEA WATER TEMPERATURE IN RESURRECTION BAY PEAKS EACH YEAR AFTER FALL STORMS

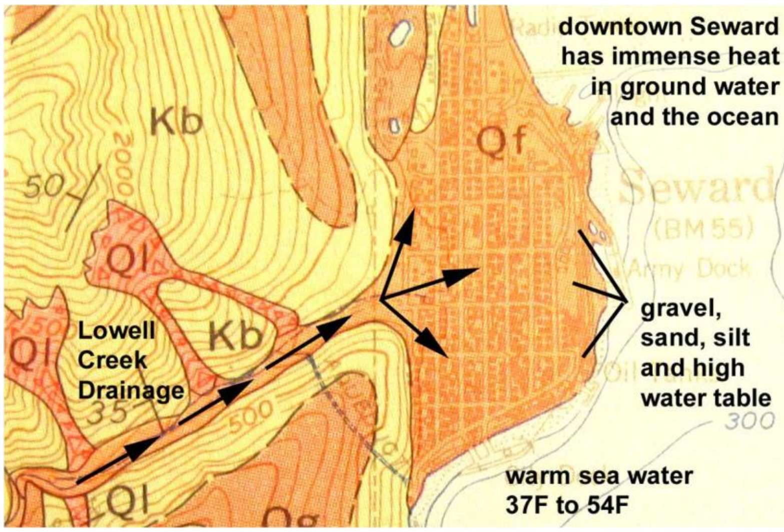
It has long been known that sea water temperatures in Resurrection Bay remain well above freezing through the long Alaska winter. The Bay stays ice free and is often steaming on cold days in early winter. This is due primarily to a large influx of warm sea water from the Alaska Coastal Current that is drawn into the bay each fall due to high volumes of fresh water storm runoff. The Alaska Coastal Current is in turn heated by the North Pacific Gyre that gains immense solar heat during its three year journey along the equator. Resurrection Bay is a world class source to operate a district heating system from.

Seawater temperatures recorded for a recent five-year period (2003 through 2008) at the Alaska SeaLife Center's raw seawater influent well were compiled to determine the average seawater temperature for each month. The maximum monthly seawater temperature (56F) and minimum monthly seawater temperature (37F) were also identified. As shown in the graph below, it is evident that the large mass of seawater contained in Resurrection Bay is slightly charged by local solar during the spring and summer months and is heavily charged by warm ocean currents in advance of the winter heating season.

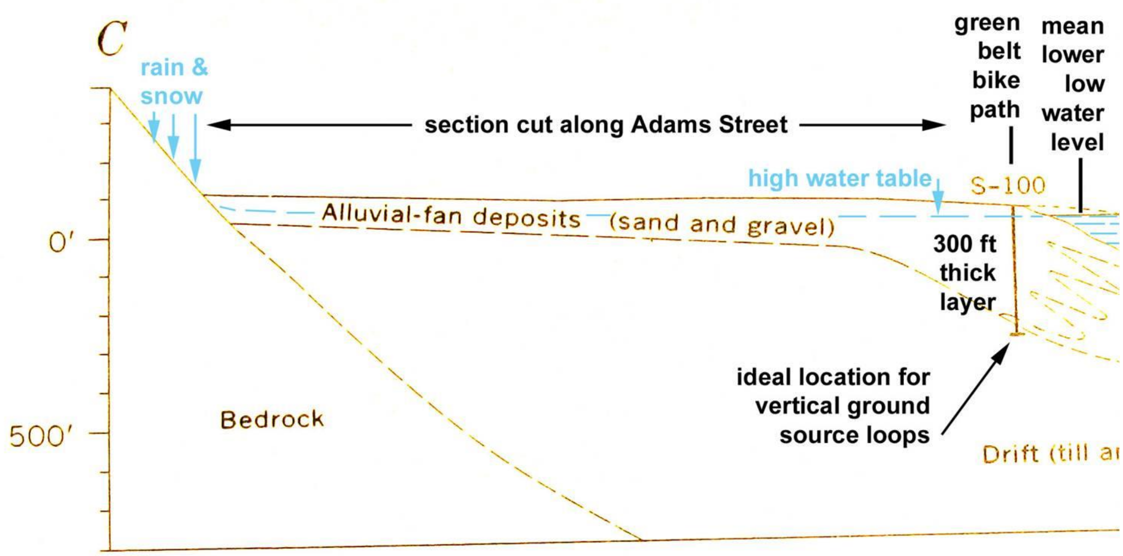


GEOLOGY AND SUB-SURFACE WATER RESOURCE BELOW WATER FRONT PARK

The existing geology and subsurface water resources of Waterfront Park in Downtown Seward show great promise as a utility grade heat source for ground source heat pumps. Most of the high density area of Seward rests upon an alluvial fan of gravel and silt deposits that have washed down from the Lowell Creek Canyon for thousands of years. Due to the steep sloping bedrock under the town site, the thickness of alluvial gravel along the shoreline is in excess of 300 feet thick. This thick layer of gravel is water saturated due to the presence of fresh water drainage from higher elevations, and seawater infiltration from the adjacent Resurrection Bay. The sea water heat is of great interest for this project.



In 1967, in response to the Good Friday Earthquake of 1964, the United States Geological Survey (USGS) compiled a report of the existing geology of Seward, with attention to the fracture zone that is parallel to the shoreline. Much of the infrastructure built along the shoreline prior to the 1964 earthquake, including rail tracks, fuel tanks, and buildings, were heavily damaged in the 1964 seismic event. The City of Seward owns the Waterfront Park that now exists adjacent to the shoreline between Ballaine Boulevard and the ocean, including the green belt bike path. A geologic profile section was developed along Adams Street, and a 300 ft deep borehole (S-100) was drilled to map the depth of gravel deposits.



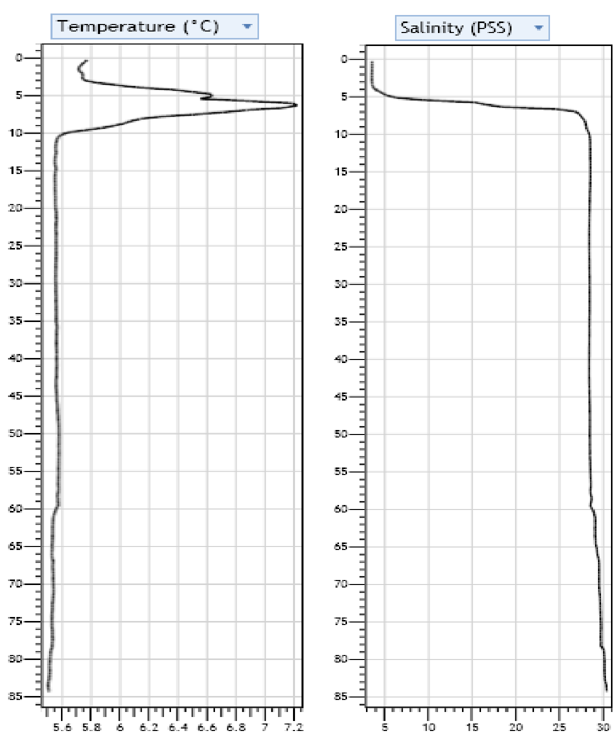
from 1967 Post-earthquake Geological Survey by USGS

DRILLING, CONSTRUCTION, AND TESTING OF TEST BOREHOLE NEAR BIKE PATH – AUG 2015

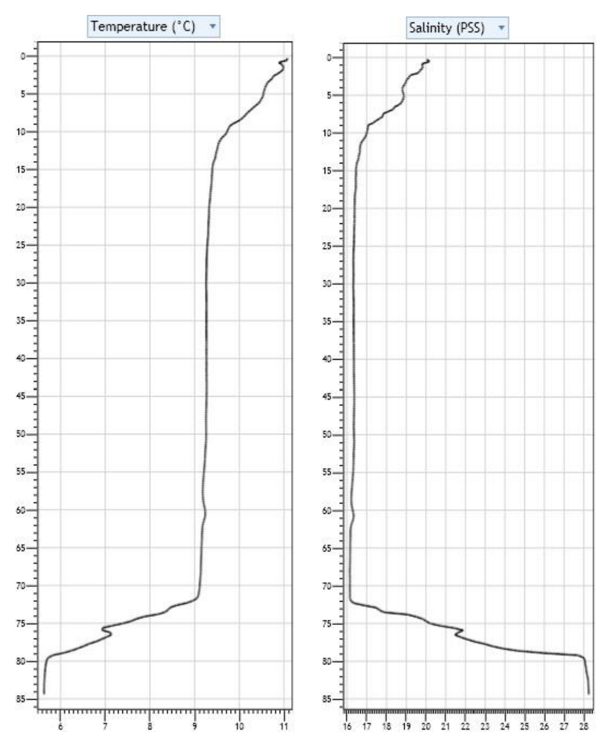
The City secured the services of Denali Drilling of Anchorage in mid July 2015 to install a 300 feet deep x 4" diameter screened test borehole near the Bike Path. The purpose of this test well was to allow measurement of the subsurface water column and confirm the influence of ocean tides in the aquifer below. The scope of the work was to drill and drive 6" diameter steel casing to depth, then insert the 4" PVC screened casing; and then extract the steel casing. This work was performed as required, leaving a 4" water column in the test borehole that closely resembles the natural water column in the aquifer.

Once installed, the City rented a Cast-Away marine data logger that could be lowered down the 4" water column. This data logger sampled temperature, salinity and depth once per second while being lowered and raised, thus profiling the thermal characteristics of the water column. Data was collected from mid August thru early September at both high and low tides to determine the difference in ocean tide influence. The data shows that the deeper portion of the aquifer (180ft to 300ft below water surface) remains a constant 42F with high salinity. The upper portion of the aquifer (0ft to 180ftbelow water surface) shows a strong influence of warm subsurface ocean water that peaks about 30 minutes after high tide. The temperature of ocean tide water in the test borehole closely resembles that measure off-shore at similar depth. The fact that warm ocean water is moving thru the gravel affords an attractive opportunity to extract heat from that ocean water via vertical HDPE ground loops that are piped to heat pumps in nearby buildings. Example temperature and salinity profiles from the data logger are below:

LOW TIDE (-1.6 ft) – AUG 18 2015 10:08am



HIGH TIDE (+12.1 ft) – AUG 31 – 3:14pm



The sub-surface water table begins at 18ft to 22 ft below grade. Vertical loops inserted in the deep gravel will then experience full contact with moving tidal water from 20ft below grade to 200 ft below grade. With 180 ft out of the 200 ft deep loop length submerged in water, and the use of double 1" HDPE u-bends in each production hole, it is anticipated that approximately 3.4 tons of heat pump capacity can be extracted from each production borehole constructed in this aquifer. The performance of these vertical loops in the deep gravel tidal zone is anticipated to be similar to a fully submerged lake or ocean loop system.

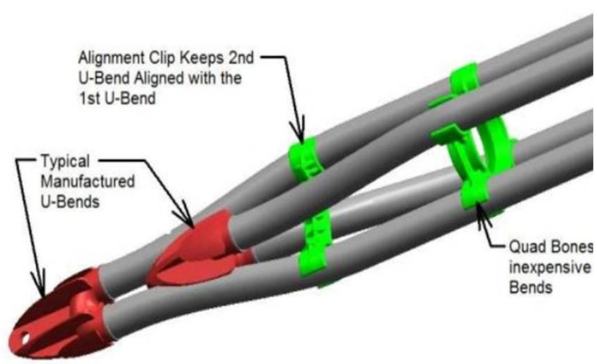
PROPOSED DESIGN OF VERTICAL GROUND LOOPS TO EXTRACT OCEAN HEAT

A field of 1" diameter HDPE vertical ground loops is proposed to extract source heat from tidal and ground water below Waterfront Park. A mixture of 80% water and 20% propylene glycol will be pumped 240 ft down hole in the 3/4" diameter HDPE SDR11 piping and looped back up to the surface, collecting tidal and ground water heat along this path. A field of vertical boreholes (each with double loops) spaced 20 feet apart will be piped in reverse return via horizontal manifold pipes buried 4 ft below the ground surface. This ensures that source glycol flow is always split evenly between the boreholes. An additional single loop of 1" HDPE will be inserted into the existing 4" test well also to 240 ft depth. 4" diameter HDPE SDR15.5 supply and return trunk line will deliver the ground source heat to the heat pump source side manifold. The entire ground source loop from the Library to Waterfront Park will be circulated via a pair of source side loop pumps arranged in main/standby configuration and located in the new Heat Pump Room in the Library basement.

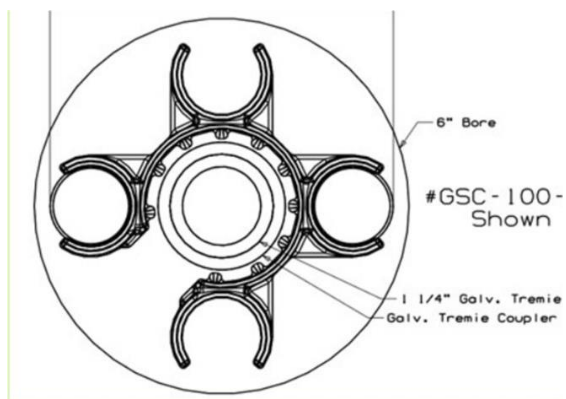
The heat extraction rate from the vertical ground loops will be enhanced by using two 3/4" diameter HDPE loops per 6" diameter hole that are held in separation by special "quad bone" clips. These high strength plastic clips are spaced every four feet along the vertical loops. The clips keep the four 3/4" diameter HDPE pipes equally spaced at the perimeter of the bore, so that any one pipe does not lose significant heat to another. In water saturated gravel this approach affords a marked increase in heat transfer rate as compared to a single loop in the same borehole.

For the four-building project, a total of 18 vertical drill holes of 6" diameter are proposed. This equates to 36 vertical loops of 3/4" HDPE in new boreholes plus one loop of 1" HDPE in the existing test hole for a total of 37 vertical loops that will be piped in reverse return to the supply & return manifolds. See also YCE Design Narrative For Seward HLP Ground Source System dated October 11 2022.

DOUBLE U-BENDS
2 typical HDPE U-Bends and Geothermal Sure Clips "Quad Bones"



Geothermal Sure Clip LLC
Double U-Bend Assembly



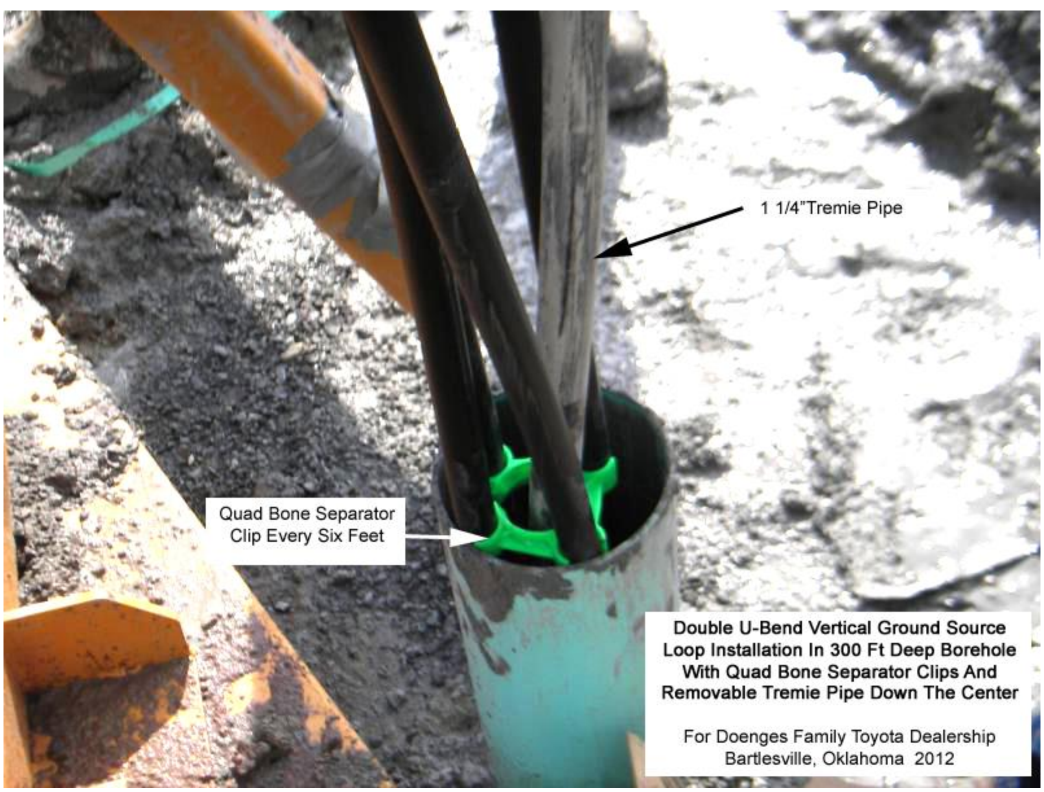
Discussions with drillers in the region suggests one possible procedure for 240 feet deep vertical loop installation in the deep and water saturated alluvial gravels below Waterfront Park near the bike path:

1. Drill and case the 6" diameter borehole to depth of 245 feet below grade. Bail out all material from inside the casing to full 245 ft depth. The casing will need to stay in place until vertical loops are inserted to keep the borehole from collapsing due to instability of loose alluvial sand and gravel submerged in the water table.

2. Fill HDPE double loops with water; install quad bone spacers; and to sink the loops to bottom of 240 ft deep casing using a 5 ft long rebar weight secured to downhole end of loops.

3. Extract casing slowly section by section, allowing the natural sand, silt and gravel down the hole to fall in and fill voids in between the four vertical 3/4" HDPE u-bend pipes.

EXAMPLE PROJECT USING DOUBLE U-BEND VERTICAL LOOPS WITH SEPARATOR CLIPS



TRENCHING OF SUPPLY & RETURN MAINS ALONG AND UNDER CITY STREETS AND ALLEYS

The quantity of open cut trenching required in both shoulder and paved streets to install district source heat piping is significant for the concept designs presented herein. The recommended strategy to minimize the cost of trenching, pipe installation, backfilling, and surface restoration is as follows:

- For ground source glycol mains from the Library to Waterfront, the use of pre-insulated SDR 15.5 HDPE with field heat fusion joints is recommended. The insulation will allow the pipe to be installed with the minimum cover of 4 feet above and allow the supply and return pipes to lay close together in the trench without heat loss to each other. The heat fusion joints will ensure long lasting integrity and flexibility of the piping at shallower depths below road grade. Vertical loops extending 200 ft below grade in Waterfront will be 1" HDPE SDR 11 piping.

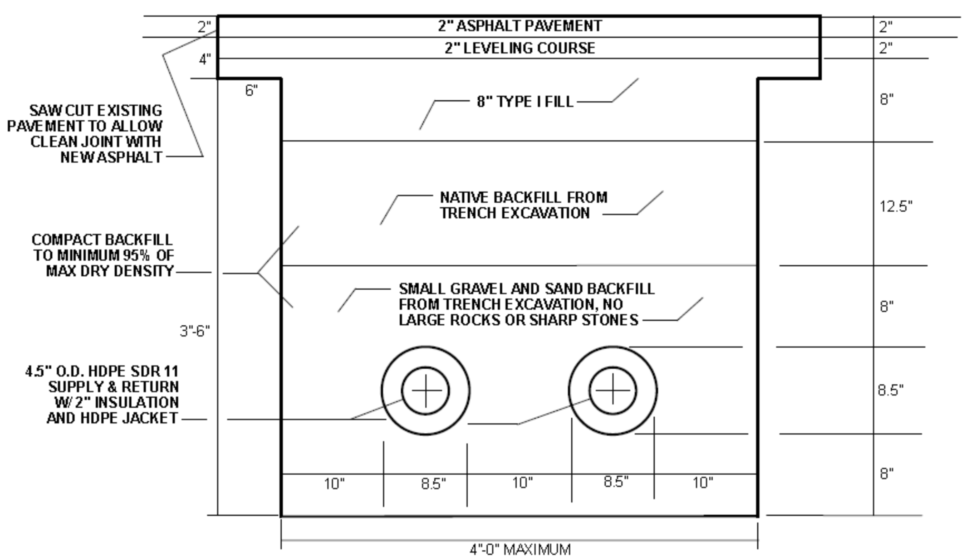
- For hot water hydronic supply and return from Library to/from other buildings, the use of flexible pre-insulated PEX, (Uponor Eco-Flex or equal) is recommended.

- The shallow cover depth above both source and hydronic supply and return mains will allow open trench excavation without trench boxes or wide cuts because the risk of trench wall collapse is very low. This reduces the amount of earth that must be removed and replaced, the cost of pipe installation, and the surface area to be restored. The shallow depth of the insulated mains also allows them to pass over deeper water and sewer mains without conflict.

- The native soil is well drained alluvial sand and gravel and this is likely suitable for both bedding and backfill material; this will reduce the need for importing materials to support and protect the pipe installation.

- The alignment of source mains along Adams Street from Ballaine Boulevard to Sixth Street can be routed in the unpaved shoulder on the south side of Adams Street where very few parallel buried utilities are known to exist.

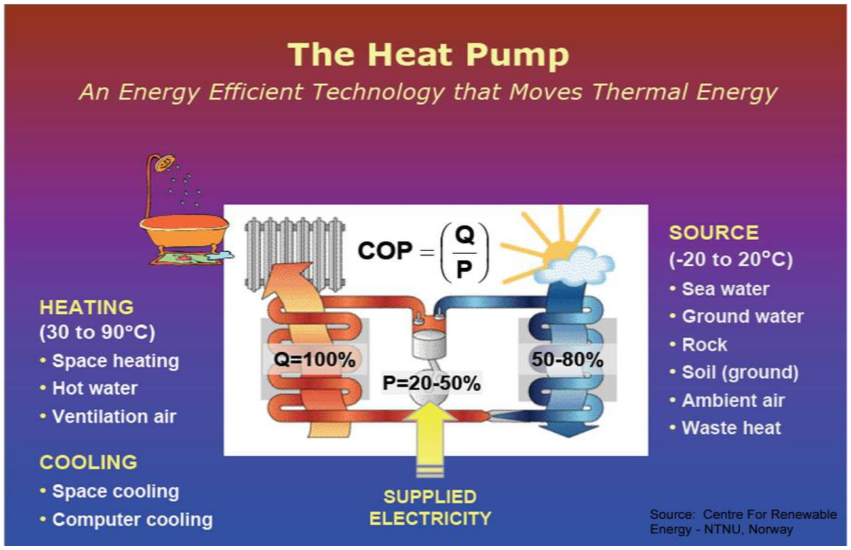
A typical pavement cut and trench section for the largest supply and return source trunk mains (4" inside diameter HDPE) is shown below. The detail shows that the shallow trench could be kept to a minimum of 4 feet width if native soils will hold a 3'-6" vertical face, this would reduce cost of trenching significantly.



PROPOSED PAVEMENT CUT AND TRENCH SECTION

NOT TO SCALE PREPARED BY ANDY BAKER, PE

GROUND SOURCE HEAT PUMP OPERATION AND COEFFICIENT OF PERFORMANCE (COP)



Coefficient Of Performance (COP) for a heat pump is the ratio of total heat output to electricity input. For ground source heat pump projects, a minimum COP value of 3.0 is desirable as this can lead to viable economic returns. Ground source heat pumps are water to water heat pumps that operate by using electricity powered compressors in combination with the physical properties of an evaporating and condensing fluid known as a refrigerant. The refrigerant used in the heat pumps in this evaluation is CO_2, known also as R-744. The vapor compression cycle of the CO_2 refrigerant is what allows heat to be lifted from ground temperature (36F to 46F) up to building loop temperature (149F to 194F). When the refrigerant vapor is compressed, its temperature is raised; this reality of physics is what allows the lifting of heat to occur at a high efficiency. It is typically far more cost effective to use a ground source heat pump than to make heat through the combustion of organic carbon, or through heat of resistance in an electrical element.

In addition to electricity used by the heat pumps, the total system COP must account for electricity use by all circulation pumps required for the heat pump system. For this project, this includes the ground source loop pump, individual source side pumps, individual load side pumps, and hydronic circulation pumps for buried heat loops from Library to City Hall Fire Hall, and Library to Annex.

The packaged CO_2 heat pumps selected for this project are identical to those operating successfully at the Alaska SeaLife Center since January 2016. They are Mayekawa Unimo each with 20-ton heating capacity.

PRELIMINARY DESIGN OF GROUND SOURCE DISTRICT HEATING SYSTEM

This design memorandum includes discussion of three options for the proposed district heat system. The option presented in the current DOE grant application is to serve all four City buildings with five 20-ton CO_2 heat pumps located in the Library basement. The second option is to serve the Library, Annex and City Hall with four 20-ton CO_2 heat pumps located in the Library. The third “economy” option for the project includes only the Library and Annex, both served by three 20-ton CO_2 heat pumps located in the Library basement.

The amount of ground source heat needed for the heat pump system options is estimated based on 54 gallons per minute (GPM) source flow for each CO_2 heat pump, and the heat transfer anticipated from the 240 feet deep vertical ground loops near the bike path in Waterfront Park. The borehole field and source glycol supply and return mains would be sized to meet the peak hourly heat load of the winter design day of 5 F outdoor air with moderate winds. A table that summarizes the sizing of critical elements of the source side loop is given below. The main supply and return noted below are the buried pipes that carry source glycol flow from the ground loops to and from the Library.

City Bldgs Served	Peak Hourly Load @5F Winter Day	# Of 3/4" Dia x 240' Deep Loops Req'd	Max Flow In Source Main	Diameter Of Source Main
Library, City Hall, City Annex & Fire Hall, Including snow melt	852,000 BTU/HR	36	150 GPM	4"
Library, City Hall, & City Annex, including snow melt	720,000 BTU/HR	30	120 GPM	4"
Library & City Annex, Including snow melt	480,000 BTU/HR	16	108 GPM	4”

Further description of critical elements of the proposed district heat system is given below:

Borehole Field - Vertical Ground Loops. Boreholes will be arranged in two rows with 20 feet separation between holes. A staggered arrangement along the bike path will allow equal access to ocean side heat for each set of vertical loops. A horizontal piping manifold buried 6 feet deep and extending along the boreholes will be piped in reverse return configuration, sending and returning an equal amount of flow to each vertical loop. A 4" diameter full depth (300 ft) test/monitoring hole was constructed by the City in 2015 to confirm the temperature, salinity and static level of the subsurface water resource. This test well will be converted to a production hole for source heat - by inserting into it a single 1” diameter u-bend loop to 240 feet depth. This test well will become part of the permanent vertical loop field.

Supply & Return Source Mains. There exists a nearly straight alignment along the south unpaved shoulder of Adams Street from Ballaine Ave to the Library that appears to be free of other parallel buried utilities. The alignment from the bike path to the north wall of the Library includes several perpendicular water and sewer main crossings, however these lines are at least six feet deep and the new trunk lines can cross above them. The supply and return source main are in practice a unitary closed loop that will be pressurized to approximately 30 psi at the highest point (Library basement) with a 20% propylene glycol / 80% clean water mixture for anti-freeze protection.

Glycol Source Main Pumps. Main/standby centrifugal pumps with integral VFD are proposed for the source side loop pumps; this ensures that adequate flow is delivered thru the long trunk mains and vertical ground loops. The source side pump will maintain a flow rate in accordance with the number of heat pumps placed on-line. 54 GPM of glycol source flow will be required for each CO_2 heat pump unit placed in operation. The ground source circulation pumps will be located in the new heat pump room in the Library basement, along with appurtenances to allow removal of sediment and trapped air, and to add glycol to the loop.

CO2 Heat Pumps And Secondary Source Side Loop Pumps. Smaller secondary glycol pumps will deliver to each CO_2 heat pump approximately 54 GPM of source side flow at 36F to 46F. The source side flow will pass thru the heat pump evaporator coils. The source side pumps are enabled when the heat pump is enabled by a call for heat from the buffer tank.

Load Side Loop Pumps. When operating, each CO_2 heat pump will receive 3 to 5 GPM load side flow at 90F to 120F and lift this load side flow to the range of 190F to 194F. Load side flow will pass thru an in-line strainer and the heat pump's internal gas cooler. The load side pumps are enabled when the heat pump is enabled by a call for heat from the buffer tank.

Buffer Tank. Unlike oil fired boilers that are designed to burn hard and fast to cover the immediate heat load in the hydronic system, the CO_2 heat pumps will work best by first supplying a 120-gallon buffer tank that then supplies the hydronic system. The buffer tank will level out the heat load demand that is required of the heat pumps and allow for higher efficiency operation.

Existing oil boilers. Existing oil boilers will be retained as a supplemental heat source in each building. This creates redundancy and reliability of the heating system and makes use of equipment already installed. The temperature set point at which the 120-gallon buffer tank will typically operate in winter is 180F. The buffer tank set point temperature will be continuously adjusted by an outdoor temperature reset schedule integral to the web-based heat pump operating system. The oil boilers will provide supplemental heat during extreme cold weather and high winds, and when heat pump units are taken off-line for maintenance or repairs.

Connections To Existing Hydronic Systems. The Annex, City Hall, and Fire Hall have medium temperature hydronic baseboards, and heating coils. The Library has low temperature radiant floors and some medium temperature heating coils. Hydronic heat from the CO2 heat pump system will be delivered to the return side of existing boilers in each building.

Heat Pumps Performance Will Be Enhanced By Heat Recovery. Waste heat recovery from the existing mechanical room, and the new heat pump room, will be included in the heat pump system design.