

City of Whitehorse

ISSUED FOR USE

**DISTRICT HEATING AND WASTE HEAT
COLLECTION FEASIBILITY STUDY
WHISTLE BEND NEIGHBOURHOOD DEVELOPMENT
WHITEHORSE, YUKON**

W23101141.005

August 14, 2009

EXECUTIVE SUMMARY**Introduction, Purpose and Scope**

EBA Engineering Consultants Limited (EBA) conducted a District Heating and Waste Heat Collection Feasibility Study for the planned Whistle Bend Neighbourhood (WBN) development for the City of Whitehorse (City), Yukon.

The broad purpose of this study is to determine the potential for hybrid geoexchange-based district heating and waste heat recovery for the WBN. Earlier parts of this program were reported in Interim Progress Report #1 (July 25, 2008) and Interim Progress Report #3 (January 20, 2009). This summary report presents the remaining work, and conclusions and recommendations for the entire project.

Geoexchange Ground Heat Exchangers

EBA completed an analysis of plausible ground heat exchangers (GHXs) for the WBN. Two practical GHX closed loop options were evaluated in detail: Vertical Drilled Borehole and Horizontal Trench. Based on a ten-point analysis, a Vertical Drilled Borehole Closed Loop GHX was shown to be the leading ground coupling option for the WBN.

Hybrid Heat Sources

For the WBN, it is neither practical nor economically feasible to design the GHX for 100% of the heating loads. Thermal assistance is required from hybrid heat sources (e.g., sewer heat recovery, solar thermal and/or auxiliary boiler systems).

Sewer heat recovery was assessed for a variety of pickup points and heat recovery technologies (both in-stream and out-of-stream methods). The best potential for sewer heat recovery is at the proposed central WBN Lift Station, based on heat source, constructability, and cost factors.

Solar thermal (glazed flat plate) collectors were considered as a practical way to offset demands on the GHX and reduce system cost. These collectors would best be mounted on commercial building rooftops (to minimize heat losses and inhibit vandalism).

The peaking heating concept presented here includes an oil-fired boiler, but other fuels could be considered depending on future availability and cost.

District Energy System Evaluation

The intended energy use of a geoexchange-based district energy system (DES) presented here is space heating only. Domestic hot water heating and space cooling were not considered. EBA developed a series of concept basis statements, clarifying geoexchange basis, schedule, extractable sewer heat, method to calculate building loads, and use of DES energy, as a foundation for the DES evaluation. EBA developed and used these six representative DES analysis scenarios:

- Scenario 1 – Development Area 1 only;
- Scenario 2 – Development Area 2 only;
- Scenario 3 – Development Areas 1 and 2;

- Scenario 4 – Development Area 4 only;
- Scenario 5 – All Development Areas except 2H and 5; and
- Scenario 6 – All Development Areas.

Figure 6.2 (in report) shows a conceptual diagram of a geoexchange-based hybrid DES for the WBN. The concept centers around a common low-temperature supply pipeline distributing energy in the form of an environmentally-friendly, water-based antifreeze solution to points of use, and allows a variety of lower-grade heat sources or sinks to be added during future growth.

EBA conducted optimization analyses to seek the minimum life-cycle cost over 50 years for each of the DES scenarios. Investment rate-of-return (ROR) was used as the economic indicator (i.e., true interest yield provided by the project equity over its life before income tax), calculated using the pre-tax yearly cash flows over the project life.

Optimization plots were constructed for each scenario (with and without sewer heat recovery), displaying the 50-yr rate of return as a function of GHX size, number of solar collectors, and annual energy fraction contributed by a peaking system. Scenario 3 is the preferred DES option, based on highest ROR (6.7% and 7.2%, with and without sewer heat recovery, respectively).

Without sewer heat recovery, this includes a GHX with nominally 250 100-m deep boreholes, 3,000 solar thermal collectors and a peaking boiler system supplying 9% of the annual heating load, with a capital cost of about \$15.2 million. With sewer heat recovery, this includes a GHX with nominally 500 100-m deep boreholes, 3,000 solar thermal collectors and a peaking boiler system supplying 1% of the annual heating load, with a capital cost of about \$18.8 million.

Environmental Benefits and Effects

Environmental benefits of utilizing a hybrid geoexchange DES include avoided greenhouse gas (GHG) emissions, improvement in outdoor air, reduced use of fossil fuels, greater adherence to City of Whitehorse sustainability principles and practices, and a leadership position in Canada, as this would be one of, if not the, largest geoexchange-based DES installations in northern Canada. Implementing Scenario 3 with sewer heat recovery would save about 1.25 million litres of fuel oil per year, or about 3,350 equivalent tonnes of CO₂ emissions per year, which is equivalent to removing about 680 cars and light trucks from the road, or planting 1,150 hectares of carbon-absorbing forest.

Potential environmental effects include groundwater and runoff control during construction and GHX drilling, aesthetic effects associated with road construction and installing solar panels, operational noise, disruption of green space, spills from peaking boiler fuel sources, and potential releases of antifreeze liquid used in the GHX and DES distribution piping.

The WBN is located within the traditional territories of the Kwanlin Dun First Nation and the Ta'an Kwach'an Council. A DES for the WBN should be designed to accommodate future expansion, and developers should keep the First Nations apprised of future design features.

Proponents should be aware of the Yukon Environmental and Socio-Economic Assessment Act (YESAA), administered by the Yukon Environmental and Socio-economic Assessment Board (YESAB). EBA does not see a need for the proponent to apply for a YESAA assessment for the DES, separate from the subdivision development.

Ownership and Financial Options

DES case studies show useful lessons learned: every project is unique, a simple approach is important, a strong promoter is needed, funding methods affect project development, secured customers are important, and a successful DES is a source of community pride.

Ownership/operation models range from full public sector (local or territorial government) ownership and operation to full private ownership and operation. Ownership allows control of the system, but also incurs liability and requires management expertise. Operation requires technical expertise, service equipment and infrastructure, administration and billing capacity. Some hybrid public/private ownership and operation model may be most suitable for the WBN development.

Financing options include community bonds, lease-purchase, revolving energy funds (like the FCM Green Municipal Fund), or a joint equity partner. Potential funding sources include user fees, taxes and local improvement charges, and grants from various funding agencies. A summary table of grant information is presented for a range of possible federal and territorial sources.

Project Meetings and Presentations

EBA presented findings of this study for review and discussion to the City of Whitehorse Council and Senior Management and at a Public Open House on June 25, 2009.

Conclusions and Recommendations

The conclusions of this report are:

1. Based on our preliminary analysis, neither gas-based or air-source heat pump alternatives to a geotransfer-based district energy system make economic or practical sense for the WBN at this time.
2. Vertical drilled borehole closed loop ground heat exchangers are the most suitable ground coupling option for the WBN.
3. The preferred location for sewage heat recovery at the WBN is at the planned central lift station.
4. A hybrid geotransfer-based district energy system for Development Areas 1 and 2 combined (Scenario 3) is the preferred option, based on investment rate of return (6.7% and 7.2%, with and without sewer heat recovery, respectively).
5. It would not be recommended to apply for a YESAA assessment for the DES separate from the subdivision development. However, it is important to contact the assessment agency early in the process to discuss the project scope.
6. A hybrid model of part public/private ownership and operation may be most suitable for the WBN development.

The recommendations of this report are:

1. The City of Whitehorse should assess the findings of this study, including technical results, economic factors, funding sources, and ownership options, to decide whether to proceed with a DES for the WBN development.
2. If the City wishes to proceed with a DES, it should identify an internal project champion to direct and advise throughout future aspects of DES development.
3. If the City wishes to proceed with a DES, it should promptly engage a professional team to design the DES in coordination with the planning and construction schedule for the development.
4. The City should stay aware of regulatory requirements and maintain regular liaison with First Nation groups with property within or adjacent to the WBN development.

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EXECUTIVE SUMMARY	i
1.0 INTRODUCTION.....	1
1.1 General Introduction	1
1.2 Purpose	1
1.3 Scope	1
1.4 Previous Project Reports	4
1.5 Organization of the Report.....	4
1.6 The Project Team	5
2.0 PROJECT DESCRIPTION.....	5
2.1 Concept Development Plan	5
2.2 Development Areas and Build-Out Schedule.....	6
2.3 Intended Energy Use	7
2.4 Estimation of Building Loads.....	8
2.4.1 Building Areas.....	8
2.4.2 Building Heat Characteristics.....	10
2.4.3 Expected Heating Loads.....	11
2.5 Base Case Fuel	14
2.6 Alternatives to the District Geoexchange Concept.....	16
2.6.1 Propane vs. Natural Gas Infrastructure	16
2.6.2 Individual Air-Source Heat Pumps	16
3.0 GEOEXCHANGE OPTIONS ANALYSIS.....	18
3.1 Ground Heat Exchanger Alternatives Analysis	18
3.1.1 Types of Ground Heat Exchangers.....	18
3.1.2 Comparative Ground Heat Exchanger and Constructability Assessment	18
3.1.3 Assessment Criteria for Practical Options.....	19
3.2 Potential Borehole Drilling Areas	20
3.3 Maximum Ground Heat Exchanger Load.....	21
4.0 SEWER HEAT RECOVERY OPTIONS	22
4.1 Location and Magnitude of Sewer Heat.....	22
4.2 Sewage Heat Recovery Options.....	26
5.0 OTHER HYBRID TECHNOLOGY OPTIONS.....	28
5.1 Solar Thermal	28

	PAGE
5.2 Peaking Boiler.....	29
6.0 DISTRICT ENERGY SYSTEM EVALUATION.....	29
6.1 Concept Basis.....	29
6.2 Evaluation Scenarios	30
6.3 Hybrid Geoexchange District Energy Concept.....	31
6.3.1 Ground Heat Exchanger	32
6.3.2 Geoexchange Heat Pumps (Water-to-Water, Water-to-Air).....	32
6.3.3 Peaking Boiler.....	34
6.3.4 Solar Thermal and Sewer Heat Balancing	35
6.3.5 Infrastructure Requirements	35
6.4 Optimization Analysis	38
6.4.1 Scenario 1	41
6.4.2 Scenario 2	43
6.4.3 Scenario 3	44
6.4.4 Scenario 4	46
6.4.5 Scenario 5	48
6.4.6 Scenario 6	49
6.4.7 Cost Estimates for District Energy Alternatives.....	51
6.4.8 Preferred Scenario.....	52
6.4.9 Environmental Effects and Benefits	56
6.4.10 Operational Matters	57
6.4.11 First Nations Matters.....	57
7.0 REGULATORY ISSUES	58
7.1 Environmental and Socioeconomic Assessment	58
7.2 Yukon Permitting Requirements	59
7.3 Yukon Utilities Board	59
8.0 OWNERSHIP OPTIONS AND MARKET ANALYSIS	60
8.1 Case Studies	60
8.2 Ownership and Operation Options.....	61
9.0 FINANCING AND FUNDING OPTIONS	62
9.1 Financing Options.....	62
9.2 Funding Options	62
10.0 PROJECT PRESENTATIONS.....	63

	PAGE
10.1 Council and Senior Management Meeting	63
10.2 Public Open House	63
11.0 CONCLUSIONS AND RECOMMENDATIONS.....	63
11.1 Conclusions	63
11.2 Recommendations	64
12.0 CLOSURE.....	64
13.0 REFERENCES.....	66

TABLES

Table 2.1	Build-Out Schedule for Development Areas (in body of report)
Table 2.2	Summary of Building Floor Areas and Building Characteristics (in body of report)
Table 2.3	Summary of Expected Heating Loads (in body of report)
Table 3.1	Plausible Ground Heat Exchanger Options for WBN (in body of report)
Table 3.2	Scoring Evaluation Table for Ground Heat Exchanger Options at the WBN (in body of report)
Table 3.3	Summary of Potential Number of Boreholes within the Whistle Bend Neighbourhood
Table 4.1	Summary of Sewage Flows in and Near the Whistle Bend Neighbourhood Site (in body of report)
Table 4.2	Summary of Sewage Heat Recovery Options (in body of report)
Table 6.1	Input Parameters for Economic Analysis
Table 6.2	Summary of Capital Costs for Each Evaluation Scenario (in body of report)
Table 6.3	Projected Annual Cash Flows for Near-Optimum Hybrid Combination of Each Evaluation Scenario (Appendix C)
Table 8.1	Summary of Case Studies for District Energy Systems
Table 8.2	Summary of Ownership and Operation Options for Whistle Bend Neighbourhood DES (in body of report)
Table 8.3	Summary of Funding Options for Whistle Bend Neighbourhood DES

FIGURES

- Figure 1.1 Location of Whistle Bend Development Area
- Figure 1.2 Air photo of Site with Borehole and Well Locations
- Figure 2.1 Final Concept Development Plan
- Figure 2.2 Graph of Historical Residential Propane and Fuel Oil Prices (in body of report)
- Figure 3.1 Potential Borehole Drilling Areas
- Figure 4.1 Sewage Temperature Monitoring Sites, City of Whitehorse
- Figure 4.2 Summary Plots of Sewage Temperature Monitoring Results, April 2009
- Figure 6.1 Summary of District Energy System Analysis Scenarios, Whistle Bend Neighbourhood
- Figure 6.2 Schematic Diagram of Geoexchange-Based Hybrid District Energy System for the Whistle Bend Neighbourhood
- Figure 6.3 Scenario 1 Optimization Plots (in body of report)
- Figure 6.4 Scenario 2 Optimization Plots (in body of report)
- Figure 6.5 Scenario 3 Optimization Plots (in body of report)
- Figure 6.6 Scenario 4 Optimization Plots (in body of report)
- Figure 6.7 Scenario 5 Optimization Plots (in body of report)
- Figure 6.8 Scenario 6 Optimization Plots (in body of report)
- Figure 6.9 Pie Chart of Capital Cost Breakdown for Scenario 3 (in body of report)
- Figure 6.10 Sensitivity of Major Cost Items on 50-year Rate of Return for Scenario 3 (in body of report)

APPENDICES

- Appendix A Geo-Environmental Report - General Conditions
- Appendix B Sewer Heat Recovery Information
- Appendix C Projected Annual Cash Flows for Each Evaluation Scenario

1.0 INTRODUCTION

1.1 GENERAL INTRODUCTION

EBA Engineering Consultants Limited (EBA) is pleased to present this Issued for Use report to the City of Whitehorse (City) summarizing the District Heating and Waste Heat Collection Feasibility Study for the Whistle Bend Neighbourhood Development, in Whitehorse, Yukon. This project was conducted according to the scope of work within the Request for Proposal dated May 12, 2008 from the City for a planned community development at the Porter Creek Bench (later named the Whistle Bend Neighbourhood (WBN)). Amendments to the original scope of work are described in Section 1.3.

Figure 1.1 shows the location of the WBN along a bend in the Yukon River, northeast of the neighbourhood of Porter Creek, and approximately seven kilometres north of the Whitehorse International Airport. Further details of physical setting, topography and drainage, geology and groundwater, climate parameters and vegetation at the WBN are presented in Interim Progress Report #1 (EBA, 2008).

Figure 1.2 shows an air photo image of site including the study area boundary (dashed line) and approximate total footprint of the WBN development (solid line).

This work was conducted in parallel with a planning/engineering study for the WBN conducted for the City by AECOM Ltd. We (the EBA team) acknowledge and appreciate the useful and open communication with the AECOM team during the course of our assignment.

1.2 PURPOSE

The broad purpose of this study is to determine the district heating and waste heat recovery potential for the planned WBN in Whitehorse, Yukon. As per the RFP, the WBN is expected to be developed to meet the City's sustainability goals of a green community that encourages energy efficiency. Based on a planning and design charrette held by the City in November 2006, alternative energy strategies were identified as key in developing a sustainable community, including geoexchange and district heating, capturing waste sewer heat, and involving hybrid technologies such as solar thermal. Based on this emphasis, this project has focused on a geoexchange basis, with addition of hybrid technologies.

1.3 SCOPE

The RFP identified two parts to this project: Part 1 – Information Gathering, and Part 2 – Technical Evaluation. Around this framework, we originally identified seven discrete work tasks with six milestone deliverables for the whole project as follows:

Task 1 – Project Management

- Project Initiation, Project Management, and Project Updates.

Part 1 – Information Gathering

Task 2 – Client Liaison

- Kick-off meeting, communication strategy, site visit (reconnaissance level).

Task 3 – Information Gathering and Technical Overview

- Gather/review background reports and City Development Plans.
- Renewable energy overview, annotated bibliography and case studies.
- Interim Progress Report #1 (*Milestone 1*).

Part 2 – Technical Evaluation

Task 4 – RFP Phase 1 Desktop Study

- Plausible ground heat exchanger (GHX) and waste heat recovery (WHR) options.
- Site visit and detailed inspection.
- Acceptance criteria & short list options.
- Estimate thermal properties; design/constructability comments.
- Capital, life cycle, cost benefit, payback analysis.
- Operational concerns; future growth potential.
- Environmental & regulatory factors.
- Ownership options; City energy capacity and ability to implement energy system.
- Market analysis; funding incentives.
- Interim Progress Report #2 (*Milestone 2*).

Task 5 – RFP Phase 2 Intrusive Testing

- Contractor quotes; test borehole siting and underground clearances.
- Drill and grout 2 closed loop test boreholes.
- Formation thermal conductivity (FTC) test.
- Drill/install one test water well.
- Water levels and temperature profiling.
- Step-drawdown and constant rate test.
- Groundwater field chemistry and sampling/lab analysis.
- Testpits near sewer lines.

- FTC and well hydraulic data analysis.
- Interim Progress Report #3 (*Milestone 3*).

Task 6 – RFP Phase 3 Selection of Geoexchange and Sewer Heat Options

- Options decision analysis for GHX and WHR options (using Stage 2 GSA method).
- Economic analysis and cost summary for options.
- Prepare presentation for facilitated meeting.
- Facilitated meeting with City and stakeholders (*Milestone 4*).

Task 7 – Reporting

- Internal senior review; summary report Issued for Review (*Milestone 5*).
- City review; report Issued for Use (*Milestone 6*).

The original scope and schedule of this project was modified in agreement with Kinden Kosick for the City, as follows:

- Part 1 was completed as planned and reported as Interim Project Report #1 (EBA, 2008).
- Part 2, RFP Phase 1 (Desktop Study) was rolled into this summary report.
- Part 2, RFP Phase 2 (Intrusive Study) was modified to exclude the FTC testing, and the water well drilling and testing, based on Part 1 findings and the results of drilling the two test boreholes. The Heiland water well was accessed for thermal profiling and water quality testing. Based on previous geotechnical work around the sewer line leading down to the Yukon River from Porter Creek, the testpit program around the sewer line was also deleted. Following the numbering in the RFP, the resulting Phase 2 work was reported as Interim Project Report #3 (EBA, 2009).
- In lieu of deleted fieldwork elements, the work scope of Part 2, RFP Phase 3 (Selection of Geoexchange and Sewer Heat Options) was expanded to include two meetings (one with Council and Senior Management and a Public Open House meeting), greater detailed assessment of hybrid technologies, and expanded review of case studies.
- In October, 2008 following our intrusive program, we put further work on hold while final concept plan options were developed by the AECOM group for selection by the City. At the end of February 2009, a final concept plan was accepted by the City and our project work resumed. We held a joint coordination project meeting on March 20, 2009 in City offices with EBA, City, and AECOM attendees to coordinate remaining work on this geoexchange feasibility project.

1.4 PREVIOUS PROJECT REPORTS

This section provides a summary of the three interim progress reports prepared for this project. These interim progress reports form integral parts of the overall reporting for this project.

Interim Progress Report #1 (Part 1: Information Gathering and Technical Overview)

This report (EBA, 2008) covered the initial information gathering and technology overview for the project including; project location, physical setting, geology and groundwater, climatic conditions, site visit findings, city development plans and an overview of geoechange-related renewable energy options.

The key conclusion of this study was that a district, low-temperature, baseload geoechange system with separate peaking system would be an appropriate general approach for heating and cooling requirements of the WBN.

Interim Progress Report #2 (Part 2: Phase 1 – Desktop Study)

As agreed with the City, the Part 2, Phase 1 Desktop Study component of this project was rolled into this summary project report.

Interim Progress Report #3 (Part 2: Phase 2 – Intrusive Testing)

This report (EBA, 2009) included a summary of the field investigations conducted in August and September 2008; including borehole drilling and U-tube installation, groundwater extraction potential, groundwater quality, soil conditions along the sewer main right of way, Yukon River temperatures and flows and deep ground temperatures and expected soil thermal conductivities. Figure 2.1 shows locations of boreholes and wells for that work.

The key conclusions were that:

- Closed loop vertical boreholes to depths of 61 m (200 ft) are expected to encounter silts and clays with a formation thermal conductivity of 1.5 to 2.0 W/m²K and deep ground temperatures of about 2.7°C.
- Aquifer conditions at the site are not likely able to support a district energy system, but may be suitable for individual home or building open loop geoechange applications.
- Native soils surrounding the sewage main on the west side of the development area consist mainly of aeolian sand, consistent with shallow soils observed elsewhere on the site.

1.5 ORGANIZATION OF THE REPORT

This report is organized in 14 sections. Sections 1 and 2 present an introduction and project description. Sections 3, 4 and 5 describe geoechange, sewer heat recovery, and other hybrid technology options pertinent to the WBN. Section 6 presents the technical and economic appraisal of district energy system (DES) alternatives for the WBN. Sections

7, 8 and 9 present regulatory issues, ownership options and market analysis, and financing and funding options applicable to the WBN. Section 10 summarizes the two project meetings held with the City and public. Sections 11-14 present conclusions and recommendations, limitations, closure and references for this report. Figures and Tables are presented both within and at the end of the report. Appendices include EBA's general conditions and supplementary information.

1.6 THE PROJECT TEAM

The project team consisted of EBA, FSC Architects & Engineers Ltd. (subconsultant to EBA), and Dr. Andrew Chiasson, P.Eng. (Associate Engineer to EBA). The following list presents key personnel and their involvement with this project:

- H. Scott Schillereff, Ph.D., P.Geo. (Principal Consultant, EBA) – Project Manager, fieldwork coordinator, geoexchange options assessment, project meetings coordinator, report coordinator.
- Andrew Chiasson, Ph.D., P.Eng. (Associate Energy Engineer to EBA) – Geoexchange options assessment, DES concept development, cost-benefit analyses for analysis scenarios, assistance with project meetings and reporting.
- Lee Fleming, P.Eng. (Senior Mechanical Engineer, FSC) – waste heat recovery options, assistance with DES concept, project meetings, and reporting.
- Katherine Johnston, P.Eng. LEED AP (Geoexchange Engineer, EBA) – Fieldwork manager, geoexchange options assessment, assistance with reporting.
- Patricia Randell, M.Sc. (Assessment and Regulatory Specialist, EBA) – Project assessment, regulatory and First Nations matters, assistance with project meetings.
- Bengt E. Pettersson, B.Sc., M.A., CCEP (Project Director, Whitehorse Environment Group, EBA) – Regulatory matters, report review.

2.0 PROJECT DESCRIPTION

2.1 CONCEPT DEVELOPMENT PLAN

Figure 2.1 shows the concept development plan adopted by the City and used as the basis for the feasibility work presented here. This is based on the AECOM Final Concept Plan (Revision 6). Minor adjustments to this concept plan should not greatly affect the findings and results presented here.

Figure 2.1 shows six different types of building allocations (Housing Mix A, Housing Mix B, Mixed Use, Commercial, Community Use and School), and four types of recreation or protected areas (Parks and Trails, Active Recreation Area, Natural and Protected Area, and Environmentally-sensitive Area). These building and areas are described in more detail below.

- **Housing Mix A** is a mix of lower density residential development including large single family lots, duplexes, townhouses, and modest condo developments. This mix of housing is focused on the single family/duplex/townhouse level of development.
- **Housing Mix B** is a mix of higher density residential development including small single family lots, duplexes townhouses, condos, and apartment blocks. This mix of housing is focused on townhouse, condo, and apartment level development.
- **Mixed Use** is a mix of residential and commercial development intended to provide vibrancy to the core of the neighbourhood. This development would have commercial on the ground floor with residential above.
- **Commercial** incorporates typical commercial development including grocery stores, doctor's offices, and other neighbourhood level commercial enterprise.
- **Community Use** areas are intended to incorporate amenities for the neighbourhood. Uses could include community gardens, playgrounds, recreation centres, and senior's housing.
- **School** sites for Whistle Bend include two elementary schools and one high school.
- **Parks and trails** provide pedestrian links and green space throughout the neighbourhood. These areas include the "green fingers" and perimeter loop trail system.
- **Active Recreational Areas** refer to the Mountain View Golf Course and the Horse and Rider Association.
- **Natural and Protected Area** is the area left undeveloped as a neighbourhood buffer. This area will remain for passive recreation usage.
- **Environmentally-Sensitive Areas** are areas which are environmentally sensitive due to wild life, ecosystem, or slope values.

2.2 DEVELOPMENT AREAS AND BUILD-OUT SCHEDULE

The six numbered Development Areas (1, 2/2H, 3, 4, 5, and 6 on Figure 2.1) were identified at the March 20, 2009 project meeting, for geographic identification and clarity in this project. These are referred to as Development Areas (rather than phases), to avoid implying a sequence of construction. Development Area 2H refers to the specific parcel owned by the Heiland family, within the overall Area 2. Development Area 5 is owned by the Ta'an Kwach'an Council. Other Development Areas are owned by the Yukon Territorial Government.

Table 2.1 presents a summary of the anticipated development schedule for all of the Development Areas, based on information obtained from the City.

TABLE 2.1 BUILD-OUT SCHEDULE FOR DEVELOPMENT AREAS		
Development Area	Infrastructure	Building Construction
1	2010-2012	2012-2018
2*	2010-2012	2013-2018
2H	2012-2014	2014-2020
3	2016-2018	2018-2023
4	2021-2023	2023-2028
5	2016-2018	2018-2025
6	2026-2028	2028-2033

Note: * = excluding Development Area 2H.

The overall span of development ranges from 2010 through 2033, or 23 years. We understand that the initial phase of development will most likely include Development Areas 1 and 2. Depending on the interests of current land owners, and the success of this initial development phase, the timing of subsequent development may vary from that shown in Figure 2.1. However, these dates constitute a reasonable estimate of anticipated development for the WBN for purposes of this study.

2.3 INTENDED ENERGY USE

The intended use of energy delivered by the geoexchange district heating system is space heating only. Domestic hot water heating is not considered, and is assumed to be provided by other means (i.e., electric) at the preference of each individual building owner. This design basis was chosen in consultation with the City's Planning and Development Services Department.

Space cooling is not considered here, as an intended energy use of the geoexchange district heating system, but cooling is possible and beneficial to the system. As described later in this report, the design concept of the geoexchange district heating system utilizes distributed geoexchange heat pumps; that is, heat pumps are located in the buildings they serve, and are not centrally-located. This design allows for options to provide cooling as well as heating with the same heat pump appliance; each individual building could operate its own heat pump as desired. Operating heat pumps in cooling mode would benefit the district geoexchange system because space cooling results in heat being rejected to the ground heat exchanger, thus replenishing energy extracted during heating season and improving its thermal performance. Energy metering and billing could be structured such that customers are charged only for energy that they consume from the district system, and are not charged for energy that they return to the system.

In summary, the intended use of energy provided by the geoexchange district heating system is for space heating only. Domestic hot water heating is not considered, and is assumed to be left to individual customer preference. As a conservative assumption, space cooling was also not considered. Some cooling will likely occur in buildings since the individual heat pumps can both heat and cool. Operating heat pumps in cooling mode will

benefit the ground heat exchanger by replenishing energy extracted during the heating season.

2.4 ESTIMATION OF BUILDING LOADS

2.4.1 Building Areas

A necessary first step in estimating the heating loads of the Whistle Bend Neighbourhood involves estimating the floor space of buildings.

A summary of building floor areas per building type is shown in Table 2.2. The floor areas per development area and building use type were calculated from density factors (i.e., building floor area per hectare of land, or m²/ha) provided by the City's Planning and Development Services Department. These factors were based on a number of considerations such as planned lot sizes, expected building sizes, and planned population density. The land area occupied by each building use type in each development area was determined by EBA by digitizing the colour-coded areas shown in Figure 2.1. Floor areas for the schools were provided directly by the Planning and Development Services Department.

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TABLE 2.2 SUMMARY OF BUILDING FLOOR AREAS AND BUILDING CHARACTERISTICS

Use	Colour Code (Figure 2.1)	Floor Area per Hectare* (m ² /ha)	Land Area of Development (ha) (Floor Area (m ²))								% of Total
			Dev. Area 1	Dev. Area 2	Dev. Area 2 (H)	Dev. Area 3	Dev. Area 4	Dev. Area 5	Dev. Area 6	Totals	
Housing Mix A	Yellow	2,717	7.9 (21,402)	12 (32,049)	5.6 (15,332)	8.4 (22,799)	0.0 (0.0)	16 (43,432)	19 (52,879)	69 (187,893)	50.8% (40.6%)
Housing Mix B	Brown	4,245	5.5 (23,233)	5.7 (24,131)	0.2 (867)	13 (54,887)	5.7 (24,347)	6.7 (28,560)	4.0 (17,022)	41 (173,047)	30.0% (37.4%)
Mixed Use - Residential	Pink	2,555	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.6 (1,634)	3.0 (7,636)	1.1 (2,843)	0.0 (0.0)	4.7 (12,113)	3.5% (2.6%)
Mixed Use - Commercial**	Pink**	2,555	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (545)	1.0 (2,545)	0.4 (948)	0.0 (0.0)	1.6 (4,038)	1.2% (0.9%)
Commercial	Red	9,000	2.3 (20,724)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	3.3 (29,336)	0.0 (0.0)	0.0 (0.0)	5.6 (50,060)	4.1% (10.8%)
Community	Orange	4,500	0.0 (0.0)	0.5 (2,405)	0.0 (0.0)	1.2 (5,217)	1.9 (8,535)	1.1 (5,005)	1.1 (4,969)	5.8 (26,131)	4.3% (5.6%)
School	Blue	***	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	5.2 (7,500)	0.0 (0.0)	3.2 (2,500)	8.4 (10,000)	6.2% (2.2%)
Totals			16 (65,359)	18 (58,585)	5.8 (16,199)	23 (85,082)	20 (79,899)	25 (80,788)	28 (77,370)	136 (463,282)	100% (100%)
% of Total			11.5% (14.1%)	13.2% (12.6%)	4.3% (3.5%)	17.2% (18.4%)	14.8% (17.2%)	18.6% (17.4%)	20.4% (16.7%)	100% (100%)	

* From K. Kosick, Planning and Development Services Department, City of Whitehorse

** Estimated by K. Kosick as equivalent to 1/3 of mixed-use residential.

*** Elementary school floor area = 2,500 m²; high school floor area = 5,000 m².

Table 2.2 shows that the total building floor area at full build-out is expected to be 463,282 m². Residential buildings account for 78% of the total floor space. Of this residential floor space, approximately 52% is Housing Mix A (i.e., predominantly single-family dwellings) and about 48% is Housing Mix B (i.e., predominantly multi-family dwellings). Commercial buildings account for the second largest floor area at about 11%, followed by community-use buildings (5.6%), mixed-use residential (2.6%), schools (2.2%), and mixed-use commercial (0.9%).

Excluding Development Area 2(H), each development area comprises a similar percentage of building floor area relative to the entire build-out floor area. Development Area 2 has the smallest percentage of building floor area at 12.6% of the total, and Development Area 3 has the largest at 18.4% of the total. Development Area 2(H) comprises only 3.5% of total building floor area.

2.4.2 Building Heat Characteristics

Two types of heating loads are important in assessing feasibility of energy systems: peak hour loads and annual loads. The peak hour heating loads dictate the size (and initial cost) of the required heating system and equipment. The quantity of annual heating energy dictates the amount and cost of fuel used each year. As discussed later in this report, annual energy also plays an important role in the size (and cost) of the ground heat exchanger.

EBA undertook a forward-looking approach to estimate the expected probable heating loads of the WBN using energy efficiency targets for Whitehorse rather than using some typical heating load values or rules-of-thumb for buildings based on past experience. Targets for efficient annual energy use in buildings are described by various standards and programs set forth by Natural Resources Canada for different building types.

For estimating probable expected annual heating energy consumption in residential buildings, EBA used energy targets set forth by the R-2000/Energuide 80 standard. The rationale for using energy targets described in this standard was based on conversations with Yukon Housing Corporation (Mr. Juergen Korn, personal communication), and EBA's understanding that the City of Whitehorse intends to adopt the R-2000 standard for new construction in the Whistle Bend Neighbourhood. R-2000 homes will typically use approximately 30% less energy than a comparable non-R-2000 home.

The annual space heating energy consumption target is defined in the R-2000 Standard as a function of volume of the residential building and the annual heating degree days for the particular location of the building. Yukon Housing Corporation has simplified the equation for Whitehorse to:

$$(Annual\ Heating\ Energy\ Consumption\ in\ kWh) = (7.9615) \times (Floor\ Space\ in\ square\ ft)$$

The R-2000 Standard does not set targets for peak hour heating load. A reasonable approximation of the peak load from the annual energy consumption in residential buildings can be computed from the degree-day procedure, which correlates annual energy

consumption to peak hour load and heating degree days. The annual heating degree days for Whitehorse are 6,915°C-day (12,447°F-day).

For estimating probable expected annual heating energy consumption in non-residential buildings, EBA used building envelope criteria similar to the R-2000/Energuide 80 standard. Specifically, this included R28 walls, R50-60 roof, double-pane windows, and maximum air leakage of 1.5 air changes per hour. We estimated heating loads with the RETScreen (NRCan, 2005) software tool. This software tool considers internal gains (i.e., lighting, people, and equipment) and occupancy schedules that are typical of non-residential buildings. This approach is consistent with meeting heating energy targets under the ecoENERGY Initiative or the LEED® rating system, should non-residential building owners choose to follow these paths.

2.4.3 Expected Heating Loads

Table 2.3 (below) presents a summary of expected probable heating loads for the WBN. The peak heating load at full build-out is estimated at 21,738 kW, and the annual heating energy load is estimated at 35,042 MWh. At this full build-out level, the electrical power requirement for heat pumps and circulating pumps will be on the order of 7 to 8 MW.

Residential heating loads by far account for most of the heating demands at 73% of the peak and 89% of the annual load. Commercial buildings account for the second largest portion of the heating loads at about 14% of the peak and 4.4% of the annual, followed by community-use buildings (7.5% of peak, 2.3% of annual), mixed-use residential (2.4% of peak, 3.0% of annual), schools (2.2% of peak, 1.3% of annual), and mixed-use commercial (1.2% of peak, 0.4% of annual).

Thermal load density is a useful parameter to determine for district energy evaluations. A high load density is desirable in district system economics because it means that a greater quantity of energy is needed over a smaller distribution area. The total build-out has a thermal load density of 258 MWh/ha. Amongst the Development Areas, Development Area 3 has the greatest load density of 300 MWh/ha, followed by Area 1 (286 MWh/ha), Area 2 (272 MWh/ha), Area 5(I) (262 MWh/ha), Area 2(H) (238 MWh/ha), Area 6 (226 MWh/ha), and Area 4 (217 MWh/ha).

There is progressively increased uncertainty with the assessment of the heating loads associated with the later development areas, since details of the actual buildings to be constructed are unknown at this time. The findings of this study are sensitive to buildings actually being constructed to the R-2000 standard. Residential buildings account for 89% of the annual heating loads, so deviation from R-2000 construction (i.e., construction to a less stringent level) will increase the annual heating energy consumption. If this were to occur, the district system owner would realize an increase in heating revenue relative to that assumed in this study. However, the increased revenue would come at some increase in capital and/or operating costs.

On the other hand, if some buildings were to be built to “SuperGreen” energy efficiency levels, DES energy revenues would be less than predicted here because SuperGreen homes use about 60% less energy than R2000 homes. In that case, domestic hot water loads could be considered for the DES.

ISSUED FOR USE

TABLE 2.3 SUMMARY OF EXPECTED HEATING LOADS

Use	Colour Code (Figure 2.1)	Peak Demand (W/m ²) (Annual (kWh/m ²))	Peak Heating Loads (kW) (Annual Heating Loads (MWh))								
			Dev. Area 1	Dev. Area 2	Dev. Area 2 (H)	Dev. Area 3	Dev. Area 4	Dev. Area 5 (T)	Dev. Area 6	Totals	% of Total
Housing Mix A	Yellow	44 (86)	935 (1,841)	1,400 (2,756)	670 (1,319)	996 (1,961)	0 (0.0)	1,897 (3,735)	2,310 (4,548)	8,207 (16,160)	37.8% (46.1%)
Housing Mix B	Brown	44 (86)	1,015 (1,998)	1,054 (2,075)	38 (75)	2,397 (4,720)	1,063 (2,094)	1,247 (2,456)	743 (1,464)	7,558 (14,882)	34.8% (42.5%)
Mixed Use - Residential	Pink	44 (86)	0 (0.0)	0 (0.0)	0 (0.0)	71 (141)	334 (657)	124 (244)	0 (0.0)	529 (1,042)	2.4% (3.0%)
Mixed Use – Commercial	Pink	62 (31)	0 (0.0)	0 (0.0)	0 (0.0)	34 (17)	158 (79)	59 (29)	0 (0.0)	250 (125)	1.2% (0.4%)
Commercial	Red	62 (31)	1,285 (642)	0 (0.0)	0 (0.0)	0 (0.0)	1,819 (909)	0 (0.0)	0 (0.0)	3,104 (1,551)	14.3% (4.4%)
Community	Orange	62 (31)	0 (0.0)	149 (75)	0 (0.0)	323 (162)	529 (265)	310 (155)	308 (154)	1,620 (811)	7.5% (2.3%)
School	Blue	47 (47)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	352.5 (353)	0 (0.0)	118 (118)	470 (471)	2.2% (1.3%)
Totals			3,234 (4,481)	2,603 (4,906)	708 (1,394)	3,822 (7,001)	4,255 (4,357)	3,638 (6,619)	3,479 (6,284)	21,738 (35,042)	100% (100%)
% of Total			14.9% (12.8%)	12.0% (14.0%)	3.3% (4.0%)	17.6% (20.0%)	19.6% (12.4%)	16.7% (18.9%)	16.0% (17.9%)	100% (100%)	

2.5 BASE CASE FUEL

In comparing engineering economic alternatives, a base case or so-called *business as usual case* needs to be established. The base case life-cycle cost serves as the reference point to which all other proposed alternatives are compared. In district energy systems, the *business as usual case* is important in setting energy selling prices to customers; which, in turn, defines an avoided cost (i.e., the cost that customers would have paid had the district system not been constructed).

The base case or business as usual case for the WBN assumes that all residents install fuel oil furnaces or boilers. The rationale for selecting fuel oil (or furnace oil) as the base fuel is as follows:

- Most buildings in the north use fuel oil as a heating source. There is generally a more established service base and supply infrastructure for fuel oil than for other heating fuel types.
- Building codes are more stringent for propane tanks than for fuel oil tanks due to higher flammability of propane.
- Except for wood, fuel oil is currently the lowest cost fuel per unit of energy. Historic retail fuel oil and propane costs since 1998 were obtained from Robert Collins, Energy Resources Analyst of Yukon Government's Energy, Mines and Resources, and are shown graphically in Figure 2.2(a). While propane is currently cheaper in terms of dollars per litre (\$/L), fuel oil is actually cheaper in terms of dollars per gigajoule (\$/GJ) because fuel oil contains approximately 50% more energy per litre than propane when combusted. Propane and fuel oil costs in terms of \$/GJ are shown graphically in Figure 2.2(b), along with linear trend lines. The trend lines show that fuel oil has been escalating at an average rate of 7%, while propane has been escalating at an average rate of about 4%.

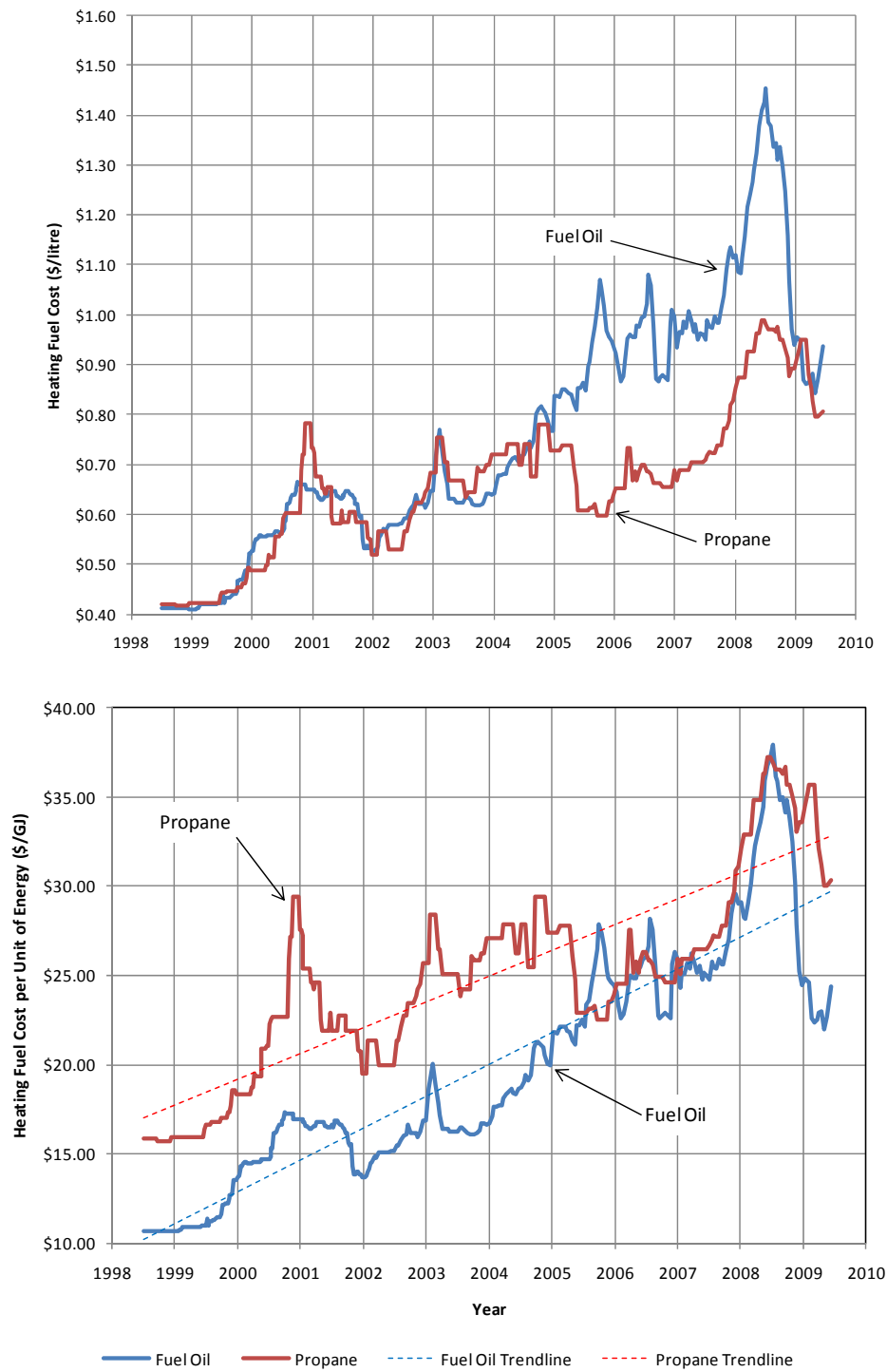


Figure 2.2: Graph of Historical Residential Propane and Fuel Oil Prices in \$/L (top figure) and in \$/gigajoule (GJ) (bottom figure)

2.6 ALTERNATIVES TO THE DISTRICT GEOEXCHANGE CONCEPT

Interest in alternatives to the district geoechange concept have arisen during the course of planning for the WBN development. These alternatives include: (i) a temporary propane-based district system with the eventual intent to replace with natural gas, and (ii) individual air-source heat pumps. Each of these options is discussed below.

2.6.1 Propane vs. Natural Gas Infrastructure

A gas-based alternative to the district geoechange concept is based on the possibility that natural gas could someday become available in Whitehorse. In the meantime, gas piping infrastructure would need to be built as the neighbourhood develops, and an interim gas fuel source (propane) would be stored in a central tank farm. At the time natural gas becomes available, the tank farm would be replaced with natural gas.

This alternative has several drawbacks and uncertainties that preclude further consideration at this time. First, as described above, propane is currently more expensive than fuel oil per unit of energy. Consequently, a district propane system is likely not to have good public uptake or perception if customers are forced to use a more expensive fuel.

Second, there is a considerable financial risk in investing in a tank farm that will someday be taken out of service. In other words, if natural gas were to become available in 5 to 10 years, a considerable amount of money would have been sunk into infrastructure that is no longer needed.

Third, the phased build-out of the WBN leaves the design and implementation schedule of this alternative difficult to define. We are aware of no natural gas delivery contract or letter of intent in place, no firm schedule for natural gas availability and no estimate of the future natural gas cost (which depends on when it might be available). These uncertainties lead to further uncertainties in the design of a propane storage and delivery system, and how many customers it should optimally be built to serve.

In summary, a temporary propane storage and delivery system in anticipation of natural gas replacement does not make economic or practical sense at this time. The decision to install natural gas infrastructure should be made when it becomes a more concrete option. At that time, development areas that have already been built could be retrofitted using horizontal drilling methods, or gas piping installation could be scheduled during times of other utility of street repair. Retrofitting neighbourhoods for natural gas service may seem costly, but the real cost of retrofitting should be weighed against the avoided cost of a temporary propane storage and delivery system.

2.6.2 Individual Air-Source Heat Pumps

This alternative to the district geoechange concept utilizes individual air-source heat pumps. In general, heat pumps are more efficient for heating purposes than fossil-fuel combustion or pure electric resistance heating because heat pumps transfer heat from a source to a use (i.e., to/from air, water, or the earth), and do not generate heat (such as in

fossil fuel furnaces). As the name implies, air-source heat pumps extract heat from outdoor air to heat homes and buildings.

Air-source heat pumps typically have favourable application in more mild climates than in Whitehorse. This is mainly a demand/marketing issue, and availability of cold-climate air-source heat pumps is still somewhat limited. Currently available air-source heat pumps generally begin requiring assistance (either electric resistance or gas) when outdoor air temperatures drop below 4°C. Below about -20°C, typical air-source heat pumps can no longer extract useful heat from the air, and the heat pump would then need 100% assistance.

Air-source heat pumps have an outdoor component, consisting of a fan that is used to extract heat from outdoor air. A practical consideration in Whitehorse is that this outdoor component must be kept clear of snow and ice. Outdoor fan noise may also be of concern.

Manufacturers report heat pump performance in terms of their coefficient of performance (COP). However, these are only reported at a standardized single temperature, and the heat pump's actual performance needs to be described by a seasonal COP (SCOP), which describes its COP throughout the season.

In order to make a reasonable assessment of seasonal performance of air-source heat pumps in Whitehorse, EBA examined typical meteorological year (TMY) data for Whitehorse. A TMY is a data set of hourly values of solar radiation and weather data elements for a one-year period. It consists of months selected from individual years that are concatenated to form a complete year. TMY data is compiled for several cities throughout North America and is available through the National Renewable Energy Laboratory in Golden, Colorado.

A review of TMY data for Whitehorse reveals that there are typically 5,300 hours per year (61% of the year) with air temperatures below 4°C, meaning that air-source heat pumps would need assistance almost half of their operating time. Whitehorse also typically has about 1,000 hours per year (11% of the year) below -20°C, which is when a typical air-source heat pump would require 100% assistance. Thus, it is estimated from TMY data that a typical air-source heat pump in Whitehorse would have a seasonal COP of about 2.2-2.5.

To put the seasonal COP of air-source heat pumps into perspective, consider the following simple economic analysis. A 2,000 ft² home built to R-2000 standards would consume about 15,900 kWh annually in energy for space heating purposes. Annual heating costs for various alternatives are summarized below, assuming \$0.13/kWh for electricity and \$1.00/L for fuel oil:

- Fuel Oil Furnace: \$1,870/yr (at 80% combustion efficiency)
- Air-Source Heat Pump: \$830 - \$940/yr (with seasonal COP of 2.0-2.5)
- Geexchange Heat Pump: \$520/yr (with seasonal COP of 4.0)

Given the above simple economic analysis, air-source heat pumps could offer attractive savings in heating costs relative to fuel oil. However, the economics of geoechange heat pumps are more favourable than air-source heat pumps. In addition, since air-source heat pumps require a supplementary heating source, the method of supplemental heating is of important concern. If the supplementary heat was by electric resistance heating, the electrical load might exceed the available power to the development during cold periods.

3.0 GEOEXCHANGE OPTIONS ANALYSIS

3.1 GROUND HEAT EXCHANGER ALTERNATIVES ANALYSIS

3.1.1 Types of Ground Heat Exchangers

The types of ground heat exchangers (GHX) which could theoretically be applied to the WBN can be grouped into two broad categories (EBA, 2008):

- **Closed loop GHX** systems rely on conductive heat transfer between the earth and a network of piping through which a thermal exchange fluid is circulated in a closed-cycle. Examples of closed loop GHX include vertical closed loop borehole systems, horizontal trenched or bored piping systems, and surface water systems.
- **Open loop GHX** systems rely on pumping of groundwater or surface water through the geoechange cycle. Examples of open loop GHX include groundwater well systems and surface water systems which pump surface water to a heat pump or heat exchanger.

3.1.2 Comparative Ground Heat Exchanger and Constructability Assessment

Table 3.1 summarizes the technical feasibility of several GHX types and identifies options warranting further consideration. Hybrid technologies and peaking options can be applied to many of the plausible GHX options. Hybrid coupling options for the leading GHX configuration are discussed further in Section 5.0.

TABLE 3.1 PLAUSIBLE GROUND HEAT EXCHANGER OPTIONS FOR WBN

GHX Option	Yes/ No	Comments
1. Vertical Drilled Borehole Closed loop GHX	Yes	Soils underlying the site are well suited to mud rotary drilling methods and possess fair thermal transfer properties. Due to a heavy load imbalance and relatively low ground temperature, large total bore length and wide borehole spacing would be required to reduce bore-to-bore thermal interference for sustainable operation.
2. Horizontal Trenched or Bored Closed loop GHX	Yes	Soils underlying the site are well suited to trenching and possess fair thermal transfer properties. Large land area will be necessary to support a significant portion of the load and the depth of installation will have to account for frost penetration on the order of 2.4 m.

TABLE 3.1 PLAUSIBLE GROUND HEAT EXCHANGER OPTIONS FOR WBN

GHX Option	Yes/ No	Comments
3. Groundwater Open Loop GHX	Possibly - for an individual building	Low yield aquifers suitable for open loop geoexchange supply for individual homes or buildings may exist at the site. Geologic interpretation of borehole and water well records for the site indicates poor likelihood of encountering an aquifer which could supply a district energy system.
4. Surface Water Open /Closed Loop GHX	No	For useful heat extraction from the Yukon River, desirable river water temperatures should be on the order of 5°C warmer than the GHX temperature. Due to the relatively low water temperatures in the Yukon River, useful heat extraction could only be accomplished for a limited number of hours in summer.

Based on Table 3.1, practical ground coupling options for the WBN include two closed loop options: Vertical Drilled Borehole (Option 1) and Horizontal Trenched (Option 2).

3.1.3 Assessment Criteria for Practical Options

As recommended in the Professional Guidelines for Geoexchange Systems in BC, Part 1 – Assessing Site Suitability and Ground Coupling Options (GeoExchange BC, 2007), EBA has qualitatively assessed the leading GHX options against ten analysis criteria described below:

1. Sustainability relates to how site conditions could affect the long-term performance of the GHX (e.g. performance to design specifications to avoid frozen or thermally saturated ground).
2. Effects on human neighbours relates to hydraulic, thermal or other degradation of existing human infrastructure (e.g. water wells, foundations, or structures).
3. Effects on ecological neighbours relates to hydraulic, thermal or other degradation of existing ecological systems or environment (e.g. thermal impacts on the Yukon River or existing kettle lakes, construction impacts on sensitive ecological settings).
4. Capital and operating costs relates to estimated values of capital and operating costs and how well they meet the owner's minimum acceptable rate of return (MARR).
5. Energy performance relates to the anticipated overall geoexchange system efficiency, and to what degree the owner's geoexchange concept incorporates integrated heat exchange between loads and heat recovery.
6. System complexity and constructability relates to the complexity of the GHX (e.g. number of boreholes, complexity of piping and controls) and ease of construction considering earth materials and site setting.

7. Resale and equity potential refers to the added value the geoexchange system will likely give the owner if the building or structure were sold.
8. Schedule for GHX installation relates to what degree the construction schedule for testing, design and installation of the GHX will impede or cause scheduling problems for other construction on the development site.
9. Contractor capabilities relates to the skills of contractors who would be available to install the GHX on the schedule required by the owner.
10. Potential for required further studies relates to the likelihood for ancillary Stage 3 studies required by regulations, the complexity of the concept or the sensitivity of the site.

Table 3.2 provides our quantitative (good, fair, poor) ranking for the two leading GHX options against the ten analysis criteria described above.

TABLE 3.2 SCORING EVALUATION TABLE FOR GROUND HEAT EXCHANGER OPTIONS AT WBN						
	Option 1 – Vertical Drilled Borehole Closed Loop GHX			Option 2 – Horizontal Trenched Closed Loop GHX		
Analysis Criteria	Good	Fair	Poor	Good	Fair	Poor
1. Sustainability	X			X		
2. Effects on human neighbours	X			X		
3. Effects on ecological neighbours	X				X	
4. Capital and operating costs		X			X	
5. Energy Performance per ground footprint area	X				X	
6. System complexity/constructability	X				X	
7. Resale equity potential	X				X	
8. Schedule for installation		X			X	
9. Contractor capabilities	X			X		
10. Potential for further studies	X			X		

Based on the ten-point analysis criteria, Option 1 – Vertical Drilled Borehole Closed Loop GHX is the leading ground coupling option. Hybrid technologies which could be applied to this GHX concept are described in Section 5.0.

3.2 POTENTIAL BOREHOLE DRILLING AREAS

Potential borehole drilling areas were discussed and selected at the March 20, 2009 progress meeting with City. Possible borehole drilling areas at the WBN site are shown in Figure 3.1. Drilling areas were limited to miscellaneous open spaces throughout the development area, streets, and trails. Open areas within the development include school yards and community properties, and open areas just outside the development include land at Horse and Rider

Club and land surrounding the future location of the YECL substation. Rectangular borehole arrays could potentially be drilled in open spaces, while linear patterns could be drilled in streets and trails. Casca Blvd. (i.e., the main ring road) is wide enough to accommodate a linear arrangement of boreholes on both sides of the street, while other streets could only accommodate one linear array in the street right-of-way. Trails are only wide enough for one linear array, and attempting to install rectangular arrays in trails would likely result in unnecessary damage to trees and natural vegetation.

Table 3.3 (attached) summarizes the potential number of boreholes within the WBN. Areas (in m²) were determined by digitizing the locations shown in Figure 3.1. The approximate number of boreholes per location was determined by assuming a 10-m borehole-to-borehole separation distance. A review of Table 3.3 shows that the development could accommodate approximately 6,000 boreholes for a ground heat exchanger. Borehole Area 1 (the largest open area) could accommodate about 1,670 boreholes, followed by Borehole Area 11 which could accommodate about 740 boreholes. Therefore, about 40% of all possible boreholes could fit into these two open areas with a footprint of approximately 23 ha.

3.3 MAXIMUM GROUND HEAT EXCHANGER LOAD

The maximum size of the ground heat exchanger (GHX) was calculated using GLHEPro software tool (Spitler, 2007). The word “maximum” is used here to mean that the GHX is sized to handle 100% of the intended loads, with no assistance from hybrid components. It was concluded in Interim Progress Report #1, however, that a hybrid geoexchange system would likely be the more cost-effective approach to the Whistle Bend Neighbourhood.

Assumptions used in sizing the GHX include:

- Intended loads are 100% of the space heating needs, no cooling loads, and no domestic hot water loads.
- 50-year design life (systems were simulated here for 100 years to ensure long-term sustainability).
- 100 m deep boreholes with a separation distance of 10 m. A large bore-to-bore separation distance effectively couples the GHX to a greater thermal mass, thereby significantly reducing required total drilling footage when compared to smaller bore-to-bore separation distances.
- Borehole diameters are 5-in. nominal with single u-tube borehole heat exchangers constructed of 1¼-in. nominal, high-density polyethylene (HDPE) plastic, grouted in place with standard bentonite grout.
- GHX heat transfer fluid is aqueous solution of 20% propylene glycol.
- Heat pump design minimum entering fluid temperature is 0°C.

- Heat pump heating coefficient of performance (COP) of 3.5 at 0°C entering fluid temperature.
- Thermal conductivity (silty clay soils): 1.75 W/(m-K).
- Thermal diffusivity (silty clay soils): 0.008 cm²/s.
- Undisturbed deep ground temperature: 3.0°C.

GHX sizing simulations reveal that 21,250 boreholes would be required to provide enough energy to meet 100% of the space heating loads of the full Whistle Bend Neighbourhood build-out. This amount of boreholes exceeds the amount that could be placed within the potential drilling areas by a factor exceeding 3. The 6,000 boreholes that could fit into all the potential drilling areas described above could only accommodate Development Areas 1, 2, and 2(H) (or some other combination of development areas with similar loads). Even if the site could accommodate 21,250 boreholes (i.e., enough to meet 100% of the space heating loads), this is not necessarily the most cost-effective approach. This demonstrates the need for consideration a hybrid design, as will be discussed in later sections of this report.

Hybrid geoexchange systems are beneficial in applications with relatively large peak hour loads and/or annually-imbalanced loads (i.e., characteristic of cold climates). In these situations, it is generally not practical nor economically feasible to design the GHX to source 100% of the heating loads without thermal assistance. One important advantage of hybrid systems derives from the behaviour of geoexchange systems, in conjunction with the fact that geoexchange systems are capital-intensive. Hybrid components can allow the use of a smaller, lower cost GHX by off-setting some portion of the heating loads and configuring the GHX portion as a “baseload” heating system.

Peaking systems such as boilers would only operate during coldest periods of the year. Use of other natural heat sources such as solar energy or wastewater can be used to improve system efficiency and sustainability if they can supply heat at greater temperatures than the GHX storage temperature. The more these natural heat sources are seasonally available, the greater their benefit when coupled with closed loop systems because the energy can be stored in the ground for later benefit via the GHX network.

4.0 SEWER HEAT RECOVERY OPTIONS

4.1 LOCATION AND MAGNITUDE OF SEWER HEAT

The heat content of sewage is typically referred to as “waste” heat because the energy is wasted. It can, however, be a resource that replaces primary heating sources through the use of a heat exchanger. For Whistle Bend, heat extracted from the wastewater via a heat exchanger could then be transferred to the closed loop geoexchange distribution system. Wastewater flow volume and temperature are the primary characteristics of the sewage system that allow for quantitative analysis of sewage heat recovery.

Whistle Bend's wastewater system will be closely tied to the Porter Creek subdivision. From the existing Porter Creek Flush Tank located at the intersection of Larch and Oak Streets in Porter Creek, wastewater gravity flows through a 4 km, 450 mm diameter force main to the Livingston Trail Environmental Control Facility. Figure 4.1 shows the relative locations of this facility and the flush tank to the new neighbourhood.

At the time of writing this report, Whistle Bend wastewater was expected to flow into a new lift station located centrally, as shown in Figure 4.1. From the lift station, a force main would be routed through the Whistle Bend green belt to the Northwest corner of the development and then up the hill to the Porter Creek Flush Tank where it would join the wastewater from Porter Creek and flow to the Livingston Trail Environmental Control Facility.

After the issuance of the "Issued for Review" version of this report, the City has advised that the underground water and sewer designers are considering two sewage lift stations in lieu of one lift station – one to service Development Areas 1 through 5 and the second to service Development Area 6. For pre-engineering level of analysis here, we assumed one single point of pick up at the main lift station. A second sewage heat recovery station would likely double the sewage heat recovery infrastructure cost and subject to the capacity of the second lift station and the alignment of the district energy system relative to the second sewage lift station, may, or may not be economically beneficial. This would have to be reviewed at time of pre-design for Development Area 6.

Porter Creek water consumption is approximately 547 litres per person per day which is higher than most other Canadian cities. This usage is comparable to the City of Whitehorse's average water usage. Whistle Bend, however, has as one of its sustainability goals the significant reduction of water usage from current City levels. As a direct result, wastewater production will be significantly reduced as well.

The target design consumption for Whistle Bend is 375 litres per person per day average residential demand, similar to current average residential usage in Canada. At a recovery rate of 90%, the Whistle Bend average daily sewage flow rate is expected to be about 337 litres per person per day.

Very little data exists regarding anticipated sewage temperatures. Therefore, temperatures at several locations including the Porter Creek flush tank were measured in April 2009. Figure 4.2 shows a summary of sewer temperature monitoring during April 7-14, 2009. These data provided a worst-case reference for typical City of Whitehorse sewage temperatures. The measurements were made in April when the wastewater is likely at its coldest due to low ground temperature and snow melt inflow, and they were taken at one of the older neighbourhoods in Whitehorse where upwards of ten bleeders are still in operation.

The sewage monitoring points were picked to provide information on sewage leading to the City sewage lagoon from both the existing Porter Creek area, and the larger Marwell lift station trunk sewer line. The Porter Creek Flush Tank is located at the top of the bluff overlooking the WBN and was initially considered as a potential sewage heat pickup point.

The Porter Creek main near the sewage lagoons is at a lower elevation and shows the sewage temperature between the flush tank and the sewage lagoon. The Marwell lift station shows temperatures for the bulk of City sewage heading toward the sewage lagoon. Finally, the Mixing Tank at the lagoon shows the temperature of amalgamated sewage just before entering the lagoon.

We note the following key points from Figure 4.2:

- Typical temperature ranges (omitting spurious peaks): Marwell Lift Station 4.6 to 7.9°C; Larch & Oak St. (Porter Creek uphill) 3.2 to 6.0°C; Porter Creek Main (near lagoon) 3.8 to 5.4°C; Mixing Tank (at lagoon) 4.4 to 7.2°C.
- Approximate mean sewage temperatures: Marwell Lift Station 6.3°C; Larch & Oak (PC uphill) 4.4°C; Porter Creek Main 4.7°C; Mixing Tank 6.0°C.
- Marwell Lift Station sewage is on average 1.9°C warmer than at Larch & Oak, and there is substantially more sewage in Marwell circuit.
- Between Larch & Oak (PC uphill) and Porter Creek Main (near lagoon), sewage temperature range compresses from 3.2 to 6.0°C (mean 4.4°C) uphill to 3.8 to 5.4°C (mean 4.7°C) near lagoon. Thus, rather than losing temperature during flush, sewage actually warms up slightly (on average 0.3°C) en route to the Mixing Tank. This may be the effect of warmer ground conditions for Porter Creek Main location at lower elevation (across the Yukon River), compared with colder ground temperatures at Larch & Oak at the higher exposed bluff location.
- Sewage temperature at the Mixing Tank (mean 6.0°C) reflects mixing of mainly warmer Marwell sewage (mean 6.3°C) with lesser flow of cooler Porter Creek Main sewage (mean 4.7°C). Simple mixing calculation based on mean temperatures at Marwell Lift Station, Porter Creek Main, and Mixing Tank suggests that the Porter Creek Main flow at the time of measurements was only ~23% of the Marwell sewage flow.
- Temperatures are smoothly varying at the Marwell Lift Station and Porter Creek Main, somewhat jagged at Larch & Oak, and most highly variable at the Mixing Tank.
- Larch & Oak is most representative of sewage heat available from Porter Creek Flush Tank area; while Porter Creek Main is most representative of sewage heat taken in future from continuously-full sewage line running downhill and under river, north of the WBN development.

One of the methods of reducing water consumption at Whistle Bend compared to current City levels is by eliminating “bleeder” volumes. Winter water bleeding is commonly included in Northern domestic water service design to prevent freezing. Cold water is continuously flowed and wasted to the sewers. Undesirable consequences to this practice include:

1. Bleed water, which is colder than sewage, lowers the sewage temperature.

2. The higher volumes of sewage are more difficult and costly to treat.

Many buildings in the City of Whitehorse have free-flow bleeders that are open all the time. In recent years there have been wide scale replacement of these with thermostatically controlled bleeders wherever possible, cutting the wasted water flow by as much as 90%. However, buildings such as residential trailers and houses with unheated crawlspaces prohibit the use of thermostatically controlled bleeders and free-flow continues. The Whistle Bend municipal designers should consider designing with heat trace or a water recirculation line, thereby eliminating bleeders altogether and contributing to the lower usage volumes described above.

For this study, the yearly average expected sewage temperature of nine degrees Celsius is assumed for Whistle Bend without any bleeding. This temperature is based on the City of Yellowknife's *Sewer Heat Recovery Feasibility Study* (July 2008), which determined their sewage to be an average of nine degrees Celsius. It is noted that this temperature is an assumption based on the Yellowknife sewage study and may be optimistic. As such, it is important that this assumed temperature **be confirmed** prior to completing design of a sewage recovery system to a) confirm the viability of the sewage heat recovery and b) to properly size the sewage heat recovery heat exchanger.

The City of Whitehorse was unable to provide a minimum design inflow temperature for wastewater entering the Livingston Trail Environmental Control Facility. In order to estimate the maximum recoverable heat from the wastewater, and to reduce the risk of freezing, a minimum allowable leaving temperature of two degrees Celsius was assumed for the Porter Creek flush tank as well as the Whistle Bend lift station. This lower temperature wastewater would be mixed with larger volumes from the Marwell Lift Station before going into Livingston Trail Environmental Control Facility, resulting in a mixed temperature of approximately five degrees Celsius. The resulting inflow temperature at this facility does not vary significantly from the heat recovery at Whistle Bend because the Porter Creek flush tank volume will represent less than 25% of the total Livingston Trail Environmental Control Facility inflow.

Whistle Bend lift station sewage flow rates are calculated based on wastewater production of 337 litres per person per day, 2.6 people per unit (as per the *Whistle Bend Planning Study* May 2007 by City of Whitehorse and UMA), and the following number of units per hectare (data from AECOM):

1. Housing Mix A = 18 units per hectare.
2. Housing Mix B = 40 units per hectare.
3. Mixed Use – Residential = 19 units per hectare.

The resulting wastewater flows are summarized by scenario in Table 4.1 below.

TABLE 4.1 SUMMARY OF SEWAGE FLOWS IN AND NEAR THE WHISTLE BEND NEIGHBOURHOOD SITE

Flows by Scenario	
Scenario	Waste Flow Rates (L/s)
1	3.3
2	4.0
3	7.3
4	2.6
5	20.8
6	27.1
Porter Creek	21.2
Total PCFT	86.4

4.2 SEWAGE HEAT RECOVERY OPTIONS

Table 4.2 presents a summary of the broad options for sewage heat recovery at WBN.

TABLE 4.2 SUMMARY OF SEWAGE HEAT RECOVERY OPTIONS

Sewage Heat Recovery Options	
Options	Heat Recovery Source Locations
A	Whistle Bend
B	Porter Creek Flush Tank
C	Whistle Bend and Porter Creek Flush Tank

Many heat exchanger designs are available, two of which are suitable for raw sewage heat recovery:

1. **In-Stream:** An in-stream pipeline heat exchanger where the sewage flow is not diverted and the heat exchanger is imbedded in sections of the sewage piping.
2. **Out-of-Stream:** A stand-alone heat exchanger where the sewage is diverted out of its pipeline for energy transfer. This type of heat exchanger is typically located in a building.

Other than the infrastructure implications with the type of heat exchanger chosen, important design considerations include heat transfer capacity, ease of installation and maintenance costs.

Four heat exchanger manufacturers that are in the business of providing heat exchangers for raw sewage exchange include:

1. Rabtherm – A Swiss company that manufactures in-stream heat exchangers.

2. DDI – A Canadian (Quebec) company that manufactures out-of-stream heat exchangers that pride themselves on low maintenance.
3. Alfa Laval – A Swedish multi-national company with offices in Canada and the US that manufactures out-of-stream spiral heat exchangers that pride themselves on their small footprints.
4. Trane – A US and international company that manufactures out-of-stream shell and tube type of heat exchangers and exchangers coupled with heat pumps.

Rabtherm sewer heat exchangers are well suited to high density complexes such as hotel, hospitals, or major City Subdivisions with anticipated quick build-out. However, the Rabtherm "in-stream" type heat exchanger were not considered practical at the WBN because:

- i) Wastewater heat extraction using Rabtherm sewer heat exchangers depends on sewer length, and they cannot extract as much heat as out-of-stream plate-type heat exchangers given the estimated available length of sewer.
- ii) Assuming that a Rabtherm heat exchanger was installed at the WBN, the sewage flow rates during the initial years until complete build-out would be less than the minimum recommended sewer flow rates. Useable heat recovery using Rabtherm sewer heat exchangers would not be realized at Whistle Bend until near the time of full build out.

For these reasons, the use of in-stream Rabtherm heat exchanger is not recommended and is not pursued further in this report. More detailed information on these companies and the types of heat exchangers they offer is included in Appendix B.

The two main practical wastewater heat recovery locations are at the Porter Creek Flush Tank and at the new Whistle Bend Lift Station. These are practical because they are the closest wastewater gathering points to the Whistle Bend neighbourhood geoexchange system. After some consideration, EBA concluded that no viable heat recovery can be obtained from the Porter Creek Flush Tank for the following reasons:

1. The sewage from Porter Creek is lower in temperature than what is assumed for Whistle Bend, thereby lowering total recoverable heat from the flush tank.
2. As the Porter Creek Flush Tank is existing infrastructure, heat recovery from this system would require a retrofit to existing sewer lines resulting in significant associated costs.
3. The Porter Creek Flush Tank is located approximately two kilometres from the proposed geoexchange loop. This distance results in higher costs to pump recovered heat to the point of use, and the energy available is compromised due to piping losses.
4. The approximate cost of a heat exchanger installation at the Porter Creek Flush Tank is upwards of \$2.5 million.

Wastewater heat recovery is potentially viable at the new Whistle Bend Lift Station based on the following points:

1. Higher grade heat will potentially be available with the elimination of bleeders. However, there is not a sufficient amount of heat available in the anticipated WBN sewage that can be relied on to provide all of the heat needed.
2. New infrastructure including heat exchanger equipment and pumps can be installed at the time of construction, reducing mobilization costs.
3. The lift station expansion to accommodate the new equipment can be built at the time of construction reducing costs.
4. The proposed lift station is near the geoexchange loop. This proximity to the point of use minimizes piping losses and pumping costs.
5. The approximate capital cost of a heat exchanger installation at the new Whistle Bend Lift Station is in the order of \$1.5 million.

5.0 OTHER HYBRID TECHNOLOGY OPTIONS

5.1 SOLAR THERMAL

As mentioned in Section 3.3, the size (and cost) of a GHX can be significantly reduced in situations where annual loads are balanced. A GHX with approximately balanced annual loads (i.e., roughly the same amount of energy is extracted as rejected over the annual cycle) also results in more sustainable operation.

“Natural balancing” of ground loads occurs in more moderate climates, due to a distinct heating and cooling season. The Whistle Bend Neighbourhood is characterized by nearly 100% heating, and consequently other heat sources are needed to help balance the annual ground loads. Ideally these heat sources are available as much as possible throughout the year, and require relatively little mechanical or thermodynamic work to capture. In addition to sewer heat recovery described above, capturing solar energy for short- and long-term GHX storage is potentially an excellent means to aid in ground load balancing at Whistle Bend. Thus, solar energy is used here to balance annual grounds without the aim of high-temperature underground seasonal storage.

Solar radiation is converted to useful heat by circulating a liquid through an engineered thermal collector device. In a cold climate like Whitehorse, the circulating fluid would need to be a water-based solution consisting of at least 50% propylene glycol to prevent freezing. Typical required flow rates through a collector are relatively low, on the order of 0.015 L/s/m², and a typical collector area is approximately 3 m². Annual collector thermal performance is dependent on its construction and mounting angle. For good year-round performance, solar thermal collectors are typically mounted at an angle equal to the site latitude $\pm 15^\circ$ (i.e., $60.7 \pm 15^\circ$ for Whitehorse).

Numerical Logics, Inc. (2008) identified and examined the performance of two types of solar collector models that were deemed suitable and available for use in Yukon. These were the (i) Thermo-Dynamics glazed flat plate collector, Model S32 and (ii) Sunda-Seido evacuated tube collector, Model 1-16. A mounting angle of 50° from horizontal was found to be sufficient for these collectors to provide good year-round performance. Numerical Logics, Inc. (2008) did not distinguish which type of collector was “better” than the other. Flat plate solar collectors have more industry maturity than evacuated tube collectors.

The hybrid geexchange district concept presented in Section 6 makes use of glazed flat plate solar collectors. These collectors could be mounted on building rooftops (as opposed to ground-mounted) to minimize heat losses to the back of the collectors and to minimize vandalism. Architectural and aesthetic issues would need to be considered upon selection of buildings for rooftop collector mounting; commercial buildings might make better candidates than residential buildings.

5.2 PEAKING BOILER

A peaking system serves to offset peak loads on the ground, thus reducing unnecessary GHX size and cost. The rationale for using a peaking system is to handle peak heating loads of short duration during extreme cold periods.

Peak heating loads occur for a relatively small number of hours per year. Whitehorse experiences outdoor air temperatures below -20°C for only 11% of the year. Consequently, it is typically not practical nor economical to size a GHX for peak loads that occur for a small fraction of the year. Further, a heating system sized for 50% of the peak load typically meets about 80-90% of the annual load, simply due to the relatively small number of peak heating hours. A peaking system takes advantage of this fact, resulting in significant size and cost reductions of the GHX.

The hybrid geexchange district system concept described in Section 6 makes use of an oil-fired boiler, but other fuels could be considered depending on future availability and cost. The actual capacity of the boiler is an economic trade-off between GHX cost savings and boiler operating costs. Economic optimization is discussed in Section 6.4 of this report.

6.0 DISTRICT ENERGY SYSTEM EVALUATION

6.1 CONCEPT BASIS

We developed the following concept basis statements as a framework for conducting our district energy system evaluation. This concept basis is analogous to a design basis used as a framework for an engineering design. These concept basis statements have been reviewed and endorsed by Kinden Kosick for the City.

1. The District Energy System (DES) was centered around a geexchange technology, with loads on the ground heat exchanger assisted by auxiliary heat sources (e.g., sewer waste heat, solar thermal and/or peaking boiler).

2. Build-out schedule for each Development Area was defined by the City (see Table 2.1).
3. The building construction in each Development Area to be complete within five years after lot sales begin (following infrastructure construction).
4. EBA requested from the City the maximum change in temperature permissible to extract out of sewage for purposes of heat recovery for the WBN development. Failing a definitive response, EBA assumed reasonable values for extractable sewage heat for purposes of this study. These assumptions were not based on an engineering review of the impact of sewage heat recovery on sewage lagoon performance. Such an engineering review would be required in future, prior to detailed design of sewage heat recovery system.
5. For purposes of our analysis, we assumed that all WBN sewage will be pumped to a central lift station in WBN, and we considered waste heat recovery from that point.
6. Estimated building heating loads were based on assigned building density values (m^2/ha) from the City, and we applied these values consistently in all six Development Areas.
7. Building heating loads calculated from summed floor areas for different building types were assigned using forward-looking building energy efficiency targets (e.g., R-2000) which the City anticipates to be applicable for the WBN.
8. The DES was evaluated for building space heating demands only.

6.2 EVALUATION SCENARIOS

With six Development Areas, there are a large number of potential combinations that could be hypothetically considered in evaluated a DES. Taking combinations of the six areas singly or groups of 2, 3, 4, 5, or 6 gives a total of 63 possible combinations. Clearly, this is too great a number to evaluate, and not all combinations are practical.

In order to proceed with a DES evaluation with a reasonable range of cases, we developed six DES analysis scenarios, as shown in Figure. 6.1.

- Scenario 1 – Development Area 1 only (represents a small mixed use area, similar to Development Area 3).
- Scenario 2 – Development Area 2 only (represents a large, mainly residential area; similar to Development Areas 5 and 6).
- Scenario 3 – Development Areas 1 and 2 (the first and most well-defined development phase).
- Scenario 4 – Development Area 4 only (a unique area, mostly Housing Mix B and Commercial building types).
- Scenario 5 – All Development Areas except 2H and 5 (a plausible full build-out scenario).

- Scenario 6 – All Development Areas (for completeness, the ultimate full build-out).

These scenarios represent a workable range of options and represent other potential options which were not explicitly evaluated. These scenarios were reviewed and endorsed by Kinden Kosick for the City.

6.3 HYBRID GEOEXCHANGE DISTRICT ENERGY CONCEPT

A conceptual diagram of the geoexchange-based hybrid district energy system for the Whistle Bend Neighbourhood is shown in Figure 6.2. The basic design concept takes advantage of a modular “plug-and-play” structure such that heat sources or sinks can be added as practical. The concept is centered around a common low-temperature supply pipeline that serves to distribute energy in the form of an environmentally-friendly, aqueous antifreeze solution to the sources and sinks. A low-temperature distribution loop was conceived in this design so that lower-grade heat sources could be rejected to the loop. A lower temperature fluid distribution loop typically requires larger diameter pipe relative to that used in a high-temperature loop. The added advantage of larger pipe diameter means more fluid volume in the loop and correspondingly more thermal mass (or thermal inertia) of fluid in the pipe, which helps to damp large fluid temperature excursions during peak load times. Amplification of the low-temperature source loop to useful temperatures for space heating is accomplished with water-to-air or water-to-water heat pumps distributed throughout the district in the buildings they serve. The minimum heat pump supply temperature of 0°C was chosen because geoexchange heat pumps still have adequate heating capacity at this temperature. Heat pump exiting fluid temperatures would be less than 0°C, and thus an aqueous antifreeze solution is necessary.

An integral component of the district energy system is the ground heat exchanger (GHX), which could consist of one central array or multiple de-centralized arrays. The GHX acts to provide a baseload heat source for heat pumps, supplemented by a peaking boiler during extreme cold periods. In addition, the GHX acts as a short-term and long-term (i.e., seasonal) storage medium for various waste and other available heat sources, which help to improve the GHX thermal performance during times when heat is needed. The waste and other heat sources considered in this study were limited to solar energy and heat recovered from sanitary sewers.

As noted in Figure 6.2, general options exist for “other heat sources and sinks”, which could include heat rejection from refrigeration systems (i.e., ice rinks) or any other source deemed practical. This box could also represent another modular GHX as the district system expands and/or additional GHX’s are incorporated at de-centralized locations.

Each of the individual components of the district geoexchange systems are described in further detail below.

6.3.1 Ground Heat Exchanger

Two types of loads are important in sizing a GHX to meet intended loads: (i) the peak hour load and (ii) the annual load. Sizing a GHX therefore differs from sizing conventional heating and cooling equipment (i.e., boilers and chillers) because the earth does not respond instantaneously to heat rejected to and extracted from it; long-term temperature changes take place in the underground GHX storage volume if annual loads are not balanced (i.e., the same amount of energy added approximately equals the amount taken out). When annual loads are not balanced, the GHX must be increased in size to accommodate long-term underground temperature changes over years and decades. Annual loads are sometimes naturally balanced by a distinct heating and cooling season, but this is not the case at Whistle Bend, and the size of the GHX to meet all of the intended loads was shown in Section 3.3 to be excessive and unnecessary. This led to this concept of a hybrid system, where supplemental systems are used to assist in damping the peak loads and annual loads on the ground.

Some of the proposed GHX construction details have been described in Section 3.3. To summarize, the GHX concept consists of a closed network of vertical boreholes drilled to approximately 100 m deep. Deeper boreholes could be considered, but would need a test hole to verify drilling conditions and soil thermal properties. Each borehole would be completed with a HDPE plastic u-tube heat exchanger grouted in place with standard bentonite-based grout. HDPE plastic is non-corrodible with a life expectancy of several decades. Heat is exchanged with the ground as a heat-transfer fluid flows down one leg of the u-tube and back up the other. The boreholes are all piped together with horizontal transfer piping with thermally-fused joints to prevent leaks. The entire GHX is buried at least one meter below grade and backfilled such that there is no surface evidence of the GHX.

For pre-design purposes, this study has assumed an antifreeze fluid consisting of an aqueous solution of 20% propylene glycol. Propylene glycol has relatively low viscosity at temperatures below 0°C, but is environmentally-friendly and biodegradable. Methanol is another antifreeze solution used in the geexchange industry, but is flammable and potentially harmful to the environment if released.

As will be described in Section 6.4, the most economically favourable combination of hybrid components results in the GHX being able fit to into one central location if desired.

6.3.2 Geexchange Heat Pumps (Water-to-Water, Water-to-Air)

As described in Section 2.5.2, the increased efficiency with heat pumps relative to fossil-fuel combustion or pure electric resistance heating is due to the fact that heat pumps do not generate heat (such as in fossil fuel furnaces); heat pumps in heating applications extract energy from a low-temperature source and transfer it to a building. A heat pump concentrates heat and distributes it to living space using the same mechanical refrigeration principles that a kitchen refrigerator uses to concentrate “cold” in a food storage compartment.

Geoexchange heat pumps are known as “water-source” heat pumps, meaning that they extract energy from a liquid stream. Geoexchange heat pumps are much more efficient than air-source heat pumps for two main reasons: (i) they extract and reject heat to a water-based liquid with a high heat capacity, meaning that the fluid stream can accept or release much more energy than air with much less temperature change, and (ii) the earth is used as a heat source/sink, which has a temperature closer to room temperature with less fluctuation relative to air. Useful heat can be extracted from fluid at temperatures as low as -4°C if the liquid is an aqueous antifreeze solution.

The coefficient of performance (COP) of geoexchange heat pumps is rated according to International Standards Organization (ISO), Standard 13256-1, at a standardized temperature of 0°C for heating (hence, the reason for selecting this temperature as the minimum design supply temperature to customer buildings). Standard COP data for geoexchange heat pumps are readily available from manufacturer’s catalogues, and typically have values ranging from 3.5 to 4.0. However, as described in Section 2.5.2, the heat pump COP varies throughout the year as the source temperature varies. One misconception of geoexchange systems is that the ground temperature remains constant. This is not the case for closed-loop geoexchange systems because they are installed in a finite earth volume which changes temperature as energy is extracted from and rejected to it. The hybrid geoexchange district concept presented here is based on providing a minimum entering fluid temperature to heat pumps of 0°C , and therefore the seasonal COP of the geoexchange heat pumps will exceed the typical range of 3.5 to 4.0 since energy will be replenished to the underground storage volume via solar energy and sewer heat recovery.

The geoexchange district energy concept presented here involves heat pumps distributed throughout the district, located in the buildings they serve. Geoexchange heat pumps would simply replace conventional furnaces or boilers in buildings, and would be installed during construction of each individual building. Geoexchange heat pumps are typically similar in size or smaller than conventional heating equipment. Note that individual heat pumps would be sized to meet the intended loads of the building; the hybrid components are only designed to assist the GHX in providing source energy to the heat pumps. Therefore, no supplemental heating is necessary within individual buildings, and emergency back-up heating in buildings would be up to the preference of the individual building owner.

The concept of providing low-temperature source water to customer buildings allows for customer flexibility to choose their preferred type of heating system, either ducted forced air or radiant floor heating. Geoexchange heat pumps are available in water-to-air or water-to-water configurations. Emergency back-up electric resistance duct heating elements are available in water-to-air units at relatively low incremental cost. The low-temperature source water also allows options for cooling if desired, since geoexchange heat pumps can both provide heating and cooling. Although not considered in this study, geoexchange heat pumps could be configured to provide domestic hot water if so desired at a future date.

Additional heating load due to domestic hot water production would add load to the geoechange-based system and would have been considered during its design.

6.3.3 Peaking Boiler

As mentioned previously, a peaking boiler system serves to offset peak loads on the ground, thus reducing unnecessary GHX size and cost. The optimum size of the boiler depends on the economic trade-off between the avoided GHX cost and the annual operating cost of the boiler. Economic optimization is discussed in Section 6.4.

For consistent delivery temperature of source fluid from which heat can be extracted by heat pumps, a peaking boiler is added to the district system concept. It becomes part of the geoechange system and will be at a centralized location such as the pumping station. The design concept presented here involves only operating the boiler during times when the fluid temperature exiting the GHX falls below 0°C, which will occur during peak heating load hours. The boiler will therefore contribute very little to operational costs. The boiler could operate on a temperature control, set to maintain a minimum supply temperature of 0°C to the district loop. An additional benefit of a peaking boiler system is that it could be used as a backup in the event of sewage heat recovery interruption (sewer heat exchanger maintenance) or GHX maintenance.

Heat can be generated from gas-fired boilers, electric boilers, biomass boilers, oil-fired boilers, or combined fuel boilers. There is no natural gas available in the Yukon, which precludes the use of natural gas boilers. Electric boilers are available and efficient, but costly to install.

Biomass boilers at present would rely on commercial supply of wood chips or pellets from outside the Yukon. These are becoming more popular, however, and with an abundant local wood resource there is a possibility that a commercial supply will become available in the near future.

Fuel oil boilers have historically been the most common type of boiler installed in the Yukon and there is an established fuel oil infrastructure. Combination fuel oil – biomass boilers have been advertised by some manufacturers however based on preliminary review, fuel switchover requires a burner and auger retrofit. Therefore, it is not a simple process to switch fuels on a regular basis.

Based on discussions with the City's planning consultant for this project (AECOM), a boiler will likely be required to heat the re-circulated potable water main. If the City of Whitehorse or Government of Yukon assumes the operation and ownership of the district energy system, these boilers for heating potable water could also be used as the district energy system peaking boiler.

Reliability of the GHX and distribution loop is to be maintained with the peaking boiler for temperature and the backup pumps for flow. The need for backup heating within individual buildings is not only dependent upon the reliability of this district energy system but of the utility that runs it. Individual building owners do not generally install backup

electricity generation nor backup water supply because of the reliability of the utilities that supply these. It is anticipated that the utility that would own the district energy system would be as reliable. Therefore, no supplemental heating is anticipated to be necessary within individual buildings, and emergency back-up heating in buildings would be up to the inclination of the individual building owner. Many heat pumps can be supplied with an electric heater option for hydronic heating or installation of a duct heater is possible for furnace systems.

6.3.4 Solar Thermal and Sewer Heat Balancing

The role of solar thermal and sewer heat balancing is to offset annually imbalanced loads on the ground by recharging the GHX with thermal energy. Balancing ground loads allows for further reductions in the GHX size and cost. As with a peaking system, the optimum size of the solar collector array and sewer heat recovery system depends on the economic trade-off between the avoided GHX cost and the capital and operating cost of the load balancing systems. Economic optimization of these systems is discussed in Section 6.4.

As shown in the district schematic concept (Figure 6.2), solar energy would be the “first” energy source added to the district loop, mainly because the most strategic location for solar collector location is on customer roof tops. Solar energy would therefore be added to the district loop immediately downstream of the heat pumps. This would be accomplished with existing off-the-shelf solar technology. Solar collectors are typically operated using a differential set point control, meaning that the collector must be warmer than the district loop by a set amount (typically at least 5°C) for useful heat transfer to occur. Thus, useful heat can be collected beginning at low solar collector temperatures (i.e., less than 5°C).

Similar to the solar recharging concept, sewer heat would be added to the loop at a strategic location as the fluid returns to the GHX. This allows heat to be collected at any time during year and stored underground in the GHX to improve its thermal performance. Useful heat could only be transferred to the district loop when the wastewater temperature exceeds the district loop temperature.

6.3.5 Infrastructure Requirements

The main infrastructure requirements for the district concept include: the GHX; a mechanical building to house the equipment associated with the distribution of the heat carrier fluid to customers; a mechanical building to house sewer heat recovery equipment; a distribution pipeline network to convey the heat carrier fluid to customers; solar energy transfer stations in customer buildings; and energy meters in customer buildings. In addition, a data acquisition and control system with web-based or remote-read monitoring would be needed.

In the district concept presented here, the geoexchange heat pumps represent the link between the district infrastructure and the customer. The economic analysis presented in Section 6.4 assumes that customers would be responsible for purchasing their own heat pump, just as they would own their own furnace or boiler. Presumably, any incremental

cost of a geoexchange heat pump relative to a conventional furnace or boiler would be rolled into mortgage payments when a home or building is purchased in Whistle Bend. However, actual ownership of geoexchange heat pumps would be up to the district system owner. Heat pump leasing options could also be considered, with lease payments rolled into energy billings. At the time of completion of this report, the incremental cost of geoexchange heat pumps relative to conventional fuel oil furnaces is estimated at about 30-50%. However, this cost premium is tentative because there is currently little to no market for geoexchange heat pumps in Whitehorse. A project such as Whistle Bend would likely stimulate the geoexchange heat pump market in Whitehorse and significantly lower heat pump capital costs.

Some construction details of the GHX have been described above. The entire GHX would be buried at least one meter below grade and backfilled such that there would be no surface evidence of the GHX existence (other than signs marking its location). Surface structures could be built over the GHX, as long as subsurface stresses are allowable on the buried pipe, but the ground surface would ideally be kept clear above the GHX to allow future access to the GHX if needed. The GHX supply and return piping would be routed to a mechanical building housing the fluid circulation pump, boiler, and associated hydronic equipment and controls. The GHX should be designed so that it can be properly flushed and purged of air. This typically involves plumbing the boreholes into groups (or flow circuits) such that individual groups can be valved off and isolated. This can be accomplished either outside the mechanical building in an underground vault, or with plumbing manifolds inside the mechanical building. As will be described in Section 6.4, the most economically favourable combination of hybrid components results in the GHX being able fit to into one central location if the final designer chooses to do so.

A mechanical building is needed to house equipment associated with the heat carrier fluid distribution system. For budget purposes, this study has assumed that a mechanical building of 150 to 185 m² would be sufficient to accommodate equipment. Actual building size and equipment requirements would need to be determined at final design stages. The major equipment items contained in the mechanical building would include a primary and back-up boiler, staged circulation pumps, and controls. An automatic control system would be installed to energize the peaking boiler in the event that the district energy system temperature falls below a minimum set point (initial set point = 0°C). Heat would be injected into the district energy system with a modulating 3-way control valve. The valve position would be controlled through an electronic controller. Booster pump operation would be automatic and would cycle weekly between duty/standby operation to ensure equal run time. Ideally, the mechanical building would be located centrally within the district it serves in order to optimally design the piping distribution system; it would not make practical sense to convey the entire quantity of flow through one pipe.

A mechanical building is also needed to house equipment associated with the sewage heat recovery system. The most practical and economic location for this building would be an expansion to the planned central lift station. For budget purposes, this study has assumed

that an expansion of 50 to 100 m² would be sufficient to accommodate the heat recovery equipment. The major equipment items contained in the expanded lift station would include the sewage heat exchanger, main and bypass piping and fittings, primary and backup pumps, and controls. Additional building heat would be required using the same heating system as the lift station. The lift station's proposed location is centrally located in the Whistle Bend neighbourhood, within development area 3 close to the town square. This is an optimal location for its proximity to the GHX fluid distribution system.

The fluid distribution system makes use of pre-insulated HDPE plastic pipe (with HDPE outer jacket) to convey the heat-carrier fluid from the mechanical building to the district customers. Insulated pipe allows for shallower burial and minimizes heat loss relative to uninsulated pipe. The selection of a low-temperature distribution loop in this district concept was partially based on the advantages of using HDPE plastic pipe. HDPE pipe joints are thermally-fused with a life-expectancy of several decades. The pipe material itself is durable and non-corrodible. A high-temperature distribution loop would require the use of steel or fibreglass pipe, because HDPE and PVC pipe are not rated for use above 60°C. Steel pipe installation is generally costly from a materials and labour perspective because of its weight. Steel pipe joints require welding, and the pipe material is corrodible. Use of fibreglass pipe in high-temperature district systems has the advantage of non-corrodibility, but extreme care must be taken in assembling the pipe joints, which is typically done with proprietary adhesives.

The layout of the distribution pipe network is beyond the scope of this study, as there are numerous ways to design the pipe network. Pipe layout is typically a designer's choice in conjunction with City preferences, and is therefore a task left for final design. However, to give some idea as to the infrastructure requirement, each development area requires a fluid flow rate on the order of 160 to 190 L/s (2,500 – 3,000 US gallons per minute) based on heat pump peak flow requirements. This fluid flow rate could be accommodated by a 12-in. nominal diameter pipe if all the flow per development area were to be conveyed through one pipe. However, locating the mechanical building in a central location would result in more manageable fluid handling, since smaller pipe diameters could be routed from the mechanical building to blocks of buildings. For example, a nominal 6-in. diameter pipe could reasonably convey approximately 40 L/s (600 US gallons per minute), or enough flow to supply about one-quarter of each development area. Pipe trenches to customer buildings would contain two pipes: one supply and one return, and would ideally be designed in a looping configuration. As a piping loop leaves the mechanical building, the supply pipe would be at its maximum diameter, and would “telescope” down in size as the fluid enters buildings. Similarly, the return pipe would telescope up in size as it makes its way back to the mechanical building.

Infrastructure requirements for solar collector arrays would involve use of off-the-shelf, glazed flat-plate solar collector technology, using 50% propylene glycol circulating liquid. Solar collectors would be mounted flush on pitched roofs, or on a rack if mounted on flat roofs. Care must be taken when mounting on flat roofs to separate successive rows of

collectors far enough apart so as to minimize shading of one row onto another. Individual solar collector loops would be separated from the main district loop by small brazed-plate heat exchangers. Solar collectors require very small flow rates, and a small circulator pump would be energized when the solar collector temperature exceeds the district loop return temperature by a differential set point (typically at least 5°C). Thus, useful heat can be collected beginning at low solar collector temperatures (i.e., less than 5°C). Small energy transfer centers would then be located in buildings with solar collectors. Each energy center would contain a brazed-plate heat exchanger, circulator pump, and controls.

Finally, energy meters would need to be installed in each building to meter customer energy usage for billing purposes. Energy meters are similar to water meters, and calculate energy use by measuring flow rate of the heat carrier fluid and the temperature of the supply and return fluid. There are a number of commercially-available energy meters that have remote-read capability.

6.4 OPTIMIZATION ANALYSIS

“Optimization”, in general, refers to a systematic investigation aimed at finding the maximum or minimum value of a particular parameter of interest. Here, optimization refers to the procedure for seeking the minimum life-cycle cost of the hybrid geoexchange district energy system for the WBN.

An optimization analysis is needed in hybrid geoexchange system design because a multitude of combinations of hybrid component sizes is possible (i.e., combinations of GHX size, number of solar collectors, sewer heat recovery, and peaking boiler size). There is a trade-off in cost savings in reducing the size of a GHX in favour of adding initial and operating cost of a hybrid component. Therefore, the objective of the optimization analysis presented here is to find workable combinations of hybrid geoexchange system components (i.e., the GHX, solar collectors, sewer heat recovery, and peaking boiler) that result in minimum life-cycle cost. It is emphasized that the goal of this optimization analysis is not to find the precise combination of hybrid system component sizes, but to provide a first approximation of whether feasible combinations exist. Precise sizing of hybrid components is an analysis left for later stages of the design process.

The methodology in conducting the optimization analysis involved examining numerous combinations of hybrid system component sizes as follows:

- For each Scenario, a non-hybrid GHX was sized to supply 100% of the thermal energy to heat pumps using GLHEPro software tool (Spitler, 2007) as described in Section 3.3.
- For each Scenario, the thermal performance of 25 hybrid geoexchange cases with various combinations of GHX size, number of solar collectors, and peaking boiler fraction were simulated with and without sewer heat recovery. Therefore, a total number of 50 combinations were examined for each Scenario (300 in total). Hybrid geoexchange energy simulations were conducted using TRNSYS (SEL, 2000), which is a state-of-the-art transient energy simulation software tool. Computer models were

configured similar to the concept diagram shown in Figure 6.2. Once constructed, the use of TRNSYS computer models allowed examination of several “what-if” alternatives. The GHX configuration and thermal properties were modeled as described in Section 3.3. Glazed flat plate solar thermal collectors were modeled with properties similar to those described by Numerical Logics (2008). Solar collector glycol-based loops were separated from the main district loop with isolation heat exchangers. The peaking boiler was controlled to maintain a minimum fluid supply temperature to building heat pumps of 0°C. Wastewater temperature and flow rates were those of the Whistle Bend Neighbourhood as described in Section 4.1. The sewer heat recovery heat exchanger was modelled with a heat exchanger effectiveness of 0.80, controlled to shut off when the wastewater temperature dropped to 2°C. Energy simulations were conducted for 100 years.

- 50-years life-cycle cost analyses were conducted for each case using the energy simulation results, along with economic assumptions summarized in Table 6.1 (attached). Fifty years represents a typical design life assigned to HDPE pipe and other municipal infrastructure. The rate-of-return (ROR) method was used as the economic indicator to evaluate options. The ROR represents the true interest yield provided by the project equity over its life before income tax. It is calculated using the pre-tax yearly cash flows and the project life. It is also referred to as the internal rate of return (IRR). It is calculated by finding the discount rate that causes the net present value of the equity to be equal to zero. Therefore, it is not necessary to establish the discount rate of an organization to use this indicator, as it is for use of the net present value method. An organization interested in a project can compare the rate of return to its required rate of return (often, the cost of capital or level of investment risk). The most obvious advantage of using the rate of return indicator to evaluate a project is that the outcome does not depend on a discount rate that is specific to a given organization. The ROR obtained is specific to the project and applies to all investors in the project.
- The most economically favourable general combination of hybrid component sizes was found graphically by constructing optimization plots. The plots display the 50-yr rate of return as a function of GHX size, number of solar collectors, and annual energy fraction contributed by a peaking system. Plots were constructed for each Scenario for cases with and without sewer heat recovery. Optimization plots were constructed using SURFER (Golden Graphics, 2002).

ISSUED FOR USE

TABLE 6.2 SUMMARY OF CAPITAL COSTS FOR EACH EVALUATION SCENARIO

Capital Cost Item	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5		Scenario 6	
	No SHR	With SHR	No SHR	With SHR	No SHR	With SHR	No SHR	With SHR	No SHR	With SHR	No SHR	With SHR
Ground Heat Exchanger	\$1.00	\$1.00	\$1.00	\$1.00	\$2.50	\$5.00	\$1.00	\$1.00	\$10.0	\$5.00	\$10.0	\$20.0
Solar Collector Arrays	\$1.61	\$2.34	\$1.87	\$1.87	\$3.50	\$3.50	\$2.04	\$2.04	\$11.6	\$11.6	\$11.6	\$11.6
Peaking Boiler System	\$0.36	\$0.19	\$0.19	\$0.19	\$0.28	\$0.20	\$0.22	\$0.22	\$0.72	\$0.43	\$0.60	\$0.37
Distribution System (<i>pipings, pumping system, mechanical building, customer connections</i>)	\$2.43	\$2.43	\$5.38	\$5.38	\$7.58	\$7.58	\$2.49	\$2.49	\$24.9	\$24.9	\$29.3	\$29.3
Sewer Heat Recovery System	\$0.00	\$0.74	\$0.00	\$0.74	\$0.00	\$0.78	\$0.00	\$0.74	\$0.00	\$1.25	\$0.00	\$1.73
Incentives/Grants	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
Design/Engineering	\$0.54	\$0.67	\$0.84	\$0.92	\$1.39	\$1.71	\$0.70	\$0.79	\$4.70	\$4.39	\$5.15	\$6.30
Total Cost	\$5.94	\$7.37	\$9.29	\$10.1	\$15.2	\$18.8	\$6.45	\$7.29	\$51.7	\$47.9	\$56.6	\$69.3
50-year Rate of Return	6.5%	6.0%	6.7%	6.3%	7.2%	6.7%	5.9%	6.3%	6.0%	6.0%	6.1%	5.7%

Notes:

SHR = Sewer heat recovery.

All values expressed in 2009 dollars.

All values in 2009 million dollars.

Additional assumptions in the economic analysis are as follows:

- The cost of capital (i.e., cost of borrowing money) was not included. The rationale for this was that the cost of capital will depend on ownership. A large project such as this will likely include capital from several sources such as grants and other incentives and/or low-interest rate loans of varying duration, for example. The capital cost of the district system infrastructure per development area was therefore assumed to occur as a single payment at the start of construction of each development area.
- Land purchase or lease for district system buildings/infrastructure is not included.
- Income taxes are not included, since ROR is usually a pre-tax analysis. Income tax rate will depend on ownership structure.
- Depreciation and depletion of assets not included, since these are included with an income tax analysis with the goal of reducing tax payment.
- Revenue and expenses was pro-rated over the assumed 5-year build-out of each development phase.

Prior to discussion of the optimization results, a general description of the plots is given here. For each Scenario, optimization plots were constructed for cases with sewer heat recovery and for cases without sewer heat recovery. Contour lines represent the number of 100-m deep GHX boreholes required to provide all thermal source energy to the district heat pumps with assistance from various numbers of solar collectors (shown on the bottom or x -axis) and annual fractions of energy from a peaking boiler system (shown on the left axis or y -axis). Therefore, the lower left-hand corner of each plot represents the case of a GHX providing energy to heat pumps with no solar or boiler hybrid assistance. The annual fraction of energy provided by a boiler system on the left or y -axis is expressed relative to the total annual building heating load. Therefore, the maximum amount of annual energy a boiler could supply, even with no GHX, is less than 100% due to heat pump thermodynamic principles. The source-side energy of a heat pump in heating mode is less than the load side energy by a factor equal to $(COP-1)/COP$. Finally, the coloured areas of the plots represent the ROR of the particular combination of hybrid components. A ROR colour legend is shown to the right of each set of optimization plots.

6.4.1 Scenario 1

Optimization plots for Scenario 1 are shown in Figure 6.3 for (a) cases with no sewer heat recovery and (b) cases with sewer heat recovery.

A non-hybrid GHX (i.e., one with no assistance from hybrid components) sized to provide all of the thermal energy to heat pumps in the district buildings with no sewer heat recovery (i.e., the lower left-hand corner of Figure 6.3a) would require approximately 2,900 100-m deep boreholes and occupy a footprint area of about 29 ha. The capital cost of a non-hybrid district geothermal system under Scenario 1 is approximately \$35 million with a 50-year ROR of about 1.0%.

With the inclusion of sewer heat recovery as the only hybrid component (i.e., the lower left-hand corner of Figure 6.3b), the GHX size reduces to approximately 2,000 100-m deep boreholes, occupying a footprint area of about 20 ha. The reduction in the GHX size is due to extraction and underground storage of thermal energy from Whistle Bend wastewater. The savings in GHX cost, with the addition of sewer heat recovery infrastructure, results in a lower overall capital cost of \$25 million and a higher 50-year ROR of about 1.9%, relative to a non-hybrid district geotexchange energy system.

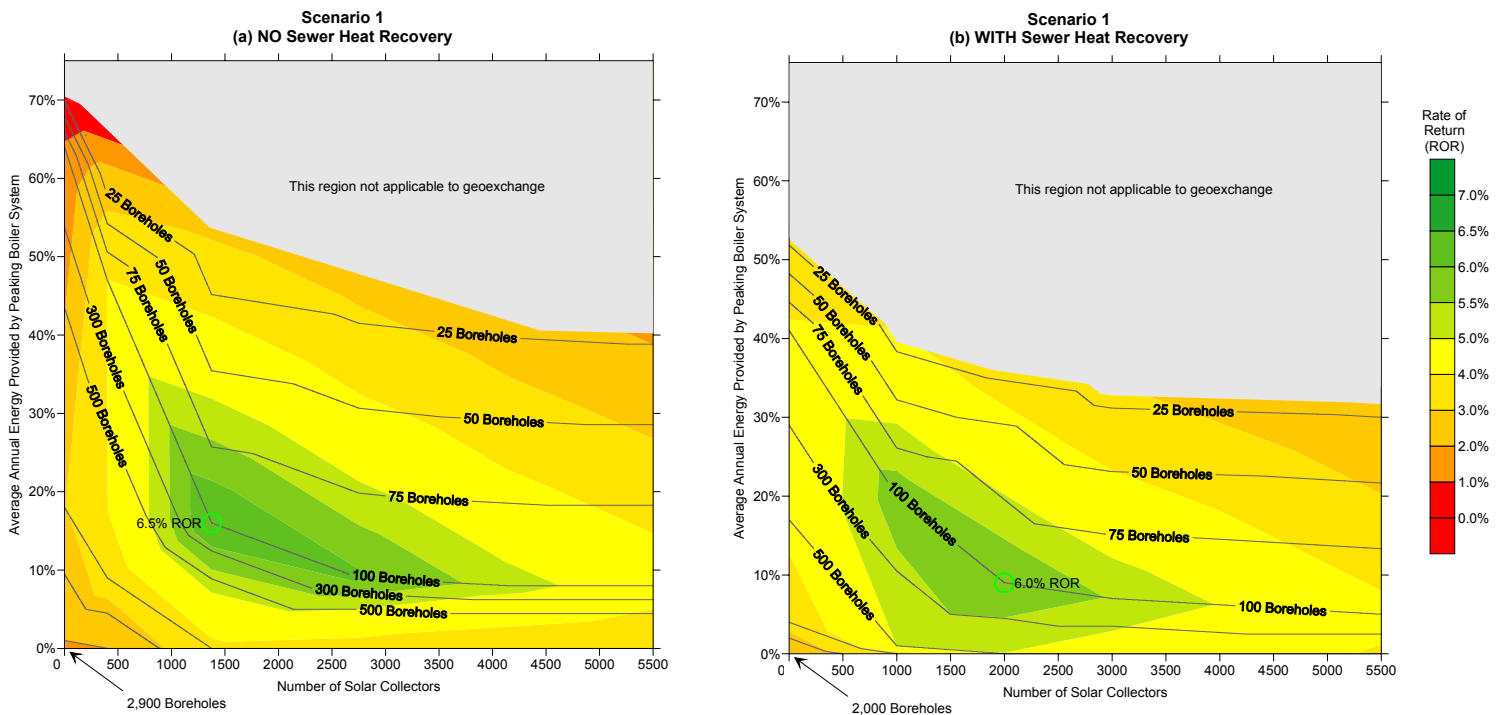


Figure 6.3: Scenario 1 Optimization Plots showing investment rate of return for number of GHX boreholes as a function of number of solar collectors, and average annual fraction of energy provided by a peaking boiler system with (a) no sewer heat recovery and (b) with sewer heat recovery.

The optimization analysis reveals that the capital cost and ROR can be significantly improved for Scenario 1 with the integration of a solar collector array and peaking boiler system. The levelling off of the borehole curves beyond about 1,500 to 2,000 solar collectors means that there is diminishing benefit for the added cost of solar collectors exceeding this amount. The near optimum ROR of Scenario 1 with no sewer heat recovery is about 6.5% with a reduced GHX of 100 100-m deep boreholes, 1,375 solar thermal collectors, and a peaking boiler system that supplies only 16% of the annual heating load. The reduced GHX size would occupy a footprint area of about 1 ha. The capital cost of this case is about \$5.94 million.

The near optimum ROR of Scenario 1 with sewer heat recovery is about 6.0% with a reduced GHX of 100 100-m deep boreholes, 2,000 solar thermal collectors, and a peaking boiler system that supplies only 9% of the annual heating load. The reduced GHX size would occupy a footprint area of about 1 ha. The capital cost of this case is about \$7.37 million.

6.4.2 Scenario 2

Optimization plots for Scenario 2 are shown in Figure 6.4 for (a) cases with no sewer heat recovery and (b) cases with sewer heat recovery.

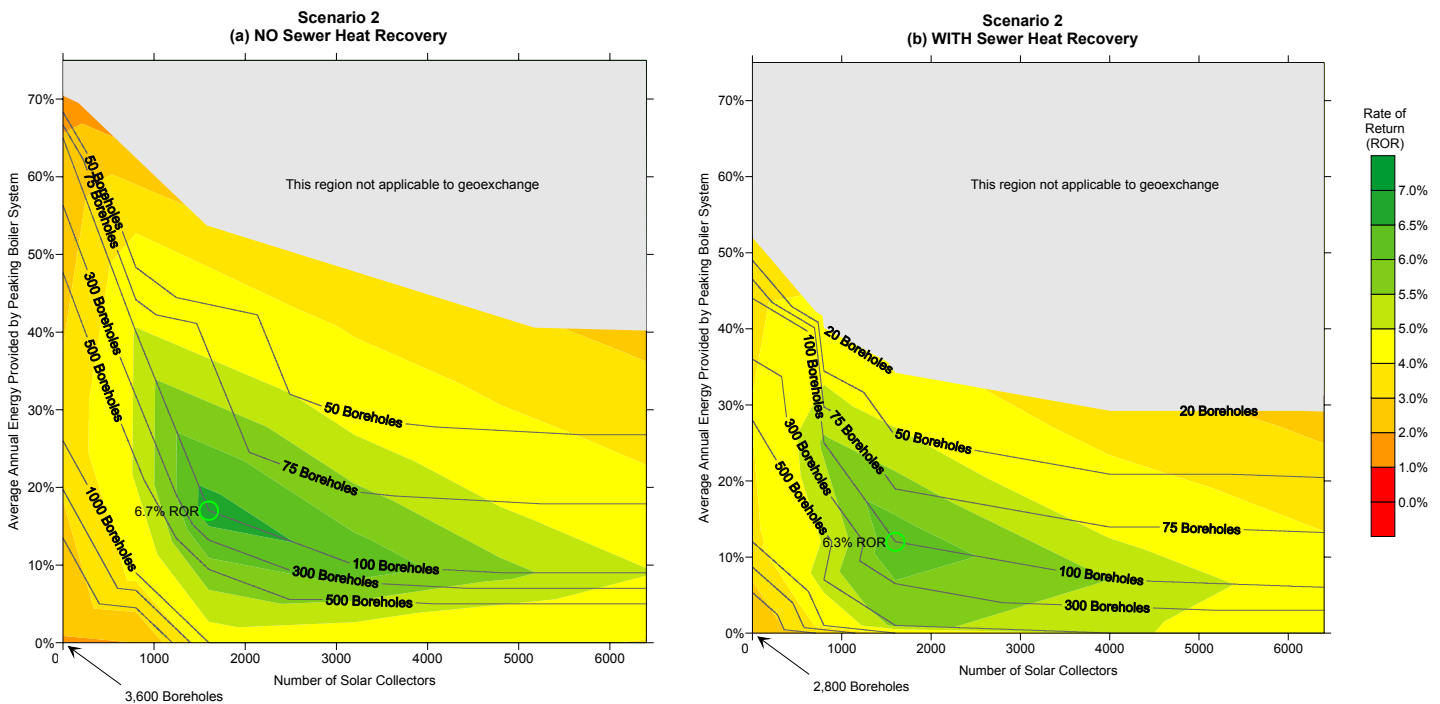


Figure 6.4: Scenario 2 Optimization Plots showing investment rate of return for number of GHX boreholes as a function of number of solar collectors, and average annual fraction of energy provided by a peaking boiler system with (a) no sewer heat recovery and (b) with sewer heat recovery.

A non-hybrid GHX (i.e., one with no assistance from hybrid components) sized to provide all of the thermal energy to heat pumps in the district buildings with no sewer heat recovery (i.e., the lower left-hand corner of Figure 6.4a) would require approximately 3,600 100-m deep boreholes and occupy a footprint area of about 36 ha. The capital cost of a non-hybrid district geoexchange system under Scenario 2 is approximately \$46 million with a 50-year ROR of about 1.3%.

With the inclusion of sewer heat recovery as the only hybrid component (i.e., the lower left-hand corner of Figure 6.4b), the GHX size reduces to approximately 2,800 100-m deep boreholes, occupying a footprint area of about 28 ha. The reduction in the GHX size is due to extraction and underground storage of thermal energy from Whistle Bend wastewater. The savings in GHX cost, with the addition of sewer heat recovery infrastructure, results in a lower overall capital cost of \$38 million and a higher 50-year ROR of about 1.9%, relative to a non-hybrid district geoexchange energy system.

The optimization analysis reveals that the capital cost and ROR can be significantly improved for Scenario 2 with the integration of a solar collector array and peaking boiler system. The levelling off of the borehole curves beyond about 1,500 to 2,000 solar collectors means that there is diminishing benefit for the added cost of solar collectors exceeding this amount. The near optimum ROR of Scenario 2 with no sewer heat recovery is about 6.7% with a reduced GHX of 100 100-m deep boreholes, 1,600 solar thermal collectors, and a peaking boiler system that supplies only 17% of the annual heating load. The reduced GHX size would occupy a footprint area of about 1 ha. The capital cost of this case is about \$9.29 million.

The near optimum ROR of Scenario 2 with sewer heat recovery is about 6.3% with a reduced GHX of 100 100-m deep boreholes, 1,600 solar thermal collectors, and a peaking boiler system that supplies only 12% of the annual heating load. The reduced GHX size would occupy a footprint area of about 1 ha. The capital cost of this case is about \$10.1 million.

6.4.3 Scenario 3

Optimization plots for Scenario 3 are shown in Figure 6.5 for (a) cases with no sewer heat recovery and (b) cases with sewer heat recovery.

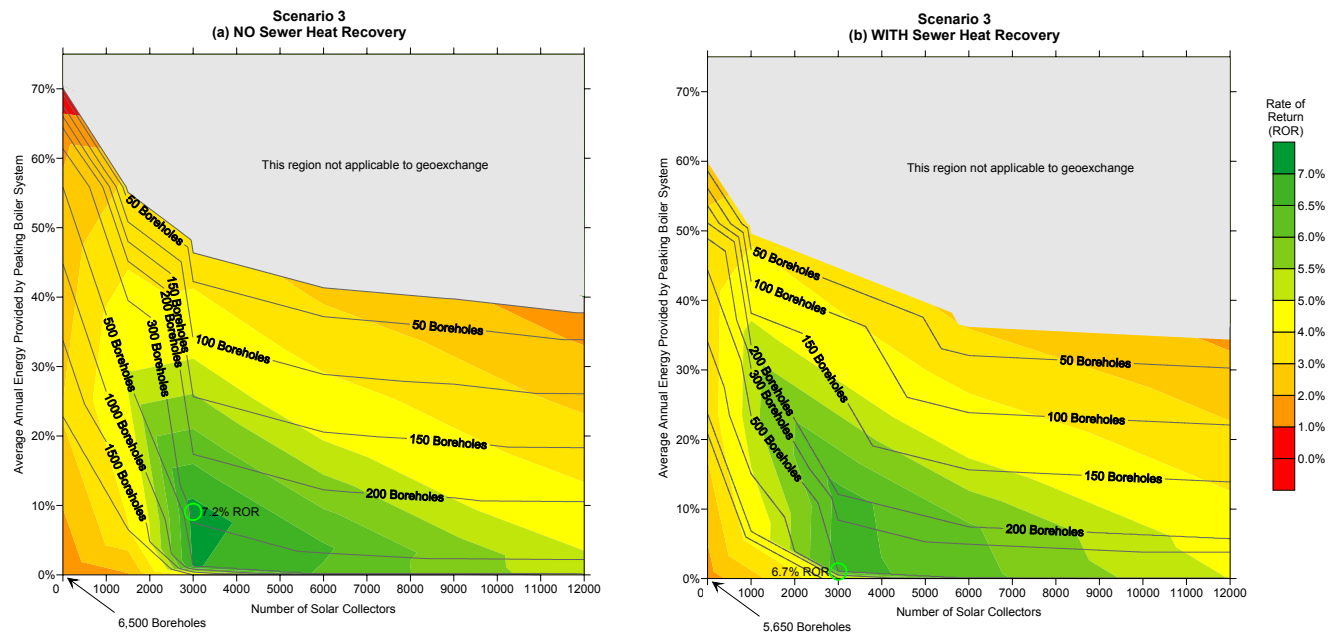


Figure 6.5: Scenario 3 Optimization Plots showing investment rate of return for number of GHX boreholes as a function of number of solar collectors, and average annual fraction of energy provided by a peaking boiler system with (a) no sewer heat recovery and (b) with sewer heat recovery.

A non-hybrid GHX (i.e., one with no assistance from hybrid components) sized to provide all of the thermal energy to heat pumps in the district buildings with no sewer heat recovery (i.e., the lower left-hand corner of Figure 6.5a) would require approximately 6,500 100-m deep boreholes and occupy a footprint area of about 65 ha, exceeding the land area available for potential drilling. As described in Section 3.2, potentially-available drilling areas could accommodate only about 6,000 boreholes. The capital cost of a non-hybrid district geoechange system under Scenario 3 is approximately \$80 million with a 50-year ROR of about 1.2%.

With the inclusion of sewer heat recovery as the only hybrid component (i.e., the lower left-hand corner of Figure 6.5b), the GHX size reduces to approximately 5,650 100-m deep boreholes, occupying a footprint area of about 56 ha. The reduction in the GHX size is due to extraction and underground storage of thermal energy from Whistle Bend wastewater. The savings in GHX cost, with the addition of sewer heat recovery infrastructure, results in a lower overall capital cost of \$71 million and a higher 50-year ROR of about 1.6%, relative to a non-hybrid district geoechange energy system.

The optimization analysis reveals that the capital cost and ROR can be significantly improved for Scenario 3 with the integration of a solar collector array and peaking boiler system. The levelling off of the borehole curves beyond about 3,000 to 5,000 solar collectors means that there is diminishing benefit for the added cost of solar collectors

exceeding this amount. The near optimum ROR of Scenario 3 with no sewer heat recovery is about 7.2% with a reduced GHX of 250 100-m deep boreholes, 3,000 solar thermal collectors, and a peaking boiler system that supplies only 9% of the annual heating load. The reduced GHX size would occupy a footprint area of about 2.5 ha. The capital cost of this case is about \$15.2 million.

The near optimum ROR of Scenario 3 with sewer heat recovery is about 6.7% with a reduced GHX of 500 100-m deep boreholes, 3,000 solar thermal collectors, and a peaking boiler system that supplies only 1% of the annual heating load. The reduced GHX size would occupy a footprint area of about 5 ha. The capital cost of this case is about \$18.8 million.

6.4.4 Scenario 4

Optimization plots for Scenario 4 are shown in Figure 6.6 for (a) cases with no sewer heat recovery and (b) cases with sewer heat recovery.

A non-hybrid GHX (i.e., one with no assistance from hybrid components) sized to provide all of the thermal energy to heat pumps in the district buildings with no sewer heat recovery (i.e., the lower left-hand corner of Figure 6.6a) would require approximately 3,200 100-m deep boreholes and occupy a footprint area of about 32 ha. The capital cost of a non-hybrid district geexchange system under Scenario 4 is approximately \$38 million with a 50-year ROR of about 1.0%.

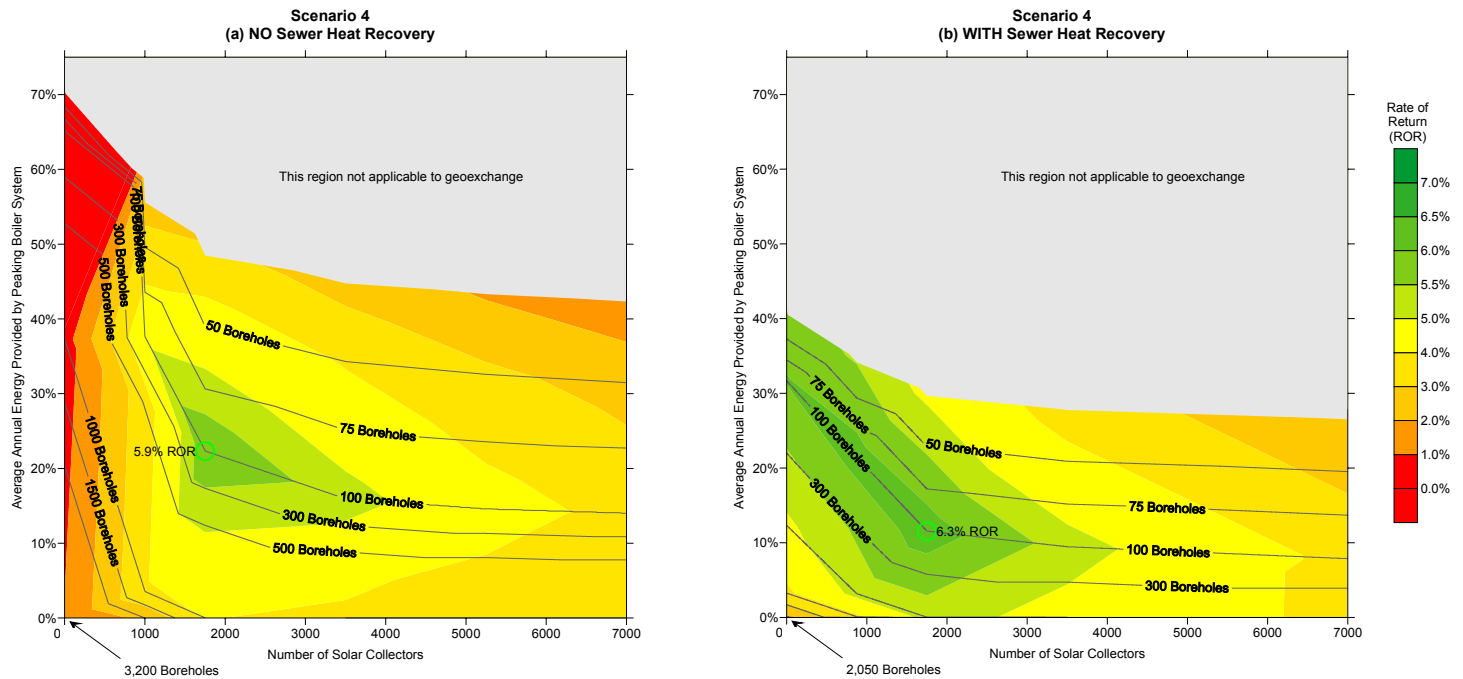


Figure 6.6: Scenario 4 Optimization Plots showing investment rate of return for number of GHX boreholes as a function of number of solar collectors, and average annual fraction of energy provided by a peaking boiler system with (a) no sewer heat recovery and (b) with sewer heat recovery.

With the inclusion of sewer heat recovery as the only hybrid component (i.e., the lower left-hand corner of Figure 6.6b), the GHX size reduces to approximately 2,050 100-m deep boreholes, occupying a footprint area of about 20 ha. The reduction in the GHX size is due to extraction and underground storage of thermal energy from Whistle Bend wastewater. The savings in GHX cost, with the addition of sewer heat recovery infrastructure, results in a lower overall capital cost of \$26 million and a higher 50-year ROR of about 2.1%, relative to a non-hybrid district geexchange energy system.

The optimization analysis reveals that the capital cost and ROR can be significantly improved for Scenario 4 with the integration of a solar collector array and peaking boiler system. The levelling off of the borehole curves beyond about 1,500 to 2,000 solar collectors means that there is diminishing benefit for the added cost of solar collectors exceeding this amount. The near optimum ROR of Scenario 4 with no sewer heat recovery is about 5.9% with a reduced GHX of 100 100-m deep boreholes, 1,750 solar thermal collectors, and a peaking boiler system that supplies only 22% of the annual heating load. The reduced GHX size would occupy a footprint area of about 1 ha. The capital cost of this case is about \$6.45 million.

The near optimum ROR of Scenario 4 with sewer heat recovery is about 6.3% with a reduced GHX of 100 100-m deep boreholes, 1,750 solar thermal collectors, and a peaking boiler system that supplies only 11% of the annual heating load. The reduced GHX size would occupy a footprint area of about 1 ha. The capital cost of this case is about \$7.29 million.

6.4.5 Scenario 5

Optimization plots for Scenario 5 are shown in Figure 6.7 for (a) cases with no sewer heat recovery and (b) cases with sewer heat recovery.

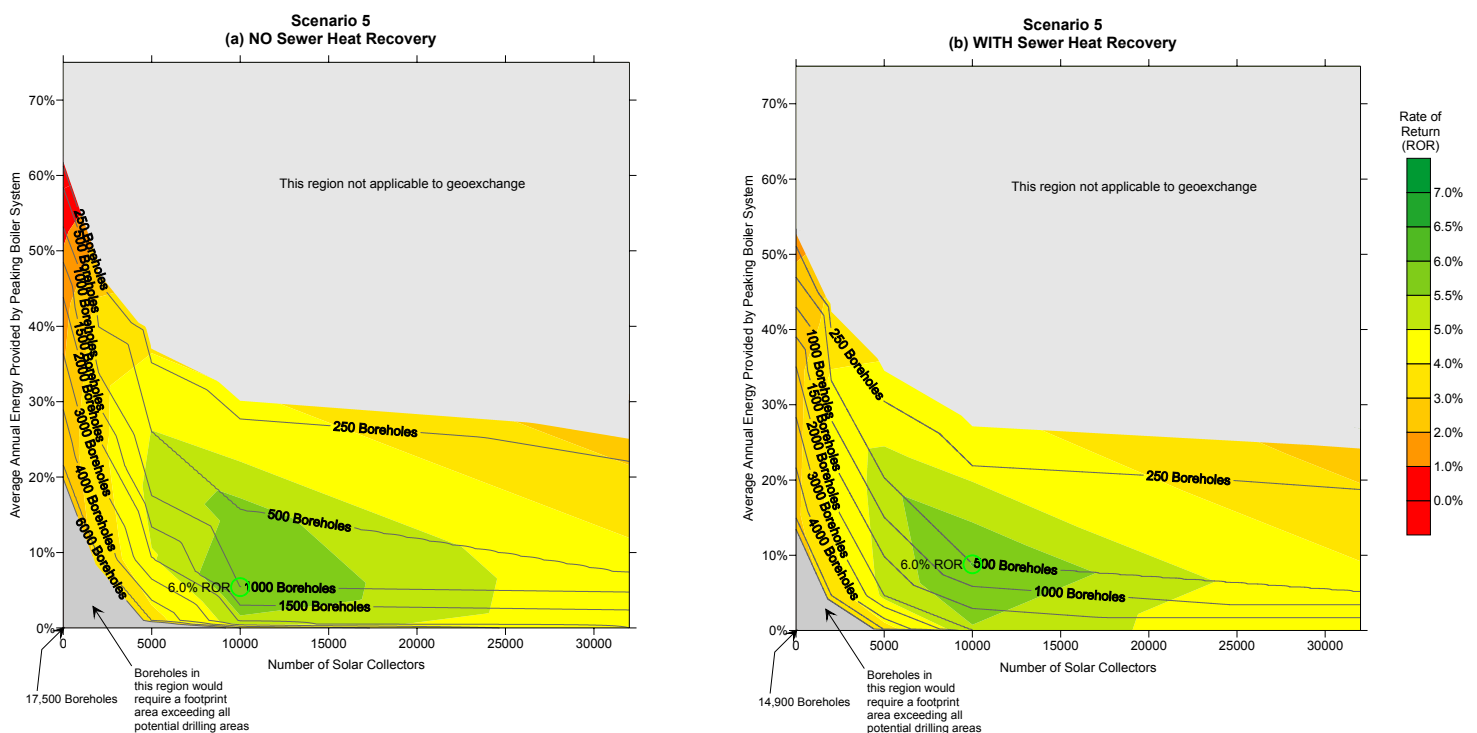


Figure 6.7: Scenario 5 Optimization Plots showing investment rate of return for number of GHX boreholes as a function of number of solar collectors, and average annual fraction of energy provided by a peaking boiler system with (a) no sewer heat recovery and (b) with sewer heat recovery.

A non-hybrid GHX (i.e., one with no assistance from hybrid components) sized to provide all of the thermal energy to heat pumps in the district buildings with no sewer heat recovery (i.e., the lower left-hand corner of Figure 6.7a) would require approximately 17,500 100-m deep boreholes and occupy a footprint area of about 175 ha, exceeding the land area available for potential drilling. As described in Section 3.2, potentially-available drilling areas could accommodate only about 6,000 boreholes. The capital cost of a non-hybrid

district geoexchange system under Scenario 5 is approximately \$220 million with a 50-year ROR of about 0.8%.

With the inclusion of sewer heat recovery as the only hybrid component (i.e., the lower left-hand corner of Figure 6.7b), the GHX size reduces to approximately 14,900 100-m deep boreholes, occupying a footprint area of about 149 ha but still exceeding the available land area for potential drilling. The reduction in the GHX size is due to extraction and underground storage of thermal energy from Whistle Bend wastewater. The savings in GHX cost, with the addition of sewer heat recovery infrastructure, results in a lower overall capital cost of \$195 million and a higher 50-year ROR of about 1.2%, relative to a non-hybrid district geoexchange energy system.

The optimization analysis reveals that the capital cost and ROR can be significantly improved for Scenario 5 with the integration of a solar collector array and peaking boiler system. The levelling off of the borehole curves beyond about 10,000 solar collectors means that there is diminishing benefit for the added cost of solar collectors exceeding this amount. The near optimum ROR of Scenario 5 with no sewer heat recovery is about 6.0% with a reduced GHX of 1,000 100-m deep boreholes, 10,000 solar thermal collectors, and a peaking boiler system that supplies only 5% of the annual heating load. The reduced GHX size would occupy a footprint area of about 10 ha. The capital cost of this case is about \$51.7 million.

The near optimum ROR of Scenario 5 with sewer heat recovery is about 6.0% with a reduced GHX of 500 100-m deep boreholes, 10,000 solar thermal collectors, and a peaking boiler system that supplies only 8% of the annual heating load. The reduced GHX size would occupy a footprint area of about 5 ha. The capital cost of this case is about \$47.9 million.

6.4.6 Scenario 6

Optimization plots for Scenario 6 are shown in Figure 6.8 for (a) cases with no sewer heat recovery and (b) cases with sewer heat recovery.

A non-hybrid GHX (i.e., one with no assistance from hybrid components) sized to provide all of the thermal energy to heat pumps in the district buildings with no sewer heat recovery (i.e., the lower left-hand corner of Figure 6.8a) would require approximately 21,250 100-m deep boreholes and occupy a footprint area of about 212 ha, greatly exceeding the land area available for potential drilling. As described in Section 3.2, potentially-available drilling areas could accommodate only about 6,000 boreholes. The capital cost of a non-hybrid district geoexchange system under Scenario 6 is approximately \$270 million with a 50-year ROR of about 0.9%.

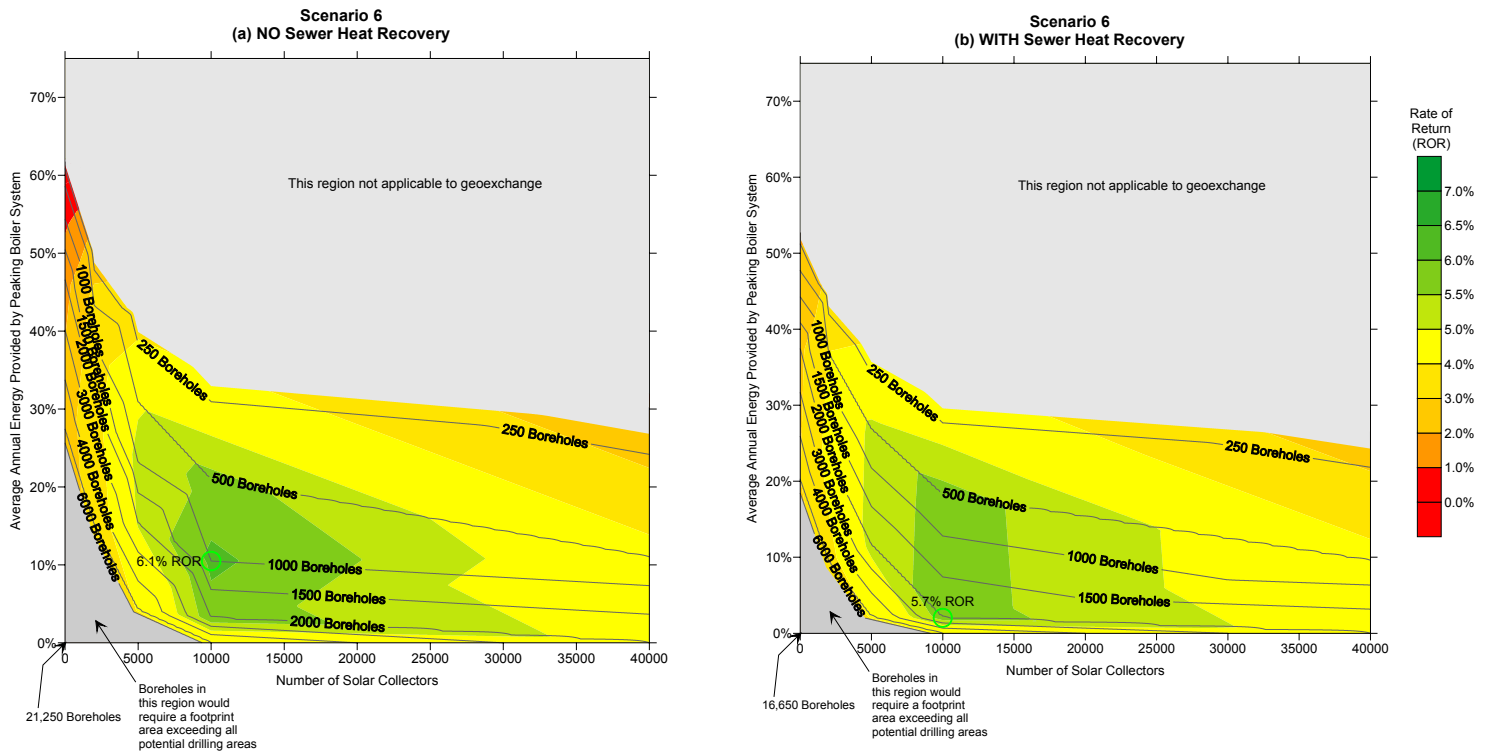


Figure 6.8: Scenario 6 Optimization Plots showing investment rate of return for number of GHX boreholes as a function of number of solar collectors, and average annual fraction of energy provided by a peaking boiler system with (a) no sewer heat recovery and (b) with sewer heat recovery.

With the inclusion of sewer heat recovery as the only hybrid component (i.e., the lower left-hand corner of Figure 6.8b), the GHX size reduces to approximately 16,650 100-m deep boreholes, occupying a footprint area of about 166 ha but still exceeding the available land area for potential drilling. The reduction in the GHX size is due to extraction and underground storage of thermal energy from Whistle Bend wastewater. The savings in GHX cost, with the addition of sewer heat recovery infrastructure, results in a lower overall capital cost of \$215 million and a higher 50-year ROR of about 1.5%, relative to a non-hybrid district geoechange energy system.

The optimization analysis reveals that the capital cost and ROR can be significantly improved for Scenario 6 with the integration of a solar collector array and peaking boiler system. The levelling off of the borehole curves beyond about 10,000 solar collectors means that there is diminishing benefit for the added cost of solar collectors exceeding this amount. The near optimum ROR of Scenario 6 with no sewer heat recovery is about 6.1% with a reduced GHX of 1,000 100-m deep boreholes, 10,000 solar thermal collectors, and a peaking boiler system that supplies only 10% of the annual heating load. The reduced

GHX size would occupy a footprint area of about 10 ha. The capital cost of this case is about \$56.6 million.

The near optimum ROR of Scenario 6 with sewer heat recovery is about 5.7% with a reduced GHX of 2,000 100-m deep boreholes, 10,000 solar thermal collectors, and a peaking boiler system that supplies only 2% of the annual heating load. The reduced GHX size would occupy a footprint area of about 20 ha. The capital cost of this case is about \$69.3 million.

6.4.7 Cost Estimates for District Energy Alternatives

Detailed assumptions used in the capital and annual cost estimates are summarized in Table 6.1 (attached), and those assumptions were used to generate the optimization plots described above. In summary, the major capital cost items that have been considered include all materials and labour associated with constructing the GHX, solar collector arrays, peaking boiler system, distribution system (piping, pumping system, mechanical building, customer connections), sewer heat recovery system. Design and engineering fees are also included. Incentives and grants were conservatively assumed to be zero. It was also assumed that the DES billing rates would be structured such that customers would realize a 10% savings relative to conventional furnace oil. Actual billing rates would be ultimately decided by DES ownership structure. The 10% customer savings was assumed here in order to determine if a DES could remain feasible while providing savings to customers.

Table 6.2 (above) is a summary of capital costs for the near optimum case of each evaluation Scenario. Additional cost details of the sewer heat recovery system are contained in Appendix B. Costs in Table 6.2 are expressed in millions of 2009 dollars. As seen in Table 6.2, the item that carries the largest portion of the hybrid geoexchange district system is the distribution network. Total capital cost estimates range from \$5.9 million (Scenario 1 with no sewer heat recovery) to \$69 million (Scenario 6 with sewer heat recovery). The 50-year rate of return for the near optimum cases ranges from 5.7% (Scenario 6 with sewer heat recovery) to 7.2% (Scenario 3 with no sewer heat recovery). As stated above, these rate of return estimates are not necessarily the precise optimum cases and better cases could exist with slightly varying combinations of hybrid component sizes.

Appendix C contains Table 6.3 which summarizes projected annual cash flows for the near optimum cases of each scenario. These cash flows, including annual inflation, were used to estimate the rate of return for each analysis case. Projected annual cash flows of the district system include revenue generated from energy sales, peaking boiler fuel consumption, district system pumping costs, boiler maintenance, sewer heat exchanger maintenance, maintenance of the distribution system infrastructure, and district system management and administration costs.

6.4.8 Preferred Scenario

Scenario 3 is the preferred option, based on rate of return. The cases with the combination of hybrid components yielding the highest 50-year rate of return of all cases examined was under Scenario 3, at 6.7% and 7.2% with and without sewer heat recovery, respectively.

The near optimum combination of hybrid components for Scenario 3 without sewer heat recovery includes a GHX with nominally 250 100-m deep boreholes, 3,000 solar thermal collectors, and a peaking boiler system that supplies 9% of the annual heating load. The capital cost of this case is about \$15.2 million. Figure 6.9 shows pie chart detailing the cost breakdowns for Scenario 3 with and without sewer heat recovery.

The near optimum combination of hybrid components for Scenario 3 with sewer heat recovery includes a GHX with 500 100-m deep boreholes, 3,000 solar thermal collectors, and a peaking boiler system that supplies 1% of the annual heating load. The capital cost of this case is about \$18.8 million.

The electrical power requirement for heat pumps and circulating pumps for the preferred Scenario 3 would be on the order of 2 MW. The total solar collector area for the preferred Scenario 3 would only be about 7% of building floor area.

Note that the size of the GHX increases from 300 boreholes with no sewer heat recovery to 500 boreholes when sewer heat recovery is added. This is because a larger GHX happens to result in the greatest ROR case with sewer heat recovery under Scenario 3. Note also that the boiler annual fraction decreases dramatically from 9% to 1% when sewer heat recovery is added. This emphasizes the nature of hybrid geexchange systems: they are **systems**, and the behaviour and performance of individual hybrid components is highly dependent on the behaviour and performance of the other components. Also, as stated above, only a limited number of control points were examined in this study, and the true optimum (i.e., highest ROR) most likely falls between the control points. Finding the true optimum is a task for later design stages.

The utilization of hybrid components in Scenario 3 significantly reduces the size of the GHX such that it could easily fit into one open area (i.e., potential drilling Area 11 as shown on Figure 3.1). Alternately, the GHX could be de-centralized into smaller arrays dispersed as convenient throughout the development areas. Actual borehole array location would be a choice for final design stages. The main conclusion here is that the compact GHX with hybrid assistance as identified in Scenario 3 would fit into available identified drilling areas.

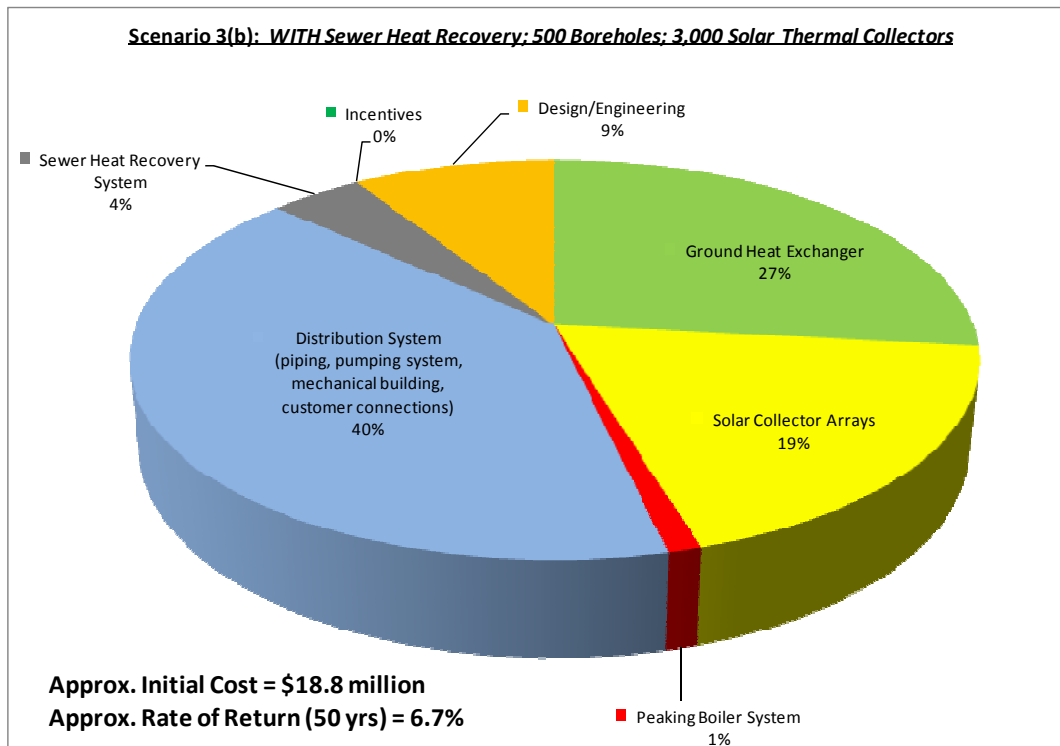
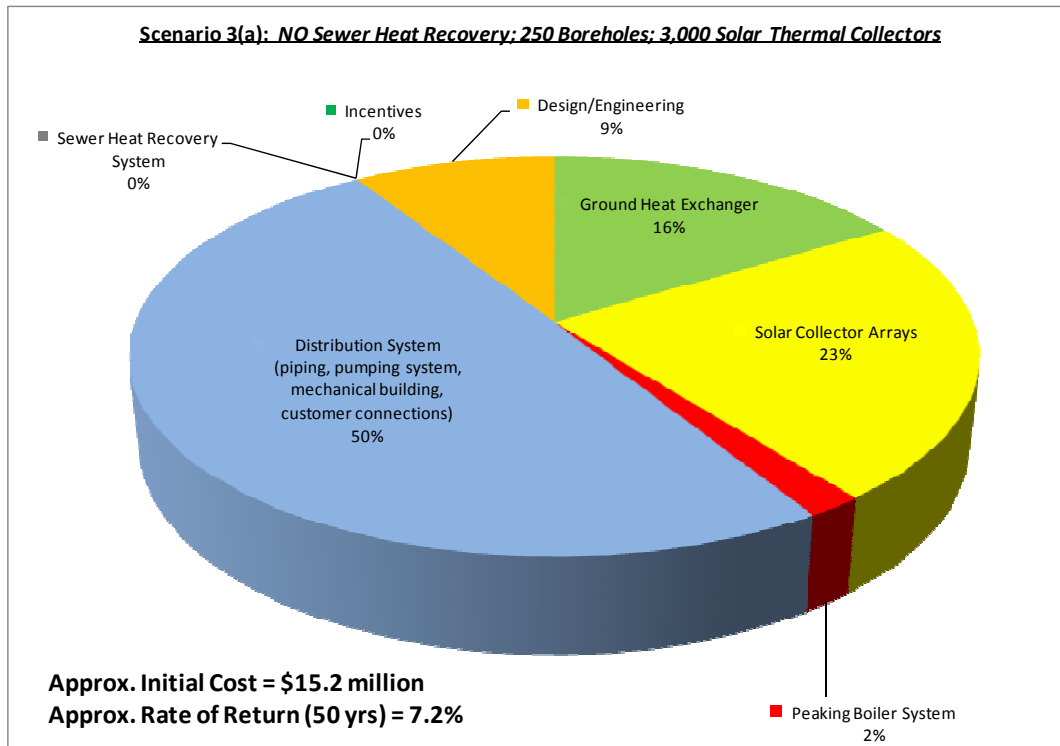


Figure 6.9: Pie chart of capital cost breakdown for Scenario 3 (a) with no sewer heat recovery and (b) with sewer heat recovery.

This feasibility study has used a number of cost assumptions, typical at this stage of a project, and a sensitivity analysis gives some insight into the effect of major cost items on the computed ROR. A sensitivity analysis is a standard method to vary input parameters to a computation individually and in a systematic way, to see the relative effect on the output (in this case ROR%). A sensitivity analysis was conducted on the Scenario 3 input parameters in order to quantify uncertainty in the cost estimates. Cost items of the hybrid geexchange district system were varied from -50% to +50% of the assumptions summarized in Table 6.1 used to calculate the ROR. The cost items varied included: annual fuel oil escalation rate, electricity escalation rate, GHX cost, solar thermal collector array cost, piping/distribution network cost, boiler costs, and sewer heat recovery system cost. The results of the sensitivity analysis are shown in Figure 6.10.

A review of Figure 6.10 reveals that the most sensitive cost item on the 50-year ROR of the hybrid geexchange district system is the annual fuel oil escalation rate. The fuel oil price was used to project energy revenues from the district system, and deviation from this assumption affects the ROR. If the annual fuel oil escalation rate were to increase by 50% (i.e., closer to what it actually has been over the past 10 years), the ROR increases to 9 to 10%. Note that a conservative escalation rate was assumed in this study. On the other hand, if the annual fuel oil escalation were to decrease by 50%, the ROR would decrease to 3 to 4%.

Sensitivity of the ROR is next most sensitive to the cost of the piping/distribution system. A 50% decrease in the piping/distribution system cost increases the ROR to 8 to 9%. A 50% increase in the piping/distribution system cost decreases the ROR to 5.7 to 6%.

The ROR is not radically sensitive to the GHX cost, solar collector array cost, or the annual electricity escalation rate. A $\pm 50\%$ change in these cost items changes the ROR by less than 0.7%. The ROR is relatively insensitive to boiler costs and sewer heat recovery system cost.

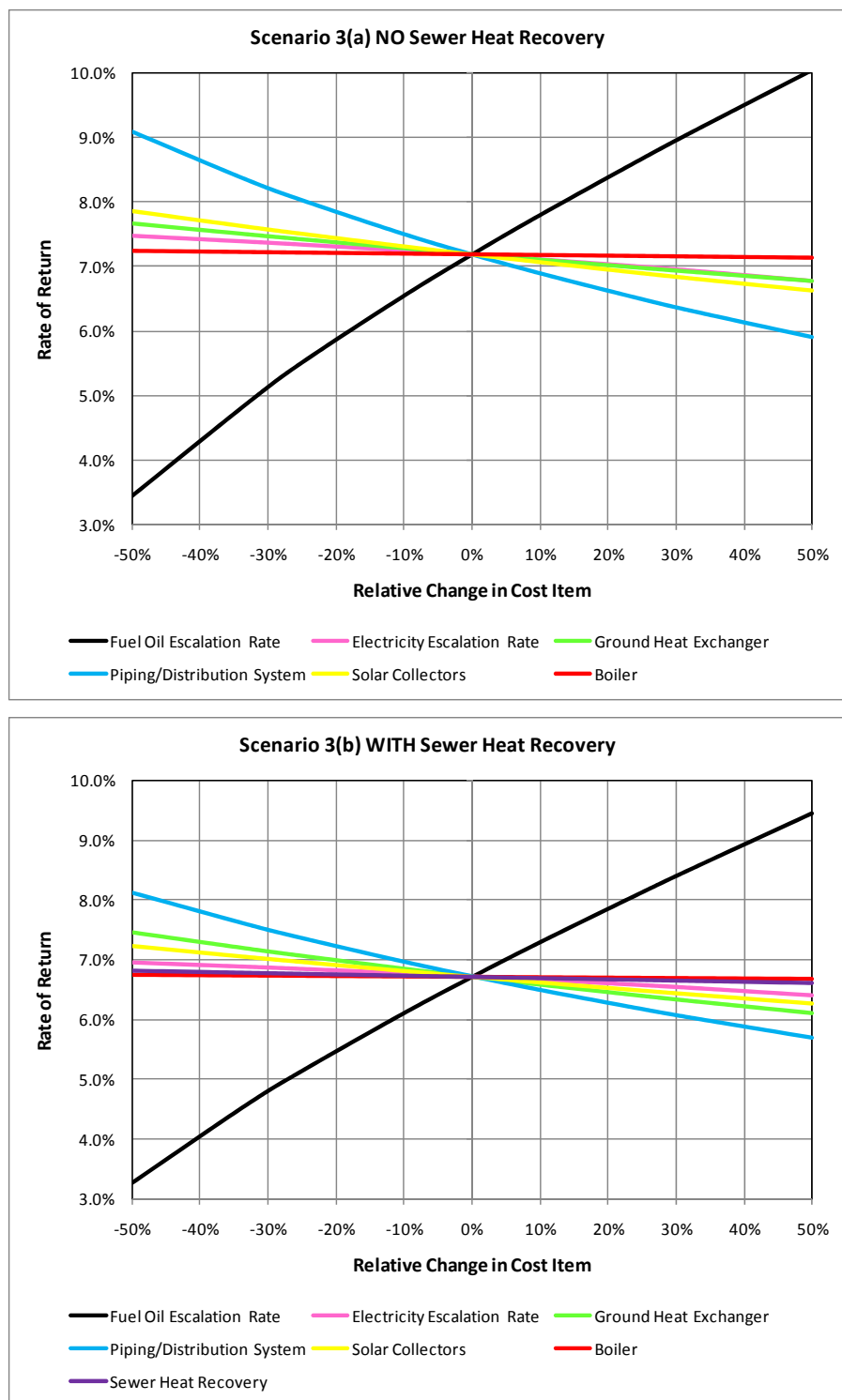


Figure 6.10: Sensitivity of major cost items on 50-year rate of return for Scenario 3 (a) with no sewer heat recovery and (b) with sewer heat recovery.

6.4.9 Environmental Effects and Benefits

Environmental effects that may be of concern during construction or use of a hybrid geoexchange DES at WBN, and therefore should receive consideration include:

- Groundwater and runoff control during construction.
- Aesthetic effects associated with construction (i.e., development of roads and clearing for BHX drilling).
- Aesthetic effects associated with the development (e.g., public perception of numerous solar thermal panels as part of integrated DES).
- Noise that can be expected as part of operating the energy system (e.g., from GHX pumps or peaking boiler system).
- Disruption and restoration of green space associated with laying pipes and other associated infrastructure.
- Emissions from fuel sources (fuel oil, or possibly biomass pellets) used for the peaking boiler system and potential effects associated with storage and handling of peaking boiler fuel sources.
- Potential effects due to releases of antifreeze liquid used in the GHX borehole circuit, and in the low-temperature DES distribution piping.

In general, the environmental benefits of utilizing a hybrid geoexchange DES would be:

- Avoided greenhouse gas (GHG) emissions compared with base case heating using fuel oil.
- Improvement in outdoor air quality (no wood smoke or air inversion issues) compared with what might be expected if residential wood stoves were used in the WBN.
- Reduced use of fossil fuels (much less consumption for peaking boiler system, than base case fuel oil heating systems).
- Greater adherence to City of Whitehorse sustainability principles and practices.
- A leadership position in Canada, as this would be one of, if not the, largest geoexchange-based DES installations in northern Canada.

The district geoexchange system reduces greenhouse gases by replacing fuel oil combustion with efficient electrically-driven geoexchange heat pumps. However, some fuel oil would be used by the district system peaking boiler. RETScreen (NRCan, 2008) was used to estimate greenhouse gas savings in Whitehorse.

Implementing the preferred Scenario 3 with no sewer heat recovery saves an estimated 1.15 million litres of fuel oil per year. This saves approximately 3,000 equivalent tonnes of CO₂

emissions per year, which is equivalent to removing about 625 cars and light trucks from the road, or planting 1,000 hectares of carbon-absorbing forest.

Implementing the preferred Scenario 3 with sewer heat recovery saves an estimated 1.25 million litres of fuel oil per year. This saves approximately 3,350 equivalent tonnes of CO₂ emissions per year, which is equivalent to removing about 680 cars and light trucks from the road, or planting 1,150 hectares of carbon-absorbing forest.

In addition, sewage heat recovery is a locally-available renewable energy resource that supports the City's goal of sustainability by reducing dependence on fossil fuels. Sewer heat recovery has lower emissions of greenhouse gases (by over half), particulate, nitrous oxide, sulphur oxide, and carbon monoxide than any traditional combustion-heating alternative. The development of a sewer heat recovery facility in Whistle Bend would be the first of its kind in the North, and would be a model for the development of this technology in other Northern areas worldwide.

6.4.10 Operational Matters

Operational matters will become more well-defined if a DES is adopted for the WBN and the system proceeds to pre-design and design stages, and when the ownership of such a system is settled. Key operational matters relate to the number and level of skilled workers needed to run and maintain the DES, and issues of noise, fuel storage, and security. It is premature to comment in detail on these matters, but it is useful to be aware of the range of considerations, especially when considering ownership options.

6.4.11 First Nations Matters

The project is located within the Traditional Territories of the Kwanlin Dun First Nation and the Ta'an Kwach'an Council. Further, both these First Nation Governments have settlement land that is located within or adjacent to the identified study area for this feasibility study. Only the Ta'an Kwach'an Council has land parcel within the footprint of the WBN development (Development Area 5).

Although most First Nation considerations are likely to be most relevant to the larger project concept, specifically protection of natural systems and compatible land use, there are considerations that should be applied to a district energy development. These considerations include:

- Developing the project in a manner that can accommodate for future expansion. It may be beneficial to discuss these opportunities with these First Nation Governments in advance of proceeding with pre-design or design of a DES at WBN.
- Keeping the First Nation Governments apprised of major project design features allows for an open and transparent dialogue and avoids potential concerns and issues that may arise in the future, specifically regarding the environmental assessment process.

7.0 REGULATORY ISSUES

7.1 ENVIRONMENTAL AND SOCIOECONOMIC ASSESSMENT

Project development activities proposed within the Yukon are subject to the Yukon Environmental and Socio-economic Assessment Act (YESAA). The YESAA assessment regime was formed from the Umbrella Final Agreement, an agreement between the Government of Canada, Government of Yukon, and Yukon First Nations.

YESAA is the legal basis for the assessment of projects in the Yukon and provides a single assessment process for projects proposed on all Yukon lands, including federal, territorial, and First Nation lands. The assessment process is governed by federal legislation and regulations as well as rules created by the Yukon Environmental and Socio-economic Assessment Board (YESAB). Except in a few special circumstances, YESAA replaces the Canadian Environmental Assessment Act (CEAA) in the Yukon.

YESAB is an arms-length independent Board that makes recommendations to decision bodies with respect to assessments pursuant to YESAA. Decision bodies are identified based on their role in a given project. Each federal department that holds a regulatory or financial responsibility for a project may be a decision body. The Government of Yukon may form one decision body for all potential authorizations, and First Nations governments within whose lands an activity is proposed may also form decision bodies.

Under the Act, YESAB administers an assessment process that carries out three different types of assessments; including, Designated Office Evaluations, Executive Committee Screenings, and a Review conducted by a Panel of the Board. Designated Offices conduct project assessments for small to mid-size projects. The Executive Committee is responsible for the screening of large-scale projects. For more complex projects, the Executive Committee may establish a Panel of the Board, tasked with undertaking a Review.

A YESAA assessment is initiated if projects meet certain criteria. For instance, if a project is for the construction and operation of a hydroelectric or fossil fuel-fired electric generating station an assessment may be required. A detailed list of activities that require YESAA project assessments is contained in the *Assessable Activities, Exceptions and Executive Committee Project Regulations* and is available through the YESAB website at www.yesab.ca.

One key aspect of the YESAA process is the use of specified timelines for each stage of the assessment, from submission of the project proposal to the issuance of a decision by government regulators. Designated Office Evaluation timelines typically range from 30-100 days of assessment related time but most assessments take approximately 60-90 days to complete. It is anticipated that activities associated with the Whistle Bend project will require a Designated Office Evaluation.

Efficiency of the process is dependent upon a number of factors including comprehensiveness and ease of use of the project proposal, responsiveness of the proponent, complexity of the project and level of public concern.

For the purposes of the Whistle Bend project the need for an assessment will likely begin with the development of subdivision infrastructure (i.e., roads). Integral to the planning of such a project is the timing of assessment and permitting as well as the compilation of the Project Proposal. Typically, it is best to proceed with a holistic project proposal for a YESAA review and therefore this would include construction of the proposed subdivision as well as any public utility infrastructure that is proposed to serve the community at large. It would not be recommended to apply for a YESAA assessment for the DES separate from the subdivision development; however, it is important to contact the assessment agency early in the process to discuss the project scope. For the Whistle Bend project this agency would be the Whitehorse Designated Office.

7.2 YUKON PERMITTING REQUIREMENTS

Where an assessment is required for a project, regulatory agencies cannot complete or issue permits or authorizations until the assessment is finalized and a decision document is issued. The main permits typically required for this form of development relate to land disposition. As the land used for geothermal infrastructure will likely be transferred from the Government of Yukon to the City of Whitehorse this form of permitting may be replaced with an agreement.

If electrical generation is ever considered in the WBN with a capacity of 1 MW or greater (e.g., a co-generation scenario), it is also anticipated that the project may require a Yukon Air Emissions Permit. This permit is issued by the Department of Environment and requires the submission of an Application for Air Emissions Permit.

Other ancillary permits may be required by Yukon Government and/or federal agencies; however a complete list cannot be provided until project details are more fully delineated. The ownership and operation of the DES would also need to be considered with respect to assessment and permitting (see Section 8.2). Yukon does not currently have legislation specific to geothermal resources.

It is not anticipated that the Whistle Bend project will require First Nation authorizations, as the project does not currently propose access to settlement lands (except for Development Area 5 owned by the Ta'an Kwach'an Council).

7.3 YUKON UTILITIES BOARD

The Yukon Utilities Board is a regulatory Board that governs Yukon utilities; currently these include the Yukon Energy Corporation and Yukon Electrical Company Ltd.

The Board's mandate which is established through the *Public Utilities Act* and Regulations and may be summarized as:

- Issuing orders that fix the rates of a public utility.
- Prohibiting or limiting proposed rate changes.

- Fixing proper and adequate rates and methods of depreciation, amortization, or depletion in respect of the property of any public utility.
- Fixing standards, classifications, regulations, practices, measurements or services to be observed, provided or followed by a public utility.
- Determining areas that services of a public utility shall provide (YUB, 2009).
- As the mandate of the Yukon Utility Board may be relevant to the Whistle Bend project, further research and understanding should be undertaken on the potential role of the Board once a decision has been made to develop the geoexchange system.

8.0 OWNERSHIP OPTIONS AND MARKET ANALYSIS

8.1 CASE STUDIES

A summary of district energy case studies is presented in Table 8.1 (attached). Numerous district energy systems are implemented worldwide that use various energy sources supplying heating and cooling needs of all types. A select few examples are presented here that have some similarities to the conceptual hybrid geoexchange district energy system for the Whistle Bend Neighbourhood development.

The main objective of examining case studies is to shed some light on lessons learned from previous experiences. The lessons presented here are not specifically focussed on engineering or technical matters, as these types of challenges can be overcome by innovation. Rather, case studies focus more on effective planning and project management of district energy systems, as these are common themes of successful projects. Successful district energy projects typically recognize the following:

- **Every project is unique.** While this may seem obvious, it cannot be understated. Each project has unique energy resources, legal and institutional considerations, and availability of goods and services. There is no “rubber-stamp” set of project development activities.
- **The ‘keep it simple’ approach is important.** “Keeping it simple” is especially important in systems with remote locations. Use of custom-made or non-conventional system components may result in undesirable down-time during maintenance. Consideration of local contractor expertise is needed during final design stages.
- **A strong promoter is needed to develop each project.** Successful district renewable energy systems usually have one or more individuals who were the chief cause of the project’s success. District energy systems are capital intensive, and there can be several legal and institutional issues to be settled. At times, financial, regulatory, legal, or other hurdles may seem insurmountable, and the guiding efforts of very dedicated project champions are necessary.

- **Funding methods affect project development.** Project funding mechanisms are important to establish as early as possible in project development. Funding mechanisms are also tied closely to decisions regarding public vs. private ownership. Cost details should be continually checked during project progression to insure availability of adequate funds for project completion. It is also necessary to insure sufficient funds for operation and maintenance of the system.
- **Customers are needed for district energy projects.** While this seems obvious, many of the Western U.S. geothermal district systems struggled economically during their early years, and faced being shut-down due to underestimation of customer participation. If customers were given a choice to join the district system, a marketing and promotional campaign is needed to essentially sell the system; the district system owner then becomes a seller of energy, competing with conventional fuel sellers. In new construction such as Whistle Bend, providing only district energy to the development is an easy and effective means to gauge customer participation.
- **Successful district renewable energy systems are a source of community pride.** Successful district renewable energy systems have the intangible benefit of promoting community pride. Successful systems can attract business and residents to the community. Promotion of the district energy system early in its development stages is beneficial in gaining public support and pride.

8.2 OWNERSHIP AND OPERATION OPTIONS

Table 8.2 presents a summary of ownership and operation options for a DES in the WBN. These five models present a range of options from full public sector (local or territorial government) ownership and operation, to full private ownership and operation. In general, ownership carries with it both control of the system, but also the liability and required expertise of managing it. Operation requires technical expertise, service equipment and infrastructure, administration and billing capacity. Based on our understanding of current approaches and attitudes in Whitehorse, it is likely that some hybrid of part public/private ownership and operation (e.g., models 3 or 4) would be selected for the WBN development.

TABLE 8.2: SUMMARY OF OWNERSHIP AND OPERATION OPTIONS FOR WHISTLE BEND NEIGHBOURHOOD DES

Models	Advantages	Disadvantages
Model 1 – Local Government Direct Utility Ownership & Operation	Direct local government control Potentially lower cost of capital Synergies with other local government departments	Risks and liability directly borne by local government Requires local government to have expertise in energy system management and operating staff
Model 2 – Local Government Ownership through wholly- owned subsidiary	Lower liability and risk Direct local government control Day-to-day operations delegated to board of directors	Some risks still carried by local government New bylaw required May be higher operating costs

Models	Advantages	Disadvantages
		compared to direct local government operation
Model 3 – Local Government Ownership, Private Operation	Lower liability and risk than direct operation Expertise from private sector Potentially lower staffing costs	Less direct government control Some risks still carried by local government
Model 4 – Less than 100% Public Ownership, Private Operation	Expertise of private sector Some private sector capital Risks shared with private partner	Less government control Revenues shared with private sector
Model 5 – 100% Private Ownership & Operation	Expertise of private sector Entirely private sector capital Risks borne by private owner	Little/no government control Needs acceptable business case for private owner All revenues to private owner

9.0 FINANCING AND FUNDING OPTIONS

9.1 FINANCING OPTIONS

Financing options presented here describe how money could potentially be raised to build and operate a DES at the WBN.

- Community Bonds – This entails borrowing within the local community. This has an advantage of generating local interest and pride in a project, and local benefits of return on investment, with interest paid to local businesses and residents.
- Lease-Purchase – In this case, ownership of the energy system rests with a third party in a lease arrangement, until a final lease payment is made, then ownership transfers to local government. This is a way of structuring debt that may be cheaper and more flexible than long-term debt.
- Revolving Energy Funds – This is a system to finance multiple energy improvements (e.g., several energy projects within a jurisdiction). A fund lends money to renewable energy projects and reinvests revenues to fund other projects (e.g., FCM Green Municipal Fund). This is included here for completeness, but may not be currently applicable for the WBN development situation.
- Joint Equity Partners – In this case, a partner invests private capital to own a share of the project. This would be the case for models 4 and 5 in Table 8.2.

9.2 FUNDING OPTIONS

Funding options describe where money could be obtained for either capital or operating expenses of a DES. Table 8.3 (attached) presents a summary of funding sources that might potentially be applicable to the WBN situation, along with some key on-line information sources.

Decisions on which of these sources to pursue would follow once an ownership and operation model was adopted. Certain funding sources (e.g., Indian and Northern Affairs Canada) has funding sources specially tailored for First Nations groups.

10.0 PROJECT PRESENTATIONS

10.1 COUNCIL AND SENIOR MANAGEMENT MEETING

EBA presented findings of this study to the City of Whitehorse Council and Senior Management for review and discussion on June 25, 2009, prior to compiling this summary report. The meeting was held at City Hall from 12:00 to 1:30 pm. Useful comments from the meeting were incorporated into this report.

10.2 PUBLIC OPEN HOUSE

A public open house meeting was convened by the City of Whitehorse and the EBA team at the Mount McIntyre events building in Whitehorse from 7:00 to 9:00 pm, June 25, 2009. A series of ten posters presenting a summary of project activities and findings were mounted on the wall. Approximately 30 members of the public attended and engaged City and EBA staff in informal discussions about the project.

11.0 CONCLUSIONS AND RECOMMENDATIONS

11.1 CONCLUSIONS

1. Based on our preliminary analysis, neither gas-based or air-source heat pump alternatives to a geexchange-based district energy system make economic or practical sense for the WBN at this time.
2. Vertical drilled borehole closed loop ground heat exchangers are the most suitable ground coupling option for the WBN.
3. The preferred location for sewage heat recovery at the WBN is at the planned central lift station.
4. A hybrid geexchange-based district energy system for Development Areas 1 and 2 combined (Scenario 3) is the preferred option, based on investment rate of return (6.7% and 7.2%, with and without sewer heat recovery, respectively).
5. It would not be recommended to apply for a YESAA assessment for the DES separate from the subdivision development. However, it is important to contact the assessment agency early in the process to discuss the project scope.
6. A hybrid model of part public/private ownership and operation may be most suitable for the WBN development.

11.2 RECOMMENDATIONS

1. The City of Whitehorse should assess the findings of this study, including technical results, economic factors, funding sources, and ownership options, to decide whether to proceed with a DES for the Whistle Bend Neighbourhood development.
2. If the City wishes to proceed with a DES, it should identify an internal project champion to direct and advise throughout future aspects of DES development.
3. If the City wishes to proceed with a DES, it should move promptly to engage a professional team to design the DES in coordination with the planning and construction schedule for the development.
4. The City should stay aware of regulatory requirements and maintain regular liaison with First Nation groups with property within or adjacent to the WBN development.

12.0 CLOSURE

This report has been prepared for the exclusive use of the City of Whitehorse for specific application to the subject site. This report is to be read in conjunction with the General Conditions (Appendix A), which form part of this report. With this report, EBA accepts no responsibility for the design or performance of future geoexchange-based systems at this site, and no responsibility for potential effects on the City's sewage lagoon performance based on the assumed values of sewage heat extraction described here. Any use of this report by a third party or any reliance on or decisions made based on this report are the responsibility of those third parties. EBA accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions taken based on this report.

We trust that this report satisfies your present requirements. If you have any questions or comments, please contact the undersigned at your convenience.

Respectfully submitted,
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TABLES



TABLE 3.3 SUMMARY OF POTENTIAL NUMBER OF BOREHOLES WITHIN THE WHISTLE BEND NEIGHBOURHOOD

Potential Borehole Drilling Area	Length Or Area		Approximate Number of Potential Boreholes			
			Per Open Area	Per Street	Per Trail	Totals
Development Area 1						
Open Areas						
Area 10	4,070	m²	50	-	-	
Area 11*	68,323	m²	740	-	-	
Streets						
Casca Blvd.**	1,071	m	-	108	-	
Tannana Drive	450	m	-	45	-	
Chakawana Drive	420	m	-	42	-	
Talbot Way	180	m	-	18	-	
Unnamed Streets	250	m	-	25	-	
Trails						
Trail L	140	m	-	-	14	
Totals:			790	238	14	1,042
Development Area 2						
Open Areas						
Area 6	5,329	m²	70	-	-	
Streets						
Casca Blvd.**	1,778	m	-	178	-	
Bellingham Loop	545	m	-	55	-	
Tarahane Drive	370	m	-	37	-	
Keno Way	120	m	-	12	-	
Keno Way 2	670	m	-	67	-	
Iskoot Way	250	m	-	25	-	
Iskoot Way 2	250	m	-	25	-	
Argonaut Way	160	m	-	16	-	
Unnamed Streets	300	m	-	30	-	
Trails						
Trail A	151	m	-	-	16	
Trail C	280	m	-	-	28	
Trail D	216	m	-	-	22	
Trail E	154	m	-	-	16	
Trail F	85	m	-	-	9	
Totals:			70	445	91	606
Development Area 2H						
Streets						
Argonaut Way	200	m	-	20	-	
Leota Close	900	m	-	90	-	
Totals:			0	110	0	110

Potential Borehole Drilling Area	Length Or Area		Approximate Number of Potential Boreholes			
			Per Open Area	Per Street	Per Trail	Totals
Development Area 3						
Open Areas						
Area 5	7,530	m²	90	-	-	
Streets						
Casca Blvd.**	2,206	m	-	221	-	
Caprice Way	160	m	-	16	-	
Aksala Way	350	m	-	35	-	
F.H. Kilbourne Drive	360	m	-	36	-	
Dora Way	180	m	-	18	-	
Keno Way	510	m	-	51	-	
Trails						
Trail B	462	m	-	-	47	
Totals:			90	377	47	514
Development Area 4						
Open Areas						
Area 7	19,619	m²	230	-	-	
Area 8	13,333	m²	160	-	-	
Area 9	12,736	m²	150	-	-	
Streets						
Casca Blvd.**	866	m	-	87	-	
Talbot Way	500	m	-	50	-	
Ididarod Drive	500	m	-	50	-	
Fulton Way 1	160	m	-	16	-	
Fulton Way 2	160	m	-	16	-	
Chakawana Drive	250	m	-	25	-	
Trails						
Trail F	85	m	-	-	9	
Trail G	128	m	-	-	13	
Trail H	54	m	-	-	6	
Trail I	149	m	-	-	15	
Trail J	43	m	-	-	5	
Trail K	264	m	-	-	27	
Totals:			540	244	75	859
Development Area 5						
Open Areas						
Area 3	11,075	m²	130	-	-	
Streets						
Independance	780	m	-	78	-	
Witch Hazel	670	m	-	67	-	

Potential Borehole Drilling Area	Length Or Area		Approximate Number of Potential Boreholes			
			Per Open Area	Per Street	Per Trail	Totals
Witch Hazel 2	400	m	-	40	-	
Zodiak	500	m	-	50	-	
Tyrell Way	200	m	-	20	-	
Tyrell Way 2	220	m	-	22	-	
Unnamed Streets	570	m	-	57	-	
<i>Totals:</i>			<i>130</i>	<i>334</i>	<i>0</i>	<i>464</i>
Development Area 6						
<i>Open Areas</i>						
Area 1*	158,745	m ²	1,670	-	-	
Area 2	6,061	m ²	80	-	-	
Area 4	19,072	m ²	220	-	-	
<i>Streets</i>						
Independance	970	m	-	97	-	
F.H. Kilbourne Drive	900	m	-	90	-	
Hootalinqua Drive	360	m	-	36	-	
Antlintoo Way	370	m	-	37	-	
Antlintoo Way 2	230	m	-	23	-	
Eldorado Way	700	m	-	70	-	
Cariboo Way	250	m	-	25	-	
Unnamed Streets	1,020	m	-	102	-	
Totals:			1,970	480	0	2,450
GRAND TOTALS			3,590	2,228	227	6,045

Notes:

* Adjacent to development area

** Length refers to both sides of street

TABLE 6.1: SUMMARY OF INPUT VALUES FOR ECONOMIC ANALYSIS

Item	Cost	Comments/Cost Reference
District System Capital Costs		
Ground Heat Exchanger (GHX)	\$100/m	Professional judgement, based on discussion with drillers/installers, and absence of geoexchange contractors in Yukon. Installed GHX costs in other parts of Canada and US typically range from \$30/m to \$60/m. These costs include all underground work.
Solar collector costs	Equation	Correlating equation of installed cost to number of collectors from ASHRAE Technical Research Project 1384 (2008) citing RS Means cost data: Solar Collector Array Cost = $\$5096(0.135N + 0.865)$, where N is the number of collectors.
Peaking boiler costs	Equation	Correlating equation of installed cost to boiler capacity from ASHRAE Technical Research Project 1384 (2008) citing RS Means cost data. Costs for a backup boiler are also included. Boiler Cost = $\$3825(-0.00430f^2 + 0.411f + 0.692)$ for $f \leq 31.2$ Boiler Cost = $\$3825(0.118f + 5.64)$ for $f > 31.3$ where f = ratio of boiler size to a nominal reference 122 MBH boiler.
Piping distribution system	\$500/m to \$700/m	These costs include piping material, installation, pumping system, and customer connections expressed per meter of street length. Street lengths are multiplied by 10% to account for branch lines to customer buildings. Piping costs are for pre-insulated HDPE pipe per quote from Marcel Baril, Ltd. in Quebec. Pipe diameters are estimated from heat pump required flow rates. The smaller unit cost applies to Scenarios with one development area, while the larger unit cost applies to Scenarios with multiple development areas. The total distribution system cost is estimated from NRCan (2008), at a proportion of 45% for pipe material, 45% for installation and connections, and 10% for the pumping system.
Mechanical building	\$1600/m ²	Unit cost from RS Means for similar buildings. Assumptions include a 150 m ² building for Scenarios with one development area, and 185 m ² building for Scenarios with multiple development areas.
Sewer heat recovery costs		Details provided in Tables X... Costs are summarized as follows: \$0.74 million each for Scenarios 1, 2, and 4. \$0.78 million for Scenario 3. \$1.25 million for Scenario 5. \$1.3 million for Scenario 6.
Engineering/design fees	10%	Percentage of capital costs estimated from RS Means cost data.
Yukon cost factor	1.3	Capital cost multiplier built into above items based on professional judgement, to allow for additional costs in remote cold regions.
Contingency	30%	Typical amount at feasibility stage.
Grants and Incentives	0	Conservative assumption.

Item	Cost	Comments/Cost Reference
District System Income		
Energy sales	10% savings incentive relative to furnace oil	The amount of avoided cost of fuel oil minus heat pump electrical costs is the maximum savings that would be realized by customers. Energy sales are based on 90% of this amount, giving customers a 10% savings/incentive.
Annual District System Expenses		
Maintenance: Distribution system	1% of capital	Typical assumption.
District system management costs	\$1/sq.m of floor space served	Estimate based on other district systems. Covers management of system, customer relations, billing, etc.
Maintenance: Boiler system	Equation	Correlating equation of cost to boiler capacity from ASHRAE Technical Research Project 1384 (2008) citing RS Means cost data. Boiler Maint. Cost = $\\$759(-0.0009f^2 + 0.0648f + 0.952)$ for $f \leq 11$ Boiler Cost = $\\$759(0.0196f + 1.367)$ for $f > 11$ where f = ratio of boiler size to a nominal reference 122 MBH boiler.
Maintenance: Sewer heat recovery system	\$800	Shown in detailed sewer heat recovery cost tables (Tables X...).
Additional Assumptions		
Boiler life expectancy	25 yrs.	Estimate. With proper maintenance.
Sewer HX life expectancy	15 yrs.	Per manufacturer (DDI).
Fossil fuel combustion efficiency	80%	For peaking boiler and fuel oil furnace base case.
Fuel oil rates (residential)	\$1/L	Based on Yukon Energy price tracking.
Fuel oil rates (commercial)	\$0.8/L	Assume 80% of residential. Actual costs are negotiated on case-by-case basis.
Blended electricity rate	\$0.13/kWh	Based on current Yukon Electric schedule.
Commercial Electric Demand Charge	\$7.3/kW	Based on current Yukon Electric schedule.
Annual inflation rate	2%	Typical assumption.
Annual fuel oil inflation rate	4%	Very conservative assumption. Actual inflation rate over last 10 years is 7%.
Annual electricity inflation rate	2%	Very conservative assumption. Actual inflation rate over last 10 years is close to 0%.

TABLE 8.1: SUMMARY OF CASE STUDIES FOR DISTRICT ENERGY SYSTEMS

Name	Location	Energy Source and Description	Similarities to Whistle Bend	Differences from Whistle Bend	Ownership Structure	Funding Sources	Other Comments
Drake Landing Solar Community	Okotoks, AB	Solar energy is used with a central high temperature underground storage volume to provide 80 to 90% of space heating to 52 residential buildings. Additional heating demands are met by natural gas.	Both use solar energy, vertical borehole heat exchangers, and a peaking system. Homes built to R2000 standards.	Drake Landing is a high temperature distribution system.	Utility operated.	Several sources, including Government of Canada, Federation of Canadian Municipalities, Climate Change Central, ATCO Gas, Government of Alberta, and private sources.	District customers are all residential. Customers require a custom-made furnace.
Halcyon Meadows Residential Development	Chilliwack, BC	A central geoeexchange district heating/ cooling system using groundwater from wells. Groundwater is discharged to infiltration pits at each home.	Both use geoeexchange heat pumps distributed in buildings	Halcyon Meadows uses groundwater from wells.	Private developer.	Mostly private sources.	District customers are all residential. Residential customers are charged a fixed monthly utility fee for heating/cooling.
Sun Rivers Resort	Kamloops, BC	A de-centralized geoeexchange system, where buildings are on their own individual geoeexchange system which is utility-owned.	Both use closed-loop geoeexchange systems with distributed heat pumps in buildings.	Buildings do not share a common GHX at Sun Rivers.	Utility owned and operated.		District customers are a mix of residential and commercial buildings. Residential customers are issued one monthly bill for all utilities including heating/cooling.
Oujé-Bougoumou Biomass District Heating System	Oujé-Bougoumou, QC	A biomass district heating system, with the heating plant consisting of two boilers; one boiler is duel-fuel (wood and oil) and the second is oil only and is used for peaking and standby purposes.	Cold climate, remote community. Both use a peaking boiler with duel-fuel options.	Oujé-Bougoumou uses biomass, and is a high-temperature distribution system.	Community owned and operated.	Government of Canada	The Oujé-Bougoumou Biomass District Heating System is a source of community pride. It has saved energy, created jobs, and has converted a waste (sawmill residues) into an energy source. It has also raised community awareness on conservation and environmental stewardship.
City of Revelstoke Biomass District Heating System	Revelstoke, BC	A biomass district heating system providing hot water heating to local commercial buildings in the downtown core.	Relatively remote community. Possible similarities in funding mechanisms.	Revelstoke uses biomass, and is a high-temperature distribution system.	Community owned and operated.	A combination of Federal and Provincial loans, grants, and investments by the City.	District customers are all commercial. Provides a working model of sustainability for the Revelstoke OCP.
Southeast False Creek Neighbourhood Energy Utility	Vancouver, BC	A district heating system using wastewater as a heat source for a central heat pump plant. The system built with plans to serve the 2010 Winter Olympic Village and the Southeast False Creek Development.	Sewer heat recovery and use of heat pumps.	Southeast False Creek uses a central heat pump plant and a high-temperature distribution system.	City owned and operated.	A combination of Federation of Canadian Municipalities loans, grants from the Union of BC Municipalities Innovations Fund, and debentures by the City.	District customers are a mix of residential and commercial buildings. The district energy system will help buildings achieve LEED standards. This project is a high-profile project, given its association with the Winter Olympics.
Western U.S. District Geothermal Heating Examples	Oregon, Idaho, Nevada, California, Utah, South Dakota, New Mexico	Approximately 18 district geothermal heating systems were developed in the Western U.S. in the late 1970s and early 1980s. The systems use warm groundwater from wells for direct-use heating purposes.	Possible similarities in funding mechanisms and ownership structure. Some U.S. examples use heat pumps.	The Western U.S. examples are open-loop, warm groundwater-based systems.	Variable, ranging from 100% private to 100% public ownership. Most systems are owned and operated by a municipality.	All cases were at least 50% funded by Federal Government grants.	These systems provided several learning lessons with respect to district renewable energy systems, including project financing, ownership scenarios, project engineering, project management, and energy billing. The age of the systems (i.e., approximately 30 years) demonstrates that projects can be successful if properly operated and managed. However, none of the projects would have been undertaken without federal financial assistance.

TABLE 8.3 : POTENTIAL FUNDING SOURCES FOR A DISTRICT ENERGY SYSTEM AT WHISTLE BEND NEIGHBOURHOOD DEVELOPMENT							
Potential Funding Source	Agency	Contact Info/website	Category of Opportunity	Key Eligibility Criteria	Possible Fund \$ or Costshare % per Application	Process & Timing	Other Comments
Funding Technologies for the Environment	Environment Canada	http://www.ic.gc.ca/eic/site/fte-fte.nsf/eng/home	Environmental Technologies	N/A	N/A	This inventory of funding and incentive programs helps to develop, demonstrate, and deploy environmental technologies by: Up-to-date comprehensive records; Streamlined application process; User-friendly site navigation; and, Increased knowledge of complementary opportunities.	General information site for many funding opportunities.
R&D Fund	Yukon Cold Climate Innovation Center	http://yccic.ca/services/funding/ Chad Gubala Ph.D. YCCIC Director Yukon Cold Climate Innovation Centre 867.456.8670 cgubala@yccic.ca	Innovative Technology	Experimental development; applied research; early commercialization costs; and support work	2008/2009 total fund was \$319,000; largest single grant to date was \$150,000	YCCIC welcomes applications to the R&D fund at any time—there are no application deadlines. Evaluations of applications take about 8 weeks.	
Green Municipal Fund	Federation of Canadian Municipalities	http://gmf.fcm.ca/GMF/default.asp Monique Delinelle, Application Coordinator 613-241-5221 ext 357 - mdelinelle@fcm.ca	Municipal Environmental Effectiveness	Municipal governments and their partners are eligible for grants for feasibility studies and field tests.	Grants for up to 50% of costs to a maximum of \$350,000	Six to nine months from application to approval.	
Green Municipal Fund	Federation of Canadian Municipalities	http://gmf.fcm.ca/GMF/GMF-2009-call-for-applications/Energy-2009-call-for-application.asp Monique Delinelle, Application Coordinator 613-241-5221 ext 357 - mdelinelle@fcm.ca	Energy efficient building retrofits and energy efficient new building construction.	Municipal governments, or municipal utility or corporation wholly owned by a municipal government in Canada	Up to \$4 million in loans and \$400,000 in grants for each project.	Applications are considered as they are received. The call for applications will remain open until at least March 31, 2010.	Loans, usually in combination with grants, to implement capital projects. For municipal governments, GMF offers interest rates 1.5 per cent lower than the Government of Canada bond rate for the equivalent term.
Scientific Research and Experimental Development (SR&D) Tax Incentive Program	Canada Revenue Agency	http://www.cra-arc.gc.ca/sred/	Technological Advancement in research and development	Generally, a Canadian-controlled private corporation (CCPC) can earn an investment tax credit (ITC) of 35% up to the first \$2 million of qualified expenditures for SR&ED carried out in Canada, and 20% on any excess amount. Other Canadian corporations, proprietorships, partnerships, and trusts can earn an ITC of 20% of qualified expenditures for SR&ED carried out in Canada.	(Depends on individual project)	(Depends on individual project).	
Integrating Energy Efficiency/Renewable Energy Technologies to Community Infrastructure Projects	Indian and Northern Affairs Canada	http://www.ic.gc.ca/eic/site/fte-fte.nsf/eng/00198.html or contact Indian and Northern Affairs Canada	Energy Efficiency Infrastructure Projects	Aboriginal and Northern Communities; Band Councils; Tribal Councils; National Aboriginal Organizations and other Aboriginal Organizations, including Professional Organizations; Aboriginal Community Groups (volunteer groups, community associations and institutions); Territorial Governments and northern organizations; and Aboriginal businesses and Aboriginal industries.	Total fund is \$15 million Maximum \$100,000 per project	Projects will be considered on a case-by-case basis until 2011(fund duration).	No funds will be given for housing projects.

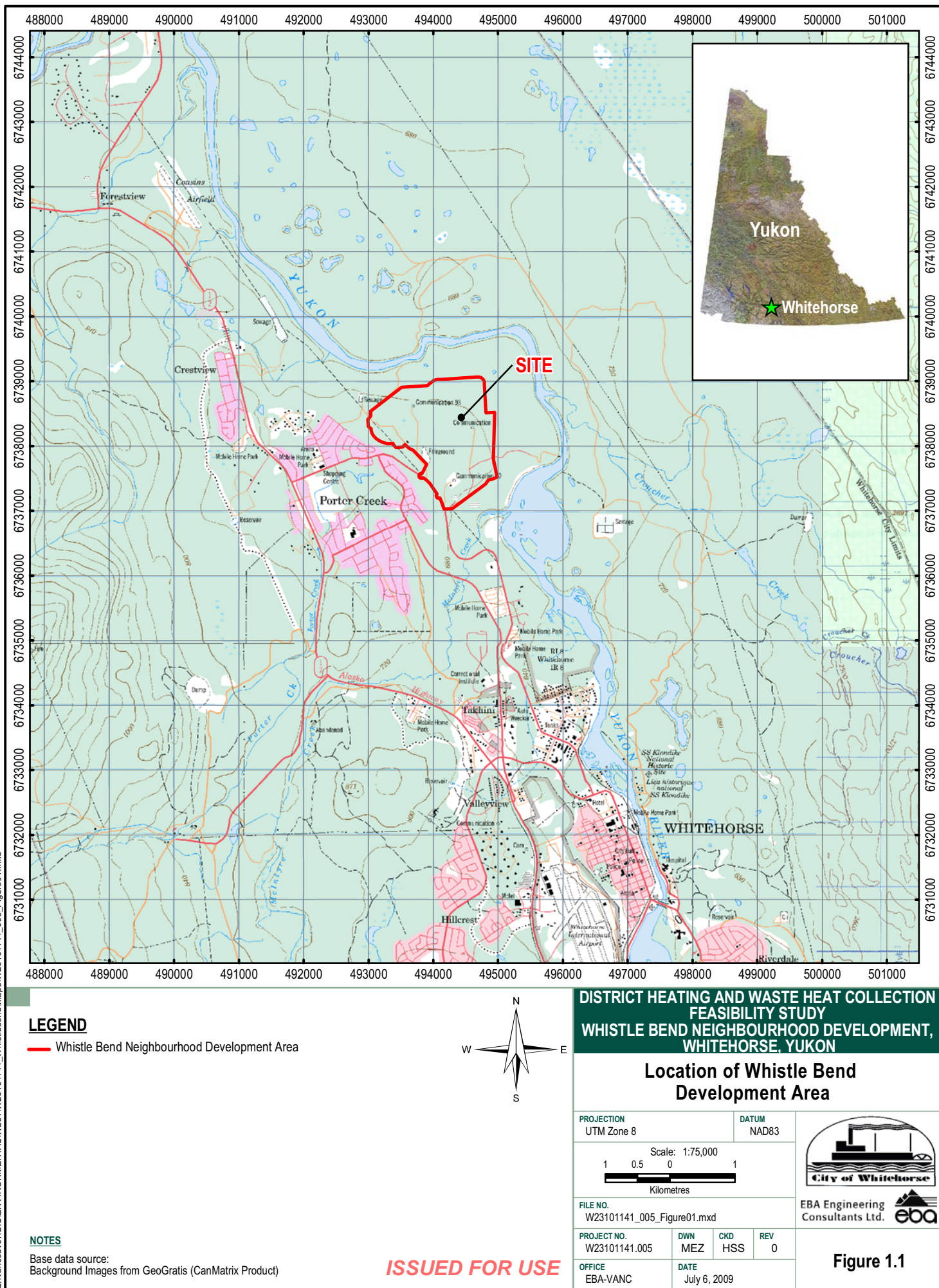
TABLE 8.3 : POTENTIAL FUNDING SOURCES FOR A DISTRICT ENERGY SYSTEM AT WHISTLE BEND NEIGHBOURHOOD DEVELOPMENT							
Potential Funding Source	Agency	Contact Info/website	Category of Opportunity	Key Eligibility Criteria	Possible Fund \$ or Costshare % per Application	Process & Timing	Other Comments
Large Energy Projects	Indian and Northern Affairs Canada	http://www.ainc-inac.gc.ca/enr/clc/pral/pfc-eng.asp or contact Indian and Northern Affairs Canada	Aboriginal and Northern Energy related activities	Aboriginal and Northern Communities; Band Councils; Tribal Councils; National Aboriginal Organizations and other Aboriginal Organizations, including Professional Organizations; Aboriginal Community Groups (volunteer groups, community associations and institutions); Territorial Governments and northern organizations; and Aboriginal businesses and Aboriginal industries.	Total fund is \$15 million Maximum \$250,000 per project Maximum % of project funding is 30% for on-grid communities and 50% for off-grid communities	Fund duration is until 2012. INAC will utilize a system to promote, receive, review, and assess clean energy projects (i.e. energy efficiency and renewable energy) submitted from INAC regions, communities and other proponents.	
Canada Strategic Infrastructure Fund	Infrastructure Canada	http://www.infc.gc.ca/ip-pi/csis-fcis/csis-fcis-eng.html or contact Infrastructure Canada	Reducing production of greenhouse gases and airborne pollutants	Provincial/Territorial Governments; Municipal Governments. Total eligible project cost must be at least \$10 million	Total fund is \$5.2 billion Under the CSIF, the contribution of the Government of Canada was set to a maximum of 50 % of total eligible costs.	Funding available until 2013.	Most CSIF funding has been committed, except for limited funding remaining in Ontario, Yukon, and Newfoundland and Labrador.
ecoEnergy for Renewable Power	Natural Resources Canada	http://www.ecoaction.gc.ca/ecoenergy-ecoenergie/power-electricite/index-eng.cfm or Contact Natural Resources Canada	Clean energy sources	Municipal Governments; Not-For-Profit Organizations; Private Companies or Individuals; and Universities and Colleges	Total fund is \$1.48 billion	Fund available until March 31, 2011 Send in a Notice of Project Application to receive the application package. Submit Technical Project Information to Natural Resources Canada.	
ecoEnergy Retrofit Incentive for Buildings	Natural Resources Canada	http://oee.nrcan.gc.ca/commercial/financial-assistance/existing/retrofits/index.cfm?attr=0 or Contact Natural Resources Canada	Energy retrofits for commercial/ institutional existing buildings	Commercial and institutional buildings, including those owned by not-for-profit and religious organizations; Provincial, territorial and municipal buildings; Multi-unit residential buildings; Mixed-use commercial/residential buildings	\$10 per gigajoule (277.8 kilowatt hours) of estimated annual energy savings; 25 percent of eligible project costs; or \$50,000 per project (\$250,000 per organization).	Must have had a pre-project energy audit before completing application. Application process includes: energy consumption information, audit information, all costs before tax, Environmental Assessment screening, and financial summary.	
Program of Energy Research and Development	Natural Resources Canada	http://www.ecoaction.gc.ca/ecoenergy-ecoenergie/power-electricite/index-eng.cfm or Contact Natural Resources Canada	Distributed power generation	Federal Government; Provincial/Territorial Governments; Municipal Governments; Crown Corporations; Not-For-Profit Organizations; Private Companies or Individuals; and Universities and Colleges	\$55.3 million annually, distributed among 9 technology areas (see comments)	Yearly, for 4 research cycles. The Office of Energy Research and Development provides Program of Energy Research and Development funds directly to partner departments and agencies, which then team up with municipalities.	Technology areas include: Frontier oil and gas; Clean fossil fuels; Clean coal and carbon capture and storage; Distributed power generation; Next-generation nuclear energy technologies; Bio-based energy systems; Low-emission industrial systems; Clean transportation systems; and, Built environment.
Gas Tax Fund	Infrastructure Canada	http://www.infc.gc.ca/ip-pi/gtf-fte/gtf-fte-eng.html or Contact Infrastructure Canada	Environmentally Sustainable Municipal Infrastructure	Provincial/Territorial Governments; Municipal Governments;	Total fund is \$13 billion \$15 million will be allocated to the Yukon in 2009-2010 Whitehorse received 7.5 million in 2009-2010	Fund duration is from 2005 to 2014. See fund agreement for the Yukon at http://www.infc.gc.ca/ip-pi/gtf-fte/agree-entente/agree-entente-eng.html	Largest component of Building Canada Plan.



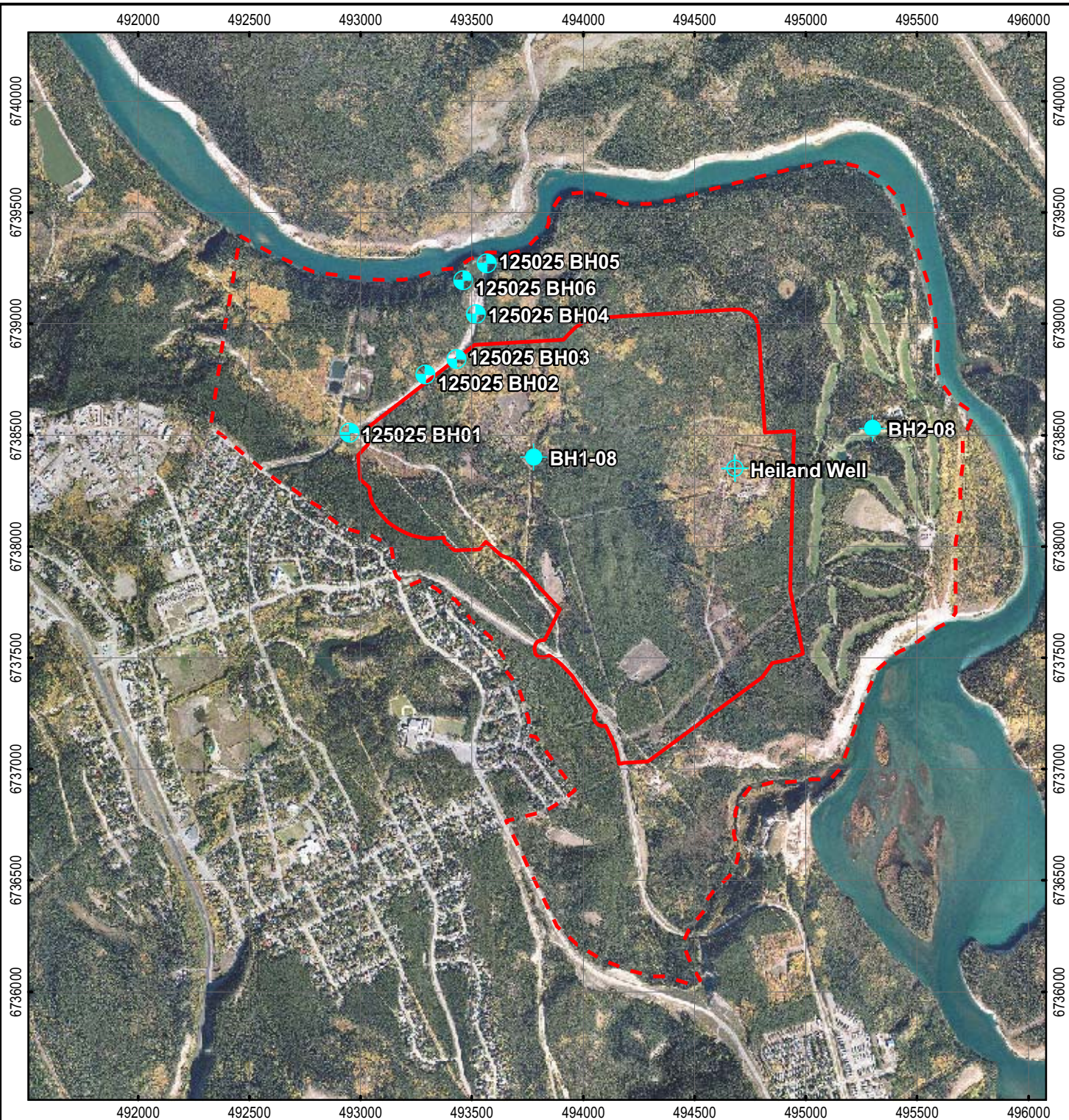
FIGURES



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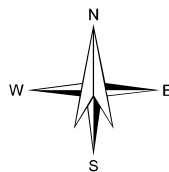


LEGEND

-  Test Borehole
-  Existing Water Well
-  EBA Geotechnical Borehole
-  Study Area Boundary
-  Approximate Development Area Boundary

NOTES

Base data source:
Background Image from Geomatics Yukon



DISTRICT HEATING AND WASTE HEAT COLLECTION FEASIBILITY STUDY WHISTLE BEND NEIGHBOURHOOD DEVELOPMENT, WHITEHORSE, YUKON

Air Photo of Site with Borehole and Well Locations

PROJECTION

UTM Zone 8

DATUM

NAD83

Scale: 1:25,000

430 215 0 430

Meters

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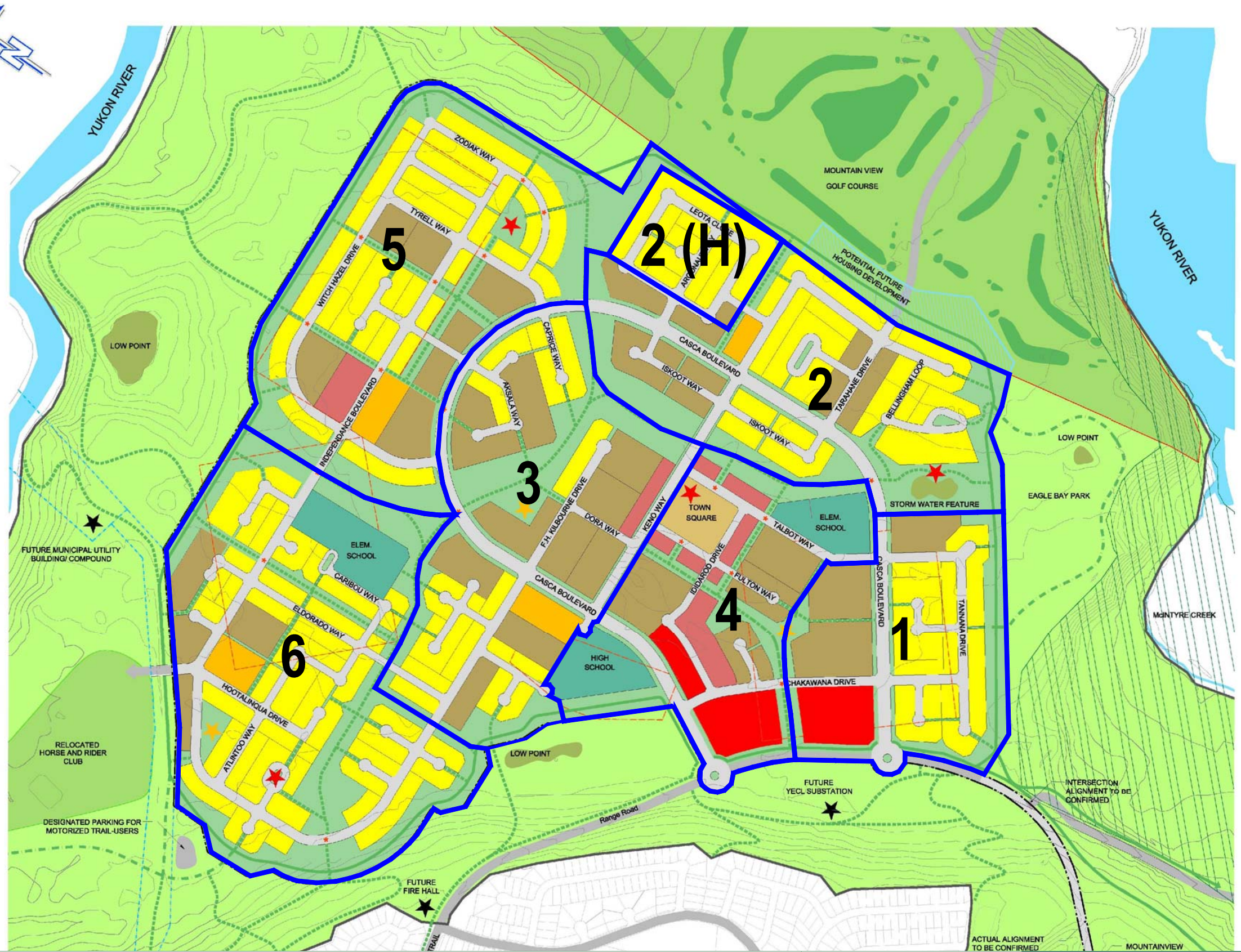
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Figure 1.2

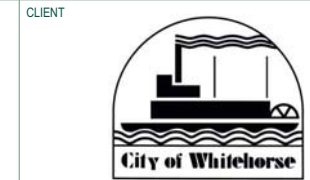
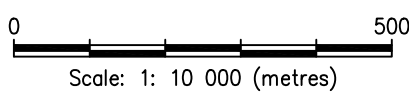
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LEGEND

- Housing-Mix A
- Housing-Mix B
- Mixed Use
- Commercial
- Community Use
- School
- Parks and Trails
- Active Recreation Area
- Natural and Protected Area
- Environmentally Sensitive Area
- Potential Future Housing Development Area
- Study Area
- Existing Parcel Boundary
- Development Boundary
- Sanitary ROW
- City Trail (Paved Perimeter Trail)
- Neighbourhood Trail
- City Trail (Motorized-uses)
- Trail/Road Crossing
- Off Site Infrastructure
- Neighborhood Focal Point
- Community Gardens



NOTE:
BASE PLAN TAKEN FROM AECOM FIGURE FINAL CONCEPT PLAN
(REVISION 6) OBTAINED FROM THE CITY OF WHITEHORSE



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DISTRICT HEATING AND WASTE HEAT COLLECTION FEASIBILITY STUDY
WHISTLE BEND NEIGHBOURHOOD DEVELOPMENT, WHITEHORSE, YUKON

FINAL CONCEPT DEVELOPMENT PLAN

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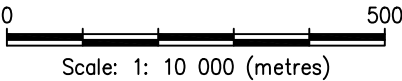
Figure 2.1

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LEGEND

- Housing-Mix A
- Housing-Mix B
- Mixed Use
- Commercial
- Community Use
- School
- Parks and Trails
- Active Recreation Area
- Natural and Protected Area
- Environmentally Sensitive Area
- Potential Future Housing Development Area
- Study Area
- Existing Parcel Boundary
- Development Boundary
- Sanitary ROW
- City Trail (Paved Perimeter Trail)
- Neighbourhood Trail
- City Trail (Motorized-uses)
- Trail/Road Crossing
- Off Site Infrastructure
- Neighborhood Focal Point
- Community Gardens
- Potential Borehole Drilling Area
- Potential Borehole Drilling Corridor
- Potential Borehole Drilling Corridor Junction
- Potential Borehole Drilling Area - Casca Boulevard

NOTE:
BASE PLAN TAKEN FROM AECOM FIGURE FINAL CONCEPT PLAN
(REVISION 6) OBTAINED FROM THE CITY OF WHITEHORSE



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DISTRICT HEATING AND WASTE HEAT COLLECTION FEASIBILITY STUDY
WHISTLE BEND NEIGHBOURHOOD DEVELOPMENT, WHITEHORSE, YUKON

POTENTIAL BOREHOLE DRILLING AREAS

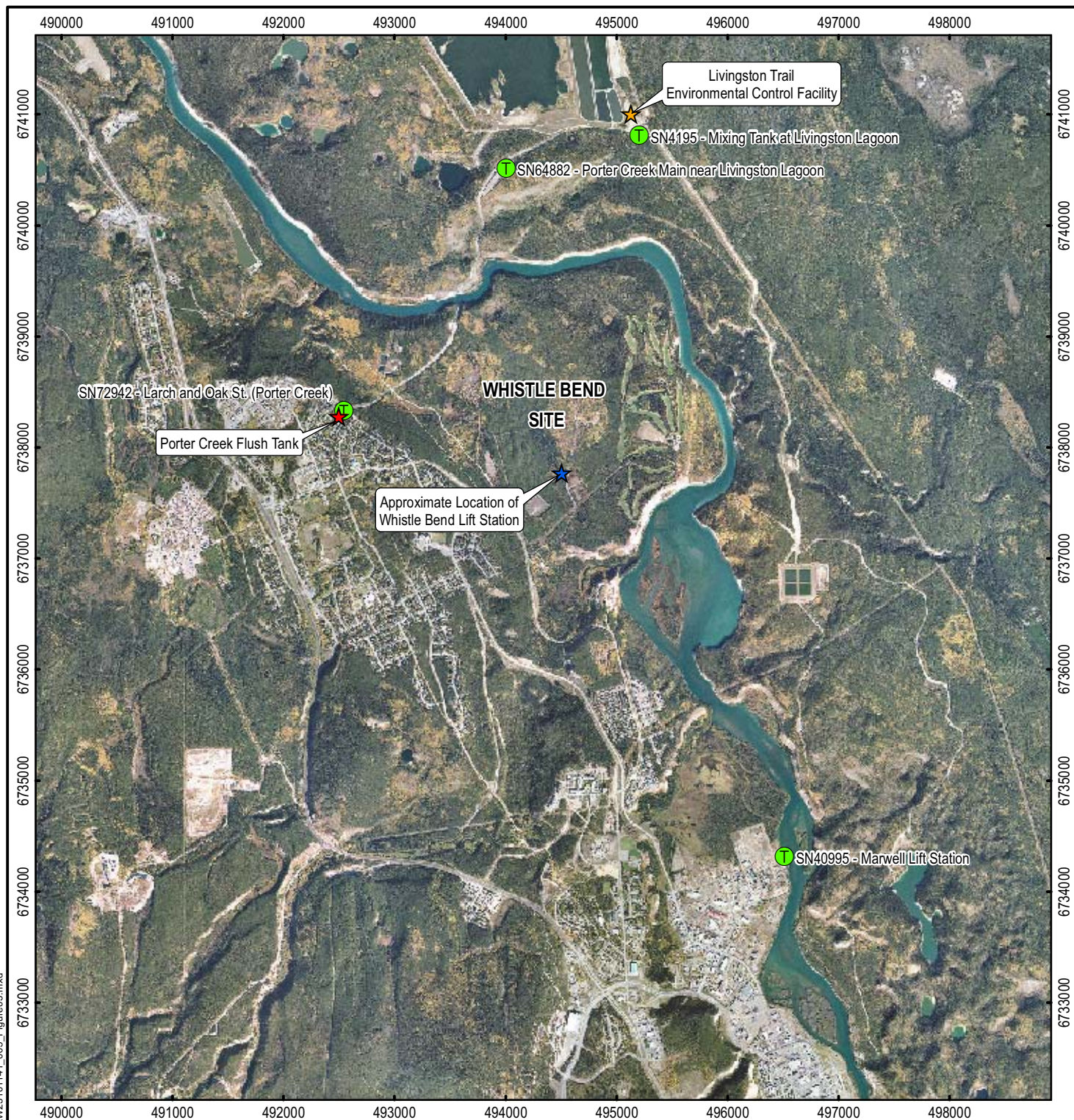
PROJECT NO. W23101141.005	DWN MEZ	CKD HSS	REV 0
OFFICE EBA-WHSE	DATE July 6, 2009		

Figure 3.1

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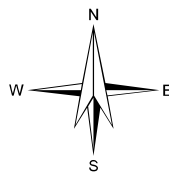
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LEGEND

 Sewage Temperature Monitoring Site



NOTES

Base data source:
Background Image from Geomatics Yukon

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DISTRICT HEATING AND WASTE HEAT COLLECTION FEASIBILITY STUDY WHISTLE BEND NEIGHBOURHOOD DEVELOPMENT, WHITEHORSE, YUKON

Sewage Temperature Monitoring Sites, City of Whitehorse

PROJECTION UTM Zone 8	DATUM NAD83
Scale: 1:50,000	
	

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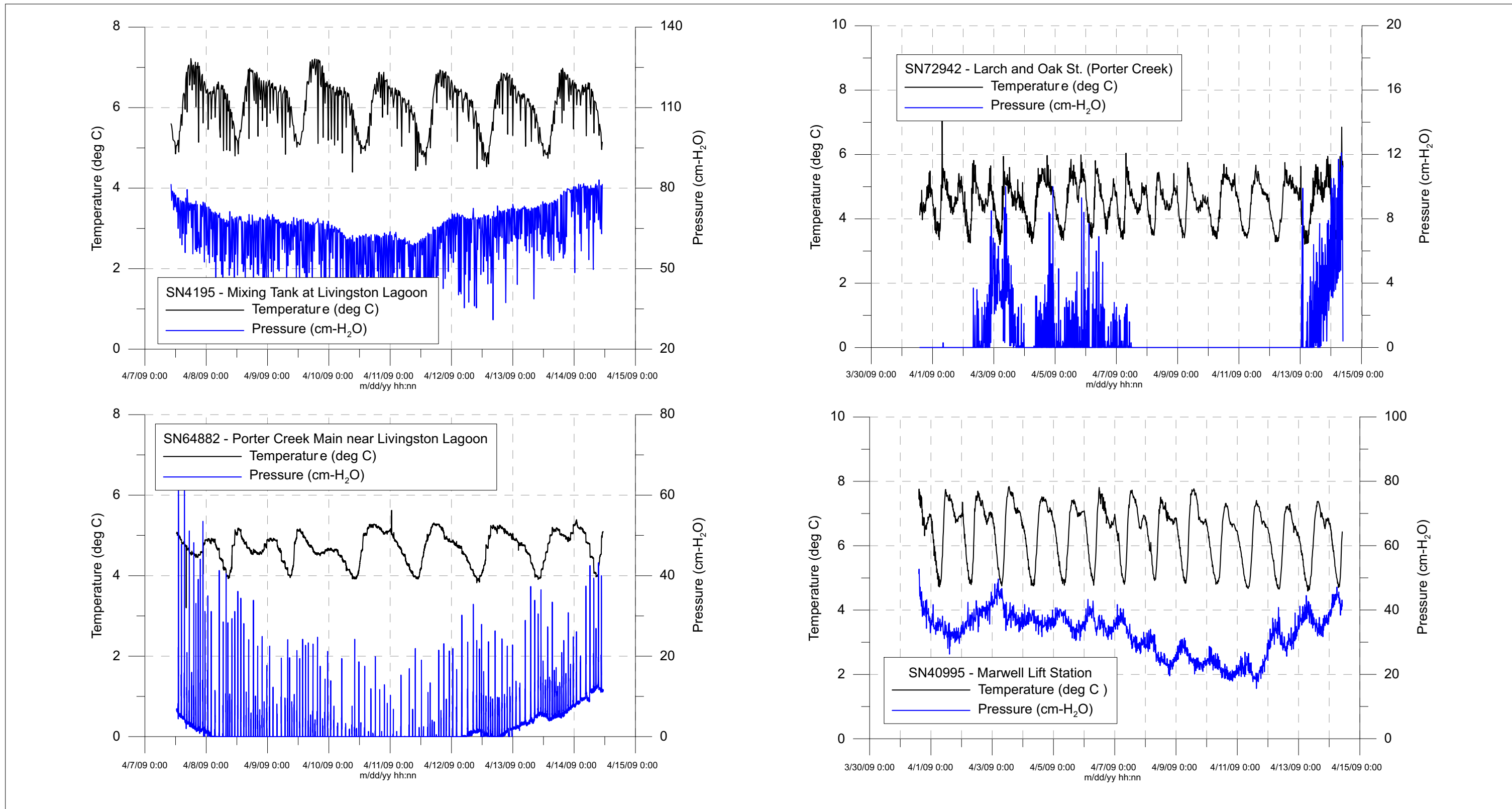
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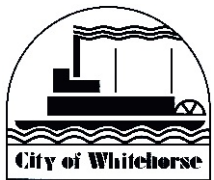
Figure 4.1

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NOTES:
Refer to Figure 4.1 for monitoring locations.

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**DISTRICT HEATING AND WASTE HEAT COLLECTION
FEASIBILITY STUDY WHISTLE BEND NEIGHBOURHOOD
DEVELOPMENT, WHITEHORSE, YUKON**

**Summary Plots of Sewage Temperature Monitoring
Results, April 2009**

EBA Engineering
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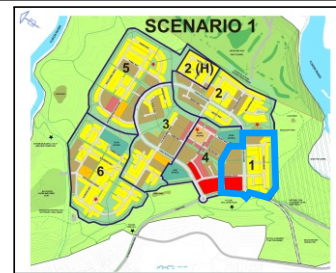
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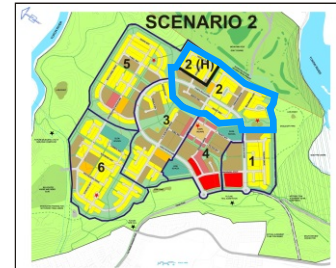
Figure 4.2

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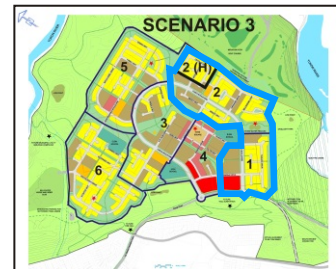
Scenario 1 - Development Area 1 only – (represents a small mixed use area; similar to Development Area 3)



Scenario 2 - Development Area 2 only – (represents a large, mainly residential area; similar to Development Areas 5 and 6)



Scenario 3 - Development Areas 1 & 2 – (the first and most well-defined development phase)



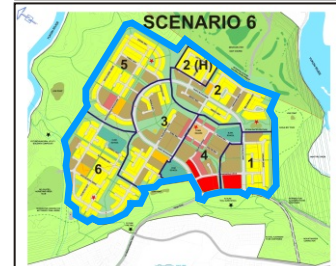
Scenario 4 - Development Area 4 – (unique area, mostly Housing Mix B and Commercial)

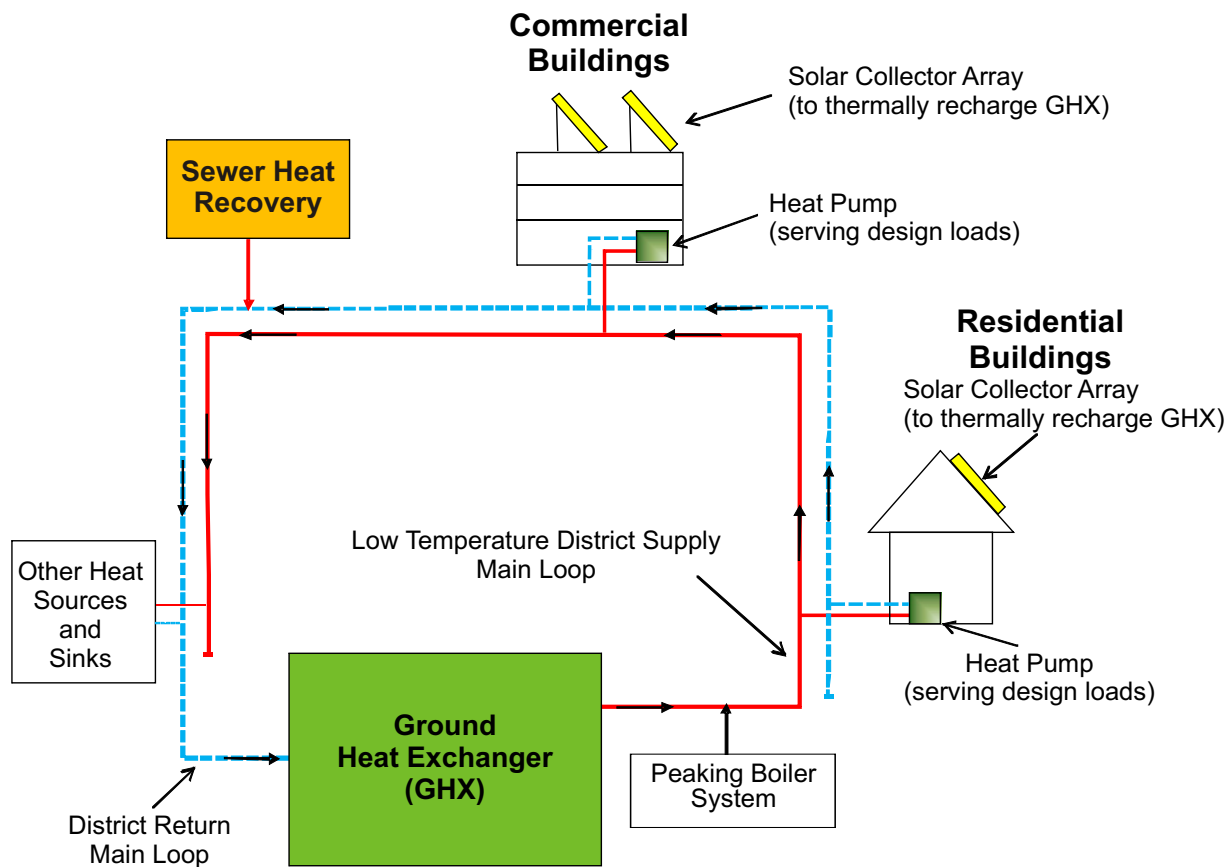


Scenario 5 - All Development Areas except 2H and 5 – (a plausible full build-out scenario)



Scenario 6 - All Development Areas – (for completeness, the ultimate full build-out)





Integrated Geoxchange District Energy Concept

CLIENT



**DISTRICT HEATING AND WASTE HEAT COLLECTION
FEASIBILITY STUDY WHISTLE BEND NEIGHBOURHOOD
DEVELOPMENT, WHITEHORSE, YUKON**

**Schematic Diagram of Hybrid
Geoxchange District Energy System**

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DATE July 6, 2009		

Figure 6.2

APPENDIX A

APPENDIX A GEO-ENVIRONMENTAL REPORT - GENERAL CONDITIONS

The customized condenser

The versatility of spiral heat exchangers makes them ideal for customized solutions

One of the best examples of the flexibility of a spiral heat exchanger is its capability as a condenser.

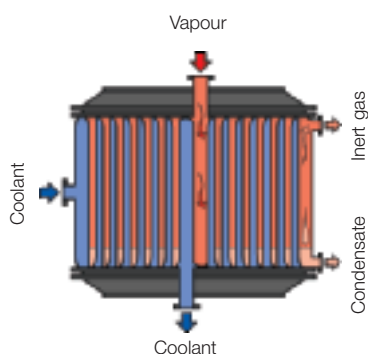
Different condensing duties place different demands on a heat exchanger. The desired condensing performance is achieved by determining the flow path of the vapour.

Alfa Laval spiral condensers perfectly complement Alfa Laval's other process condensers – the AlfaCond and the Compabloc – to provide customers with a full range of condensers for the entire range of their processes and applications.

Maximum product recovery with counter-current condensing

To condense a mixture of vapours and inert gases, a heat exchanger needs a long flow path. In a spiral heat exchanger this is easily achieved, as the vapour flows in a direction that is counter-current to the cooling liquid.

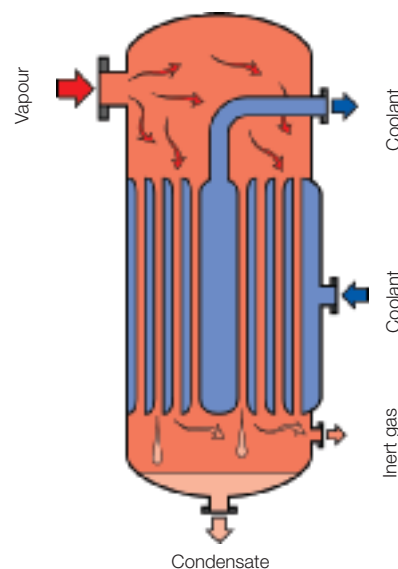
This results in a very compact condenser with the best heat transfer efficiency for maximum product recovery. The counter-current spiral condenser can also be designed to sub-cool the condensate and/or the inert gases.



Cross-flow condensing with the lowest possible pressure drop

Condensing large volumes of pure vapour needs a unit with a large cross-sectional area and a short flow path. To achieve this, the vapour passes through the condensing channel in cross flow.

When the vapour/condensate operate in cross flow, the pressure drop is virtually undetectable. This makes the spiral condenser ideal for systems that operate at very low pressure.



Working closely with our customers helps them to optimize their processes and introduce new forms of heat exchange – such as this fully built condensing tower with three spiral bodies.

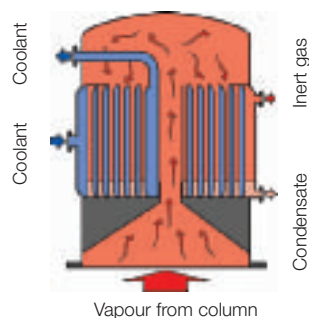


Two units in one – cross-flow and counter-current paths in the same unit

The flexible flow-path arrangement and installation possibilities provided by spiral heat exchangers give them important advantages compared with other condensing solutions.

Two heat exchange duties can be performed within a single spiral to further reduce capital equipment costs, and to maximize operating efficiency.

For example, a spiral heat exchanger can act as a condenser and sub-cooler for condensate and/or inert gases, or as a pre-heater to remove sub-cooling for vaporizer and reboiling duties.



Installation costs reduced still further

Because of their function, condensers are often mounted high up at the top of distillation columns.

Due to this high placing, all the ancillary equipment must be supported on a separate structure. This greatly increases the costs of installation, running and maintenance.

Spiral condensers, however, are available as self-contained units or, more importantly for many customers, as a column-mount to fit directly onto or within an existing distillation column or stripper tower.

It is also possible to build more than one spiral heat exchanger unit into a complete condensing tower to accommodate multiple condensing stages, such as cooling water, chilled water and refrigerant.

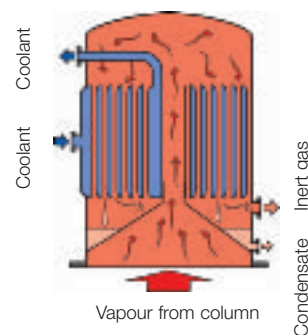


Direct mounting of a spiral condenser at a stripper tower reduces installation costs, increases product recovery and reduces pollutant escape.

Condensers can also separate

Separation of the condensate produced from the inert gases takes place inside the spiral. Condensate can therefore easily be fed back into the column for reflux, or removed for further processing, without the need for external separation equipment.

Fitting a spiral condenser to a tower thus not only increases condensing performance, but also reduces ancillary equipment costs and removes the need for support structures.



History, experience and expertise

It takes experience to build the kind of expertise that provides answers



The largest manufacturer of heat transfer equipment in the world

Our worldwide sales and service representatives ensure that we can provide excellent local service to all prospective and existing customers, while also drawing on the wider experience and expertise accumulated within our global organization.

This wealth of knowledge and experience is especially relevant to the spiral heat exchanger.

Alfa Laval has been making spiral heat exchangers for more than forty years. During this period, Alfa Laval has produced more than 30,000 spiral units for a wide variety of industries and customers all over the world.

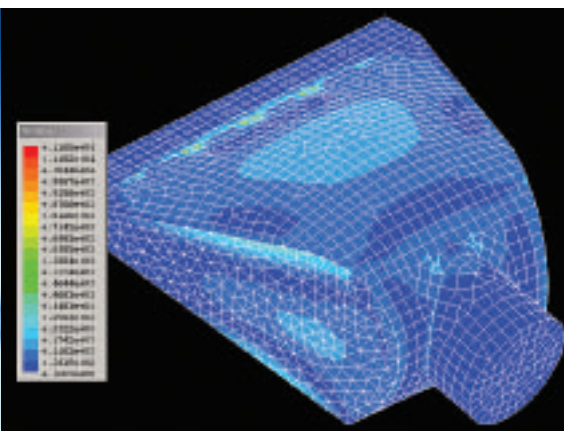
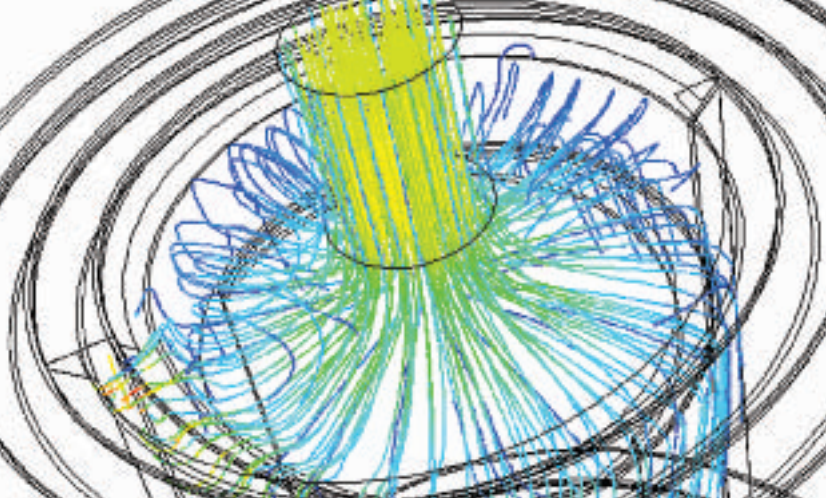
Today, Alfa Laval has three production sites that provide worldwide supply and service to its spiral heat exchanger customers.

They are situated in:

- France
- The United States
- India

Please contact your local Alfa Laval representative to arrange a visit and request a tour of our facilities.





Continual development

Spiral heat exchangers are a well-established product, and have been around for a long time. Nevertheless, Alfa Laval heat exchangers are designed using the very latest techniques and testing methods.

Our sales staff are equipped with sophisticated, state-of-the-art calculation and quotation tools.

Our manufacturing and R&D departments are constantly working to make improvements on production techniques and component design – again drawing on the vast pool of skills and know-how available within Alfa Laval.

Inspiration from our customers

Our best source of information and inspiration is our customers.

Spiral heat exchangers are customized products, engineered to meet the needs of each new installation. After all, no two customers are alike, and neither are their plants or their processes.

Over time, spiral heat exchangers have become standard equipment for a great many processes in many industries.

We enjoy working closely with our customers to meet the challenge of improving their processes. Selecting spiral heat exchangers can help customers in the following ways:

- by improving an existing thermal duty
- by helping to develop alternative solutions and new processes

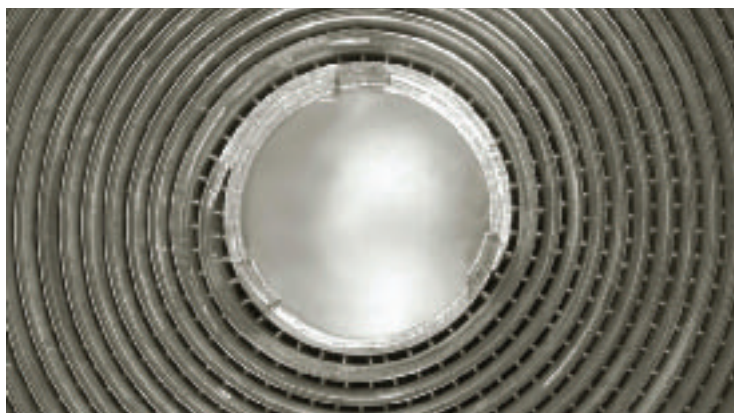
Whatever the duty, Alfa Laval has an extensive catalogue of references, the necessary experience, and a complete heat exchanger product portfolio. We are confident of being able to recommend the best heat exchange solution for your process.



Performance and applications

Performance range

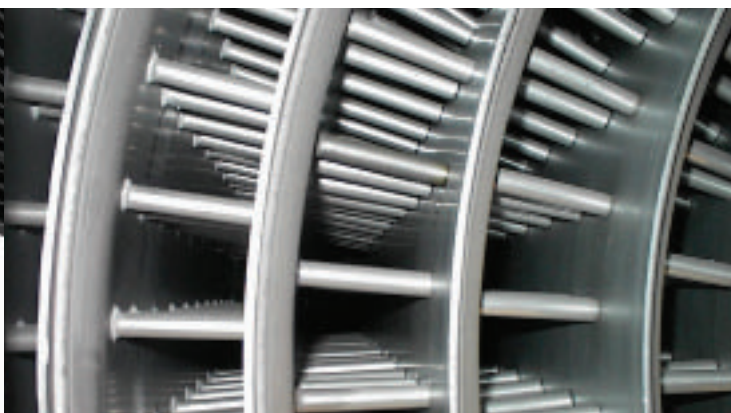
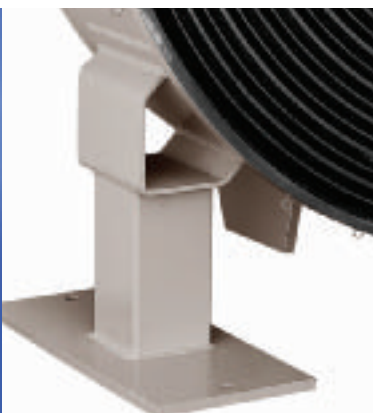
	Minimum	Maximum
Area range per body	1 m ² 10 ft ²	700 m ² 7000 ft ²
Design temperature	-100°C -150°F	400°C 750°F
Design pressure	Full vacuum	40 barg and above 580 psig and above
Pressure vessel codes	PED, ASME, AS1210 and others	
Standard construction materials	Stainless steel, carbon steel	
Other construction materials	Any metal that can be cold formed and welded – including Duplex, titanium, Hastelloy, 904L	





Typical applications

Type of fluids and gases	Fouling liquids – containing solids, fibres, liquors, slurries and sludges. Gases – pure vapour and mixtures with inert gases.
Type of duty	Liquid/liquid – preheating, heating, cooling, interchanging, heat recovery. Vapour/liquid – top condensers, reflux condensers, vacuum condensers, vent condensers, reboilers, gas coolers.
Type of industry	• Petrochemical • Refinery • Steel making • Pulp and paper • Metal/ore processing • Wastewater treatment • Pharmaceutical • Vegetable oil processing • Distillery



Nonstop Performance

A lifetime commitment

For us at Alfa Laval, our obligation to you as a customer does not stop short at delivery. Our Parts & Service organization is there to ensure that your process always runs at peak performance. This is a commitment that extends throughout the lifetime of the system. We call it Nonstop Performance.

Nonstop Performance is based on our global network of experts, who are always on standby to provide you with genuine spare parts on site, in more than 50 countries, 365 days a year, right around the clock.

In terms of service, we speak your language. Alfa Laval service is based on a profound insight into the needs of the process industry. We see every product as part of a process and understand the role it plays within that process. We can therefore work in close collaboration with you to tailor an individual service package that matches your requirements perfectly.

Service must result in bottom-line benefits. We therefore help you to calculate the savings that will result from any proposed service package, and the real-term benefits it will provide.

Challenge us to show you!





GEO-ENVIRONMENTAL REPORT – GENERAL CONDITIONS

This report incorporates and is subject to these “General Conditions”.

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This report pertains to a specific site, a specific development, and a specific scope of work. It is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site or proposed development would necessitate a supplementary investigation and assessment.

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Electronic files submitted by EBA have been prepared and submitted using specific software and hardware systems. EBA makes no representation about the compatibility of these files with the Client’s current or future software and hardware systems.

3.0 NOTIFICATION OF AUTHORITIES

In certain instances, the discovery of hazardous substances or conditions and materials may require that regulatory agencies and other persons be informed and the client agrees that notification to such bodies or persons as required may be done by EBA in its reasonably exercised discretion.

APPENDIX B

APPENDIX B SEWER HEAT RECOVERY INFORMATION

Sewage Heat Recovery Potential Calculations

WBN Pop. Projections and Waste Production						
Devel. Area	Units	Pp/unit	People	Water m3/yr	Yearly Avg. Waste m3/yr (l/s)	
1	361	2.6	938	115,530	103,977	3.3
2	440	2.6	1143	140,834	126,750	4.0
2H	110	2.6	285	35,148	31,634	1.0
3	681	2.6	1769	217,968	196,172	6.2
4	287	2.6	746	91,905	82,714	2.6
5T	578	2.6	1504	185,214	166,692	5.3
6	511	2.6	1328	163,577	147,219	4.7

Porter Creek Population and Waste Production						
Area	Units	Pp/unit	People	Water m3/yr	Waste m3/yr (l/s)	
PC			3353	743,826	669,443	21.23

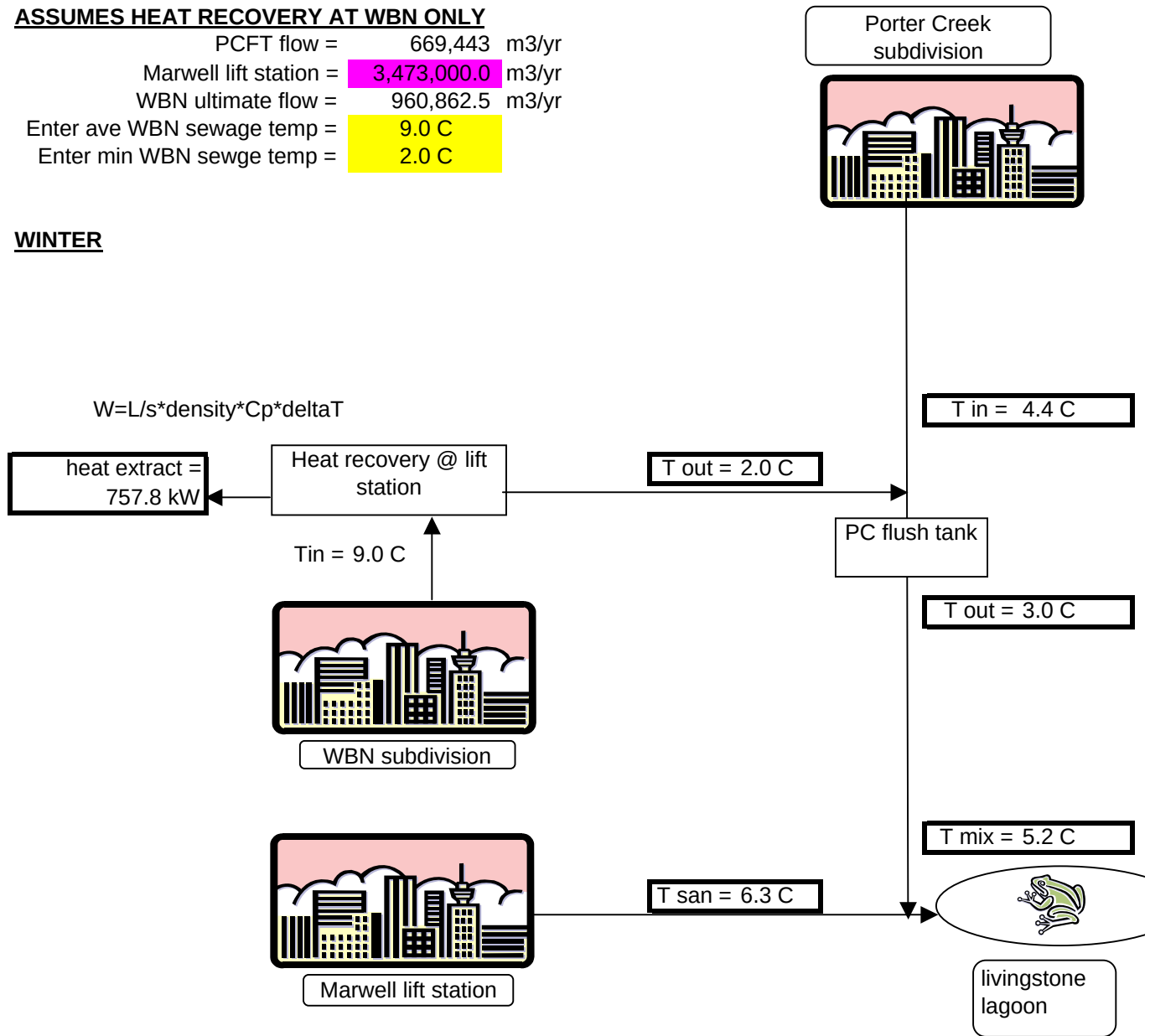
HEAT RECOVERY POTENTIAL BY DEVELOPMENT AREA						
Devel. Area	<u>WINTER</u> Heat available, kW	<u>SUMMER</u> Heat available, kW	Theoretical Recoverable heat, kW <u>WINTER</u>	Theoretical Recoverable heat, kW <u>SUMMER</u>	Energy, Winter, kWh	Energy, summer, kWh
PC	213 kW	621 kW	181 kW	528 kW	792,844 kWh	2,312,461 kWh
1	96 kW	96 kW	82 kW	82 kW	359,169 kWh	359,169 kWh
2	118 kW	118 kW	100 kW	100 kW	437,834 kWh	437,834 kWh
2H	29 kW	29 kW	25 kW	25 kW	109,272 kWh	109,272 kWh
3	182 kW	182 kW	155 kW	155 kW	677,637 kWh	677,637 kWh
4	77 kW	77 kW	65 kW	65 kW	285,720 kWh	285,720 kWh
5T	155 kW	155 kW	131 kW	131 kW	575,806 kWh	575,806 kWh
6	137 kW	137 kW	116 kW	116 kW	508,541 kWh	508,541 kWh
WBN	793 kW	793 kW	674 kW	674 kW	2,954 GWh	2,954 GWh
PC	213 kW	621 kW	181 kW	528 kW	793 GWh	2,312 GWh
total	1,006 kW	1,415 kW	855 kW	1,202 kW	3,747 GWh	5,266 GWh

HEAT RECOVERY POTENTIAL BY SCENARIO							Waste Flow Rates
Scenario	<u>WINTER</u> Heat available, kW	<u>SUMMER</u> Heat available, kW	Theoretical Recoverable heat, kW <u>WINTER</u>	Theoretical Recoverable heat, kW <u>SUMMER</u>	Energy, Winter, kWh	Energy, summer, kWh	
1	96 kW	96 kW	82 kW	82 kW	359,169 kWh	359,169 kWh	3.3 l/s
2	118 kW	118 kW	100 kW	100 kW	437,834 kWh	437,834 kWh	4.0 l/s
3	214 kW	214 kW	182 kW	182 kW	797,004 kWh	797,004 kWh	7.3 l/s
4	77 kW	77 kW	65 kW	65 kW	285,720 kWh	285,720 kWh	2.6 l/s
5	609 kW	609 kW	518 kW	518 kW	2,268,902 kWh	2,268,902 kWh	20.8 l/s
6	793 kW	793 kW	674 kW	674 kW	2,953,979 kWh	2,953,979 kWh	27.1 l/s
PC	213 kW	621 kW	181 kW	528 kW	792,844 kWh	2,312,461 kWh	21.2 l/s
total	1,006 kW	1,415 kW	855 kW	1,202 kW	3,747 GWh	5,266 GWh	86.4 l/s

ASSUMES HEAT RECOVERY AT WBN ONLY

PCFT flow = 669,443 m³/yr
Marwell lift station = 3,473,000.0 m³/yr
WBN ultimate flow = 960,862.5 m³/yr
Enter ave WBN sewage temp = 9.0 C
Enter min WBN sewage temp = 2.0 C

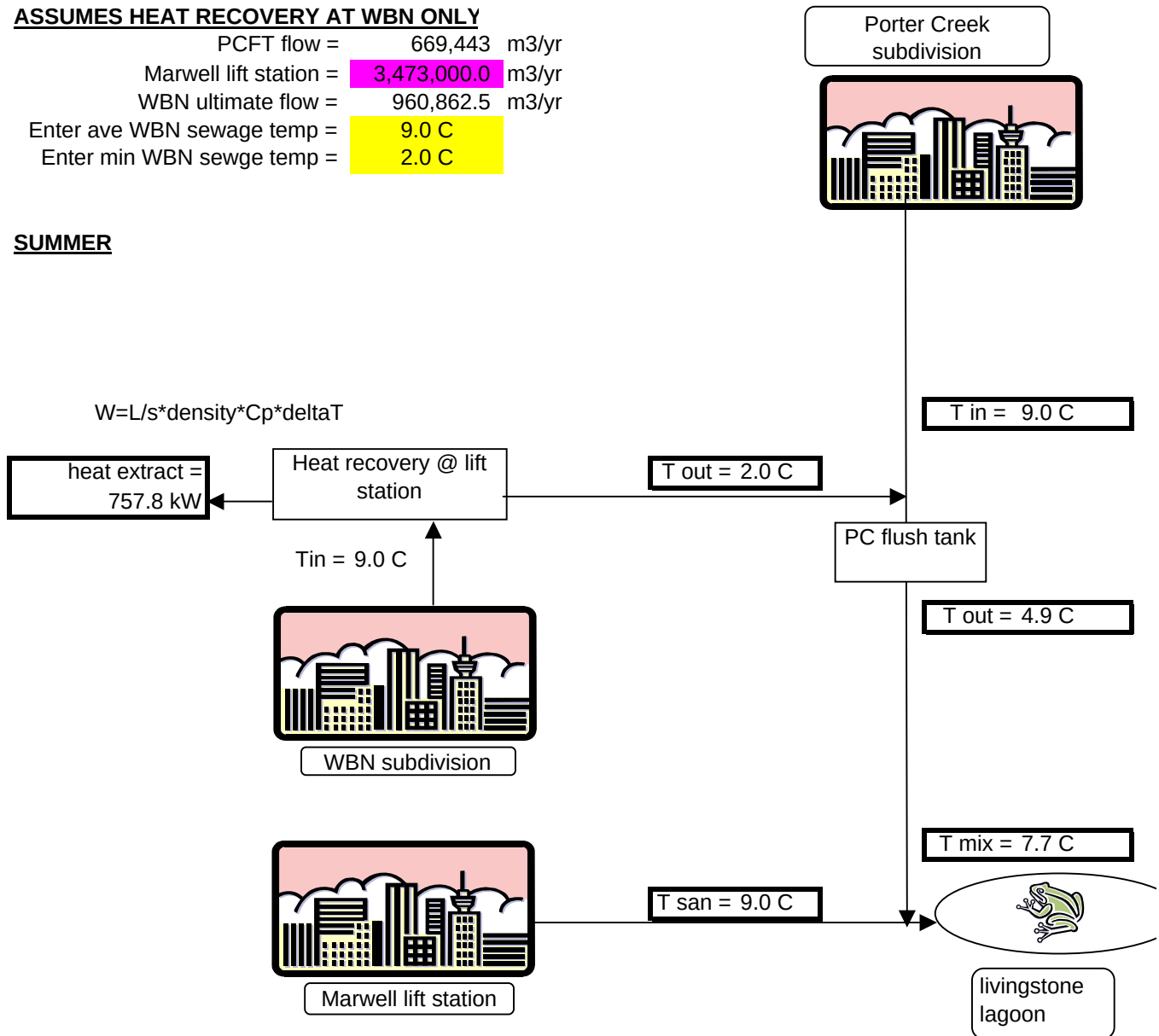
WINTER



ASSUMES HEAT RECOVERY AT WBN ONLY

PCFT flow = 669,443 m3/yr
Marwell lift station = 3,473,000.0 m3/yr
WBN ultimate flow = 960,862.5 m3/yr
Enter ave WBN sewage temp = 9.0 C
Enter min WBN sewage temp = 2.0 C

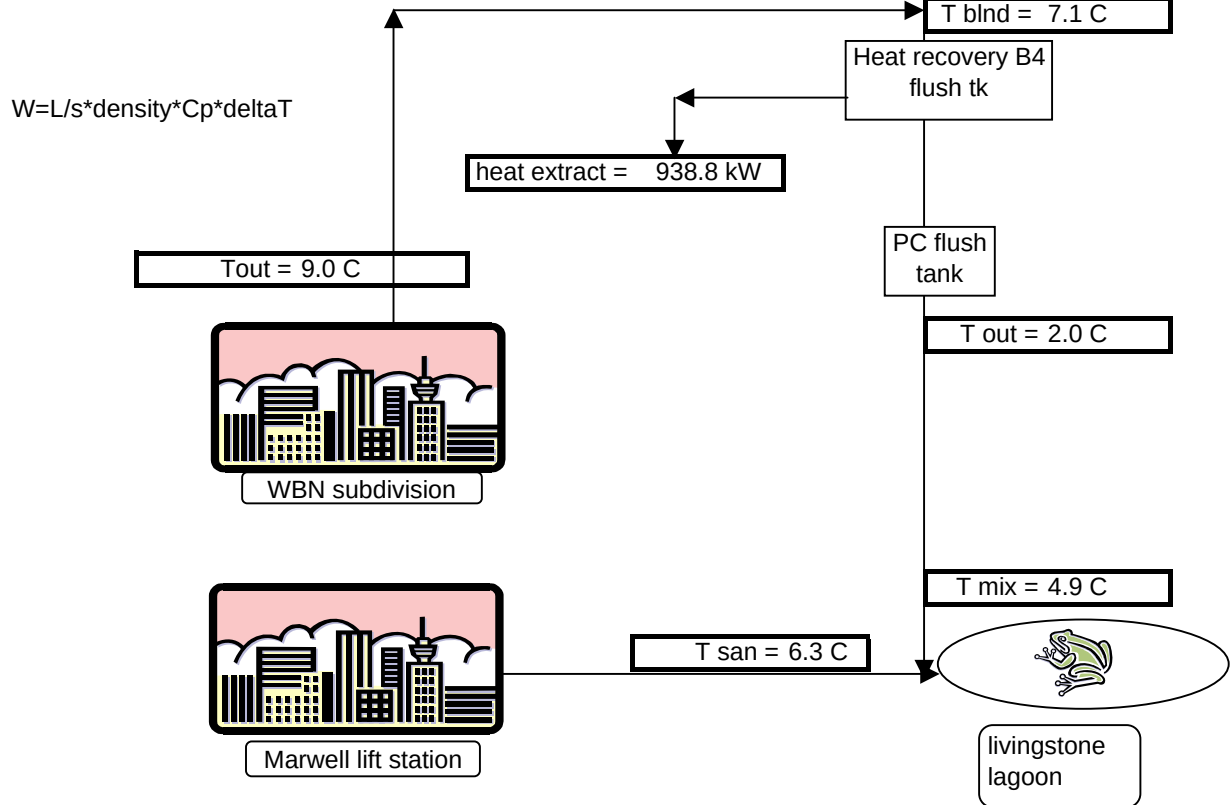
SUMMER



ASSUMES HEAT RECOVERY AT WBN & PC combined

PCFT flow = 669,443 m³/yr
Marwell lift station = 3,473,000.0 m³/yr
WBN ultimate flow = 960,862.5 m³/yr
Enter ave WBN sewage temp = 9.0 C
Enter min WBN sewage temp = 2.0 C

WINTER

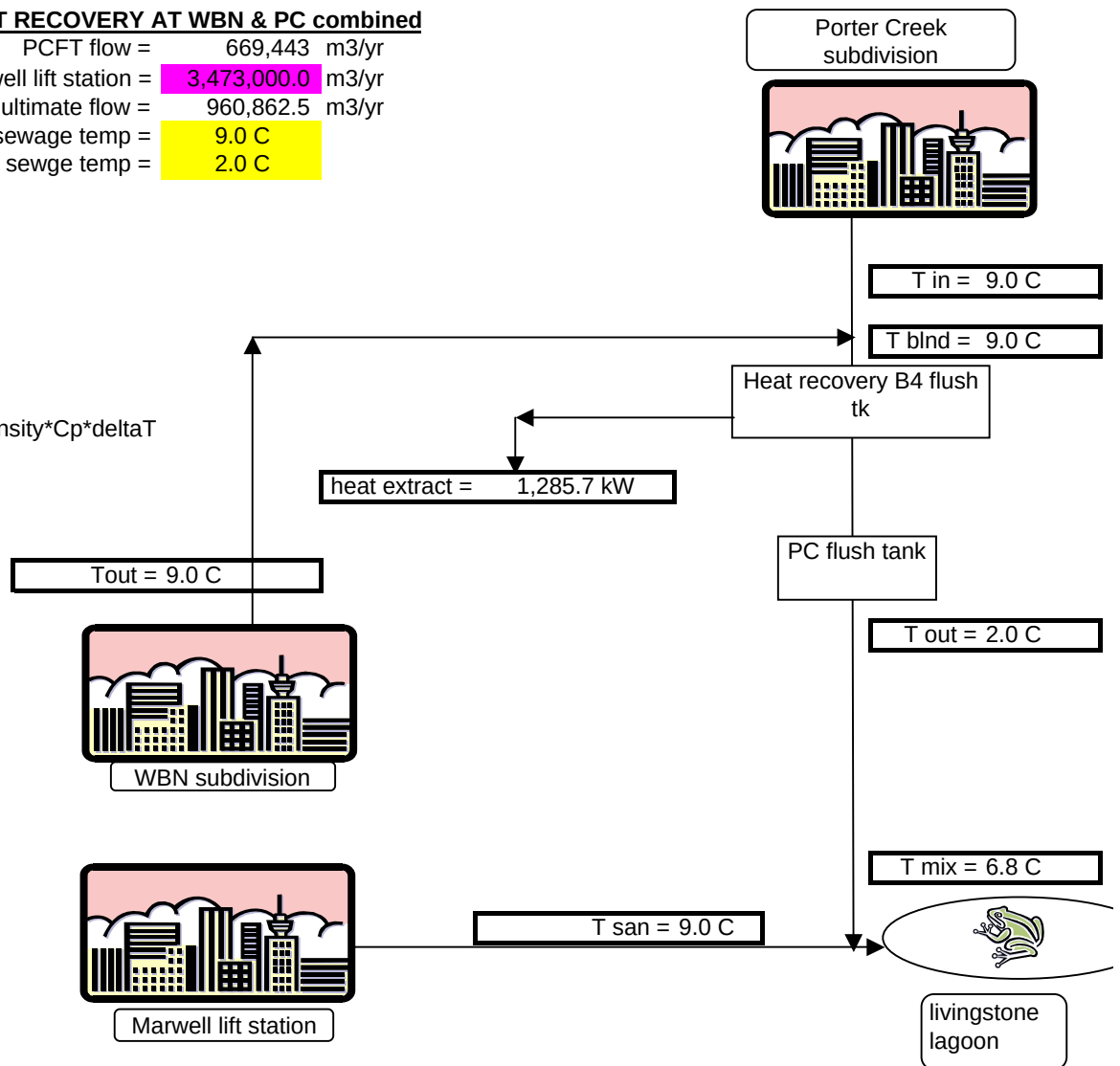


ASSUMES HEAT RECOVERY AT WBN & PC combined

PCFT flow = 669,443 m³/yr
Marwell lift station = 3,473,000.0 m³/yr
WBN ultimate flow = 960,862.5 m³/yr
Enter ave WBN sewage temp = 9.0 C
Enter min WBN sewage temp = 2.0 C

summer

$$W=L/s*\text{density}*C_p*\text{delta}T$$



ASSUMES HEAT RECOVERY AT WBN AND PCFT

PCFT flow = 669,443 m³/yr
Marwell lift station = 3,473,000.0 m³/yr
WBN ultimate flow = 960,862.5 m³/yr
Enter ave WBN sewage temp = 9.0 C
Enter min WBN sewage temp = 2.0 C
Min outflow temp @ PCFT = 2.0 C

SUMMER

heat extract =
528.0 kW

$$W = L/s * \text{density} * C_p * \Delta T$$

heat extract =
757.8 kW

Heat recovery @ lift
station

T_{in} = 9.0 C



WBN subdivision



Marwell lift station

Porter Creek
subdivision



T_{in} = 9.0 C

heat recovery B4
flush tank

T_{out} = 2.0 C

T_{out} = 2.0 C

PC flush tank

T_{out} = 2.0 C

T_{mix} = 6.8 C

T_{san} = 9.0 C

livingstone
lagoon



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RABTHERM AG opens new branch office in North America and enters into new markets in East Europe. [Continue...](#)

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Die neuen gesetzlichen Grundlagen und staatlichen Fördermöglichkeiten in Deutschland unterstützen seit 1.1.2009 die umweltschonende Wärmenutzung aus Abwasser.

RABTHERM - Gold Under Our Feet!

After the slogan - ecologically, competently and economically, RABTHERM AG is engaged since March 2000 with the marketing of the patented system RABTHERM - **heat utilization from waste water for heating and cooling of buildings** -, as well as the development of a comprehensive system, which uses and produces renewable energy.

Since mid of 2007 [the investor circle Brains To Venture](#) invested into RABTHERM AG. The re-orientation sets the priority on professional, respectable and competent job execution. Responsibility opposite the customer, long-term customer relation and a target group oriented marketing are the factors for business success. RABTHERM AG supplies a unique product solution and an outstanding technical knowledge. The focus lies therefore especially in the economical, process orientated, as well as in the marketing field.

In the market for renewable heat energy RABTHERM strives for a leading position. Thanks to the technical know-how of RABTHERM - it's possible to follow the "recycling" principle and to provide an important contribution to the ecology. With this new energy system approx. 20 per cent of the heating market can be covered profitable and economically on a long-term basis.

Our services contain:

- **ROUGH ANALYSIS**
- **LOCATION / FEASIBILITY STUDY** with drains and heat burner
The studies contain the local clarifications drains data (inclusive condition) and burner data, the calculations of production costs and the cost of the investment
- **CLARIFICATIONS** with the users
- **CONSULTATION/SUPPORT** for conveyance request
- **ADDITIONAL SERVICES:**
 - Solutions for drying sewage sludge
 - Cooling water in industries as energy source
 - Cooling of domestic drinking water
 - Snow and ice melt systems for roads
 - Airconditioning and cooling in protected oldtown zones
 - (cooling with waste water instead of cooling towers on the roof)

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HEAT EXCHANGERS

Sludge Heat Recovery

ddi-heatexchangers.com

- ◆ **“Cube” Non Plug Design**
(2 inch channel gap min.)
Low Pressure Drop
- ◆ **Minimal Maintenance**
(Once / 5 years)
- ◆ **Compact Units, small footprint**
- ◆ **Cost Efficient Heating & Cooling of Sludge**
- ◆ **Customized units to suit your requirements**
- ◆ **DDI Heat Exchangers for Waste Water Treatment Process:**
Pulp & Paper, Dairies, Distilleries, Mining, Metallurgical, Breweries, Oil & Gas, Agriculture Industries.



DDI

COMPARISON: "DDI CUBE"™ "SQUARE"™ HEAT EXCHANGER vs COMPETITION

DESCRIPTION	DDI CUBE™ SQUARE™	Spiral or Tube in Shell
INITIAL COST 1,250,000 BTUH:	EQUAL	EQUAL
APPLICATION:	Sludge to Sludge and/ or Water to Sludge	Water to Sludge mainly
SLUDGE SIDE GAP:	2.75" to 6" channel	0.75" TO 1.5" channel with studs or annulus
		4" & 6" tube
WATER SIDE GAP:	1" to 6" channel	0.5" to 1" channel or annulus
INSTALLATION COSTS:	EQUAL	EQUAL
MAINTENANCE COSTS:	—	—
<i>Frequency of cleaning due to plugging with rugs etc.</i>	Scheduled once in 5 years	As often as every two weeks (26/year)
<i>Cost per clean-up 16 Man/hour at \$40/hr</i>	\$640	\$640
<i>Annual cost of clean-up</i>	\$128	\$16,640 or more
TOTAL Cost of clean-up prorated 20 yrs.	\$2,560	\$332,800
GASKETS:	\$8,000	\$8,000
MACERATOR:	Not required	\$15,000
<i>Initial cost of unit</i>	Not required	\$8,000
<i>Installation (piping, valves)</i>	Not required	\$20,000/20 years
<i>Replacement Parts (blades etc)</i>	Not required	\$73,320/20 years
<i>Electric power 10 hp</i>	Not required	\$4,000/20 years
TOTAL MAINTENANCE FOR 20 YEARS CYCLE	\$10,560	\$461,120
NET SAVING OF: OVER 20 YEARS	\$450,560	

NOTES:

- DDI's Heat Exchangers are generally less costly to purchase.
- DDI's Heat Exchangers are built with large gaps (Non Plug feature).
- DDI's Heat Exchanger Design has No obstacles in the flow.
- DDI's Heat Exchanger can pass more hot water for increased heating capacity and efficiency at a lower operating pressure with round curves.
- DDI's Heat Exchanger requires minimal maintenance.
- DDI's Heat Exchanger are less costly to operate.
- DDI's Heat Exchanger can achieve efficient flow in both sides for Heat Recovery of Sludge to Sludge (Tube in Shell cannot) and still keep minimum Gap for non-plug conditions.

REFERENCES

"7 Years + of Trouble-Free operation without any maintenance and continuously working within the original specifications"
WWTP, Chief, Antoine Laporte, Repentigny



305 Raffen, Montreal, Qc, CANADA H9A 3G4

TEL: (514) 696-7961 FAX: (514) 696-8344

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REPRESENTATIVE



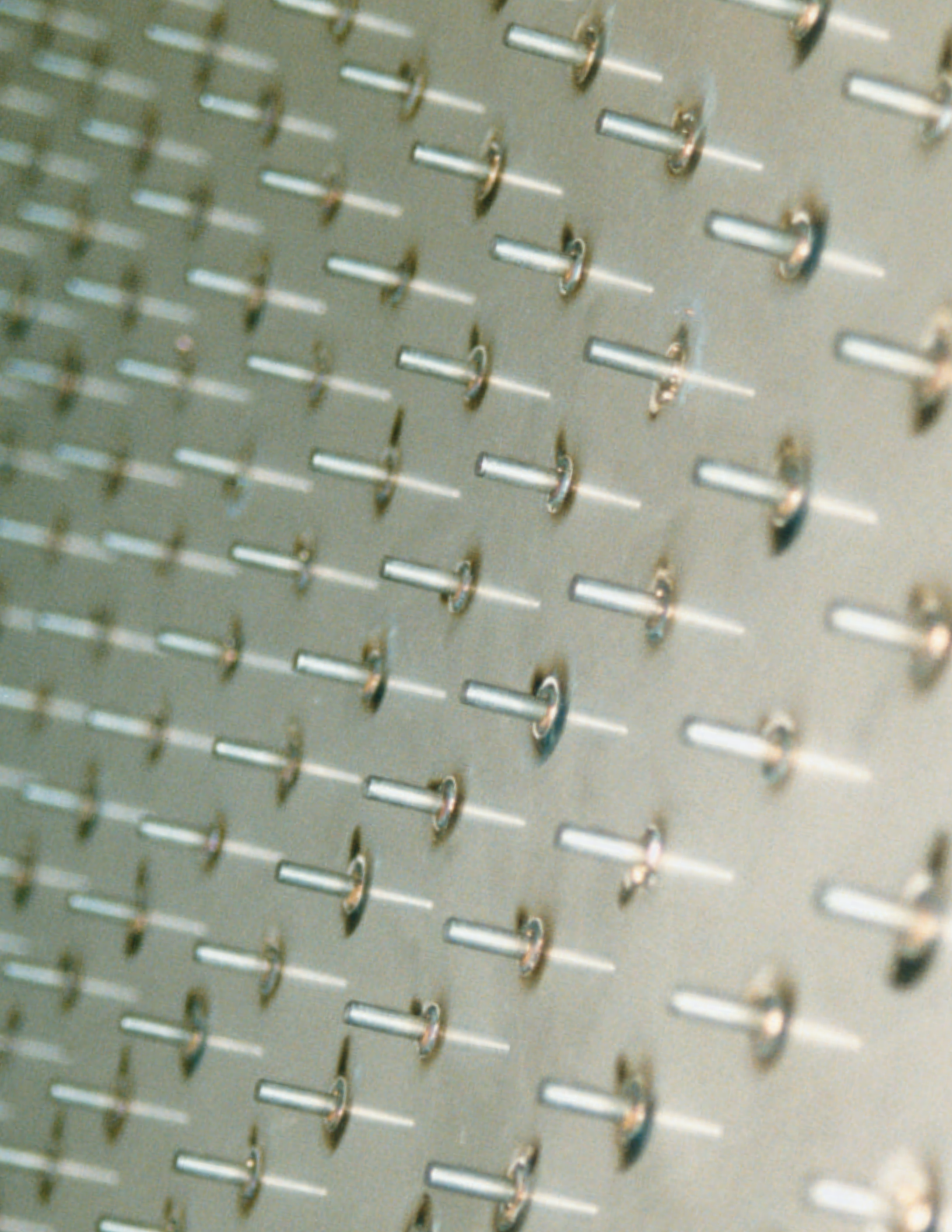
Alfa Laval – spiral heat exchangers

The all-round heat transfer solution



Spiral-shaped heat exchangers are not a new idea
– but Alfa Laval has perfected the design.

Exceptional compactness and self-cleaning design
make Alfa Laval spiral heat exchangers extremely
versatile. Ideal for everything from dirty fluids to high
vacuum condensation.



The perfect solution

From dirty fluids to high vacuum condensation

– spiral heat exchangers from Alfa Laval can do it all

The idea of using spiral-shaped fluid channels for heat transfer arose in response to a particular customer's process problem. Other technologies had failed, but in this case a spiral proved to be the perfect solution.

That was nearly 70 years ago.

Today, spiral heat exchangers fit perfectly into Alfa Laval's extensive product portfolio – still providing customers with optimum process solutions.

Spiral heat exchangers are particularly useful when a process is "dirty" or "difficult". In such circumstances, spiral heat exchangers have clear advantages over other products that employ heat exchange technologies.

Alfa Laval spiral heat exchangers are designed on the basis of our extensive thermal and mechanical experience, acquired from both our customers and our production sites.

Product ranges

We provide fixed-size and customized product ranges to meet the needs of our customers.

Fixed-size ranges

We make small units for general use, and for application-specific purposes such as the wastewater industry.



Customized range

To meet requirements for a range of sizes and specifications, the majority of the spiral heat exchangers we supply are individually customized.



Customer needs met with customized design

No two customers are alike, and neither are their plants or their processes. To meet all these different needs, engineering solutions and process equipment must be adaptable.

Each Alfa Laval spiral heat exchanger design can be customized to meet the precise process and application needs of individual customers.

Unique shape has unique properties

A spiral heat exchanger is precisely what it says – a circular heat exchanger with two concentric spiral channels, one for each fluid.

The curved fluid channels provide optimum heat transfer and flow conditions for a wide variety of fluids, while keeping the overall size of the unit to a minimum.

The result is a heat exchanger that provides maximum heat transfer efficiency, while only taking up a minimum of installation space.



Strong on customized solutions

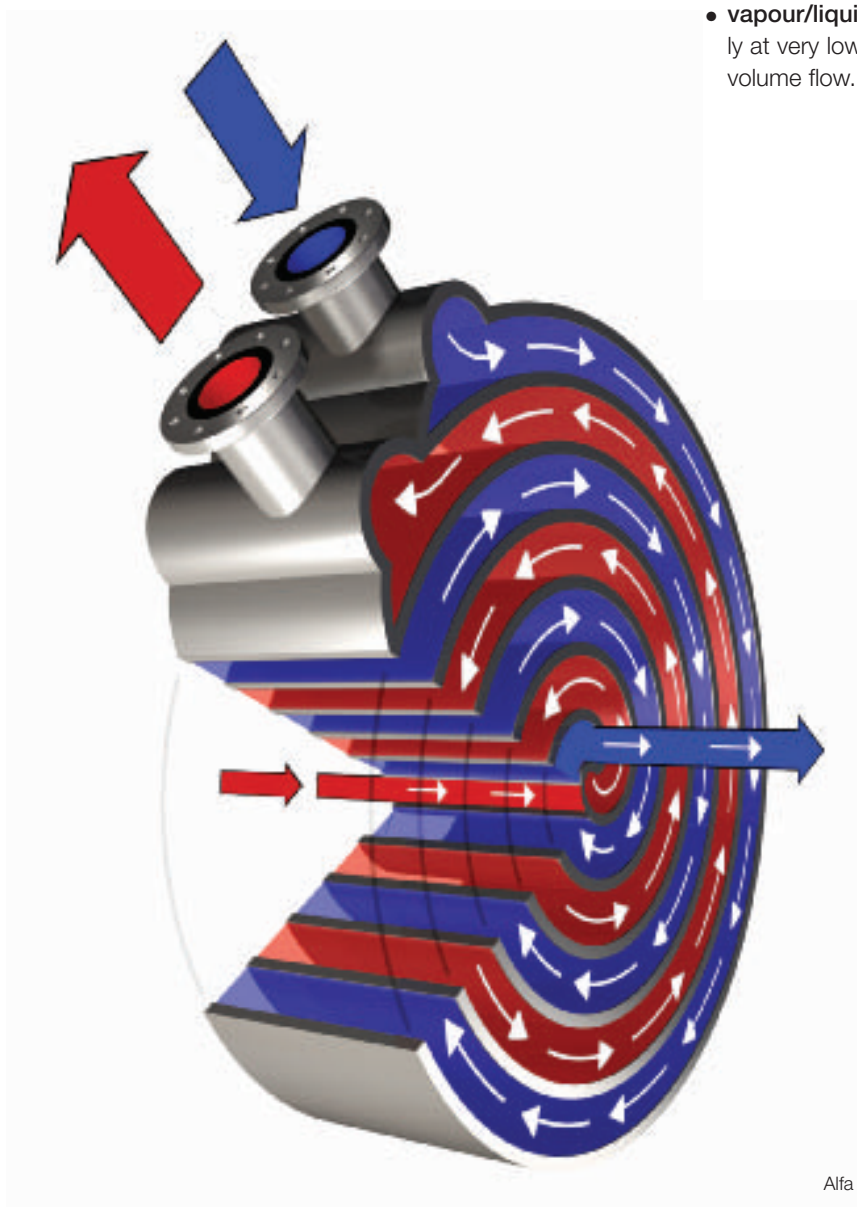
The spiral heat exchanger is a very versatile product.

Many of the duties performed by heat exchangers require one channel per fluid, and this can be a distinct benefit.

The design, shape and size of the spiral channels can be customized so that they are a perfect match for the demands associated with a wide range of process fluids, thermal duties and industrial applications.

Heat exchange duties that benefit from the strengths of spiral heat exchangers include:

- **liquid/liquid** heating, cooling or heat recovery, where one or both of the fluids may cause fouling.
- **vapour/liquid** condensing, particularly at very low pressure and/or high-volume flow.

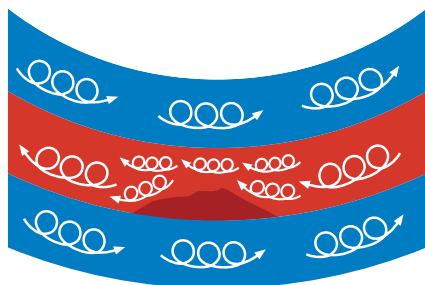


The self-cleaning heat exchanger for demanding liquid/liquid duties

Single channel technology makes keeping clean easier

Some customers choose spiral heat exchangers to boost the performance of their existing processes. Others use them for thermal duties in processes that would otherwise simply be impossible.

Whether replacing existing “inefficient” technology or being used in revolutionary new applications, spiral heat exchangers are the first choice for processes that involve demanding liquid/liquid duties.



Single channel technology – what goes in must come out

As the name indicates, single channel technology means that both fluids occupy a single channel, which allows fully counter-current flow. One fluid enters the centre of the unit and flows towards the periphery. The other fluid enters the unit at the periphery and moves towards the centre.

The channels are curved and have a uniform cross section, which creates a “spiralling” motion within the fluid.

The fluid is fully turbulent at a much lower velocity than in straight tube heat exchangers, and each fluid travels at constant velocity throughout the whole unit. This removes any likelihood of dead spots and stagnation.

Solids are thus kept in suspension, and the heat transfer surfaces are kept clean by the scrubbing action of the spiralling flow.

Self-cleaning keeps costs down

The self-cleaning properties of spiral heat exchangers ensure that the reliable performance of efficient heat transfer is guaranteed, with minimum down time for maintenance.

In some duties where alternative heat exchangers would need regular cleaning, disassembly, repair and maintenance, a spiral heat exchanger

performs for much longer periods, and only requires maintenance during routine plant shutdowns.

Fewer units

The increased thermal efficiency resulting from the fully counter-current flow very often means that a particular assignment requires fewer spiral heat exchangers than the straight-tube alternative.

Lower installation costs

Spiral heat exchangers only require a very small area for mounting and access, resulting in lower unit installation costs compared with other heat exchangers.



Fewer units, less down time

In a coke oven plant, four shell-and-tube units were replaced by just one spiral heat exchanger. This saved space and cost, while increasing performance at the same time.

Unique performance – the spiral's high efficiency and easy access design make heat recovery possible with two fouling fluids – shown here at a municipal sludge pasteurization plant.



Easy access

When processes involve fluids that are capable of causing a high degree of fouling, it is important to have easy access to the inside of the heat exchanger for cleaning and inspection.

Compared with other types of heat exchanger, spiral units provide the best access to their heat transfer area – with no special tools or lifting equipment required.

Each fluid channel is easily accessed via its cover, exposing the whole of the heat transfer surface.

Two covers enable one or two fouling fluids

Both hot and cold channels are designed to perfectly match the special needs of the fluids being used and the thermal duty being performed. This provides total operational security when using either one or two fluids that cause high fouling.

This is a major advantage for customers that want to recover heat from one dirty fluid to another.

Spiral units are the only type of heat exchangers capable of direct heat interchange between two fluids that cause high fouling.

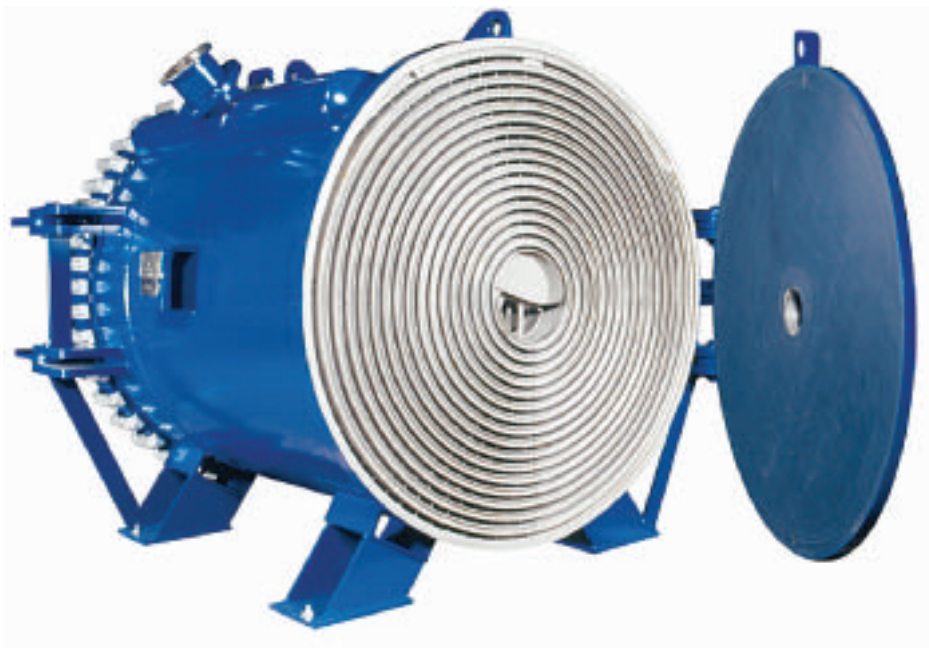


Full draining for batch operation

All spiral heat exchangers can be drained in position, without any need to disconnect pipework or to open the units.

For applications where complete draining of the process fluid is required on a regular basis, the spiral heat exchanger can be installed in an upright position.

This is particularly useful for batch production processes as it makes it possible to empty all fluid from the unit between batches.



Alfa Laval in brief

Alfa Laval is a leading global provider of specialized products and engineered solutions.

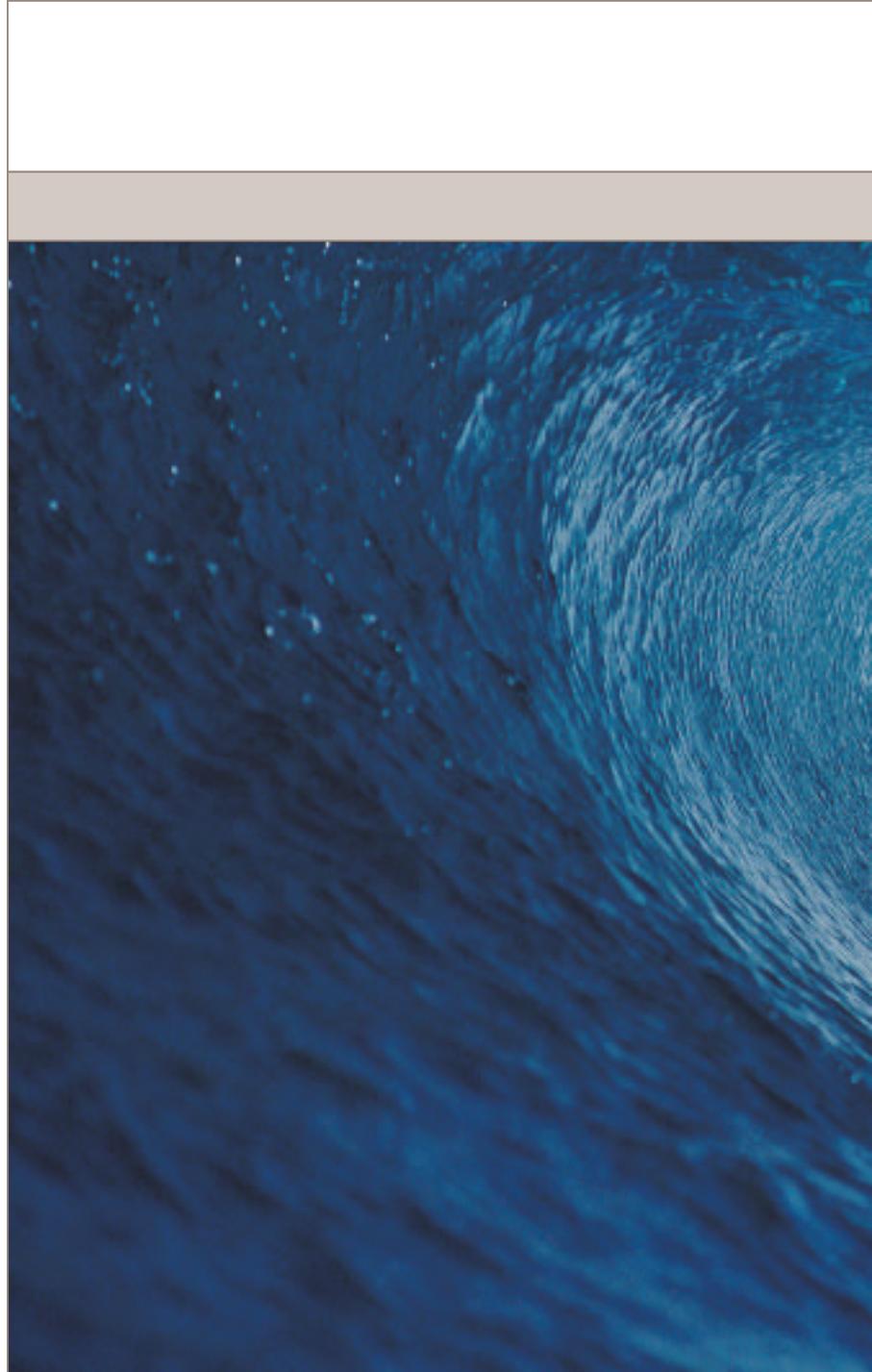
Our equipment, systems and services are dedicated to helping customers to optimize the performance of their processes. Time and time again.

We help our customers to heat, cool, separate and transport products such as oil, water, chemicals, beverages, food-stuffs, starch and pharmaceuticals.

Our worldwide organization works closely with customers in almost 100 countries to help them stay ahead.

How to contact Alfa Laval

Up-to-date Alfa Laval contact details for all countries are always available on our website at www.alfalaval.com



Project: **Whistle Bend Neighbourhood Geoexchange**
FSC No: 2008-4300
Date Prepared: June 3, 2009
Prepared By: S.Birrell
Mhr: rate: \$85.00 /hr avg labour rate
Construction factor: 1.3 construction, inflation factor

Porter Creek Flush TaNk
DDI IN-BLDG HEX

Description	No.	unit	Material		Labour		TOTAL
			cost	factored \$	mhrs	mhr cost	
<u>New Building for Waste HEX</u>						\$0.00	\$553,246.00
Mobilization/Demobilization	1	LS	\$25,000.00	\$32,500.00		\$0.00	\$32,500.00
Building construction	337.6		\$450.00	\$197,496.00		\$0.00	\$197,496.00
Exhaust fan	2	ea	\$1,500.00	\$3,900.00	10	\$1,700.00	\$3,900.00
overhead monorail	1	LS	\$10,000.00	\$13,000.00		\$0.00	\$13,000.00
washroom	1	LS	\$3,000.00	\$3,900.00		\$0.00	\$3,900.00
Heating (elec heat) @ 30 btuh/ft2 = 3 kW - UH	2	ea	\$1,000.00	\$2,600.00	5	\$850.00	\$3,450.00
fencing	1	LS	\$20,000.00	\$26,000.00	0	\$0.00	\$26,000.00
property (City sells to utility)	1	LS	\$150,000.00	\$195,000.00	0	\$0.00	\$195,000.00
power to building	1	LS	\$60,000.00	\$78,000.00		\$0.00	\$78,000.00
<u>Pump & HEX in new bldg.</u>							\$1,382,512.33
Waste Heat Exchanger	1	ea	\$95,700.00	\$124,410.00	200	\$17,000.00	\$141,410.00
HEX injection pump (lead/lag)	2	ea	\$12,000.00	\$31,200.00	80	\$13,600.00	\$44,800.00
HEX sewage pump	2	ea	\$12,000.00	\$31,200.00	80	\$13,600.00	\$44,800.00
Expansion Tank	1	ea	\$700.00	\$910.00	8	\$680.00	\$1,590.00
Temperature Indicators	10	ea	\$150.00	\$1,950.00	1	\$850.00	\$2,800.00
Pressure Indicators	10	ea	\$150.00	\$1,950.00	1	\$850.00	\$2,800.00
Control valve & bypass piping	1	LS	\$5,000.00	\$6,500.00		\$0.00	\$6,500.00
Trenching/Backfill for cold side GWS/R to pump	6560	ft	\$39.80	\$339,382.81	0	\$0.00	\$339,382.81
Insulated buried piping for cold side	13120	ft	\$41.00	\$699,296.00	0	\$0.00	\$699,296.00
Trenching/Backfill for hot side WWS/R to pump	100	ft	\$39.80	\$5,173.52	0	\$0.00	\$5,173.52
Insulated buried piping for hot side	200	ft	\$41.00	\$10,660.00	0	\$0.00	\$10,660.00
Cold & hot side added piping within bldg	2	LS	\$8,000.00	\$20,800.00	100	\$17,000.00	\$37,800.00
Cold & hot side piping Insulation within bldg	2	LS	\$4,000.00	\$10,400.00		\$0.00	\$10,400.00
Controls	1	LS	\$12,000.00	\$15,600.00		\$0.00	\$15,600.00
O&M manual	1	LS	\$7,500.00	\$9,750.00		\$0.00	\$9,750.00
Tie in at WBN DES	1	LS	\$2,500.00	\$3,250.00		\$0.00	\$3,250.00
Bypass sewage inside pumphouse	1	LS	\$5,000.00	\$6,500.00		\$0.00	\$6,500.00
		LS		\$0.00		\$0.00	\$0.00
sub-total							\$1,935,758
contingency	20%						\$387,152
Total - construction							\$2,322,910
Engineering	10%						\$232,291
TOTAL*							\$2,555,201

*This opinion of probable cost is conditional to the following: No taxes included, built in 2010, competitive tender with minimum 3 valid bids.

Project: **Whistle Bend Neighbourhood Geoexchange**
 FSC No: 2008-4300
 Date Prepared: June 3, 2009
 Prepared By: S.Birrell
 Mhr: rate: \$85.00 /hr avg labour rate
 Construction factor: 1.3 construction, inflation factor

Scenario 6
RABTHERM IN-PIPE HEX

Description	No.	unit	Material		Labour		TOTAL
			cost	factored \$	mhrs	mhr cost	

Lift Station Expansion for Pump

							\$73,225.00
Mobilization/Demobilization	0	LS	\$60,000.00	\$0.00			\$0.00
Building construction	100		\$450.00	\$58,500.00			\$58,500.00
overhead monorail	1	LS	\$10,000.00	\$13,000.00		\$0.00	\$13,000.00
Heating (elec heat) @ 30 btuh/ft2 = 1 kW - UH	1	ea	\$1,000.00	\$1,300.00	5	\$425.00	\$1,725.00
fencing	0	LS	\$20,000.00	\$0.00	0	\$0.00	\$0.00
property (City sells to utility)	0	LS	\$150,000.00	\$0.00	0	\$0.00	\$0.00
power to building	0	LS	\$60,000.00	\$0.00	0.25	\$0.00	\$0.00

Pump in Lift Stn

							\$239,954.85
HEX injection pump (lead/lag)	2	ea	\$14,600.00	\$37,960.00	80	\$13,600.00	\$51,560.00
Expansion Tank	1	ea	\$700.00	\$910.00	8	\$680.00	\$1,590.00
Temperature Indicators	6	ea	\$75.00	\$585.00	1	\$510.00	\$1,095.00
Pressure Indicators	6	ea	\$75.00	\$585.00	1	\$510.00	\$1,095.00
Control valve & bypass piping	1	LS	\$5,000.00	\$6,500.00		\$0.00	\$6,500.00
Trenching/Backfill for cold side GWS/R to pump	820	ft	\$39.80	\$42,422.85	0	\$0.00	\$42,422.85
Insulated buried piping for cold side	1640	ft	\$41.00	\$87,412.00	0	\$0.00	\$87,412.00
Cold side added piping within bldg	1	LS	\$8,000.00	\$10,400.00	100	\$8,500.00	\$18,900.00
Cold side piping Insulation within bldg	1	LS	\$4,000.00	\$5,200.00		\$0.00	\$5,200.00
Controls	1	LS	\$3,600.00	\$4,680.00		\$0.00	\$4,680.00
O&M	1	LS	\$7,500.00	\$9,750.00		\$0.00	\$9,750.00
Tie in at WBN DES	1	LS	\$2,500.00	\$3,250.00		\$0.00	\$3,250.00
Bypass HEX inside pumphouse	1	LS	\$5,000.00	\$6,500.00		\$0.00	\$6,500.00

In-sewer pipe HEX

							\$581,483.78
Trenching/Backfill for cold side piping to hex	50	ft	\$39.80	\$2,586.76	0	\$0.00	\$2,586.76
Insulated buried piping for cold side piping	100	ft	\$41.00	\$5,330.00	0	\$0.00	\$5,330.00
Waste Heat Exchanger - 30m	1	ea	\$424,000.00	\$551,200.00	320	\$27,200.00	\$578,400.00

Added and Offset costs

Sewage piping reduction due to HEX	-30	m	\$123.92	-\$4,832.98		\$0.00	-\$4,832.98
Increased sewage pumping costs	0	HP	\$0.00	\$0.00		\$0.00	\$0.00

sub-total **\$894,664**

contingency 20% \$178,933

Total - construction **\$1,073,596**

Engineering 10% \$107,360

TOTAL **\$1,180,956**

*This opinion of probable cost is conditional to the following: No taxes included, built in 2010, competitive tender with minimum 3 valid bids.

Project: **Whistle Bend Neighbourhood Geoexchange**
 FSC No: 2008-4300
 Date Prepared: June 3, 2009
 Prepared By: S.Birrell
 Mhr: rate: \$85.00 /hr avg labour rate
 Construction factor: 1.3 construction, inflation factor

Scenario 6

Feasibility Estimate
DDI IN-BLDG HEX

Description	No.	unit	Material		Labour		TOTAL
			cost	factored \$	mhrs	mhr cost	

Lift Station Expansion for Waste HEX

Mobilization/Demobilization	0 LS			\$0.00			\$0.00
Building construction	416.5		\$450.00	\$243,652.50			\$243,652.50
overhead monorail	1 LS		\$10,000.00	\$13,000.00		\$0.00	\$13,000.00
Heating (elec heat) @ 30 btuh/ft2 = 4 kW - UH	3 ea		\$1,000.00	\$3,900.00	5	\$1,275.00	\$5,175.00
fencing	0 LS		\$20,000.00	\$0.00	0	\$0.00	\$0.00
property (City sells to utility)	0 LS		\$150,000.00	\$0.00	0	\$0.00	\$0.00
power to building	0 LS		\$60,000.00	\$0.00		\$0.00	\$0.00

\$261,827.50

Pump & HEX in Lift Stn

Waste Heat Exchanger	1 ea		\$234,300.00	\$304,590.00	200	\$17,000.00	\$321,590.00
HEX injection pump (lead/lag)	2 ea		\$14,600.00	\$37,960.00	80	\$13,600.00	\$51,560.00
Expansion Tank	1 ea		\$700.00	\$910.00	8	\$680.00	\$1,590.00
Temperature Indicators	6 ea		\$75.00	\$585.00	1	\$510.00	\$1,095.00
Pressure Indicators	6 ea		\$75.00	\$585.00	1	\$510.00	\$1,095.00
Control valve & bypass piping	1 LS		\$5,000.00	\$6,500.00		\$0.00	\$6,500.00
Trenching/Backfill for cold side GWS/R to pump	820 ft		\$39.80	\$42,422.85	0	\$0.00	\$42,422.85
Insulated buried piping for cold side	1640 ft		\$41.00	\$87,412.00	0	\$0.00	\$87,412.00
Cold & hot side added piping within bldg	2 LS		\$8,000.00	\$20,800.00	100	\$17,000.00	\$37,800.00
Cold & hot side piping Insulation within bldg	2 LS		\$4,000.00	\$10,400.00		\$0.00	\$10,400.00
Controls	1 LS		\$4,800.00	\$6,240.00		\$0.00	\$6,240.00
O&M	1 LS		\$7,500.00	\$9,750.00		\$0.00	\$9,750.00
Tie in at WBN DES	1 LS		\$2,500.00	\$3,250.00		\$0.00	\$3,250.00
Bypass sewage inside pumphouse	1 LS		\$5,000.00	\$6,500.00		\$0.00	\$6,500.00

\$726,142.35

Added and Offset costs

Increased sewage pumping costs	15 HP		\$7,125.00	\$138,937.50		\$0.00	\$138,937.50
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sub-total **\$987,970**

contingency 20% \$197,594

Total - construction **\$1,185,564**

Engineering 10% \$118,556

TOTAL **\$1,304,120**

*This opinion of probable cost is conditional to the following: No taxes included, built in 2010, competitive tender with minimum 3 valid bids.

Project: **Whistle Bend Neighbourhood Geoexchange**
 FSC No: 2008-4300
 Date Prepared: June 3, 2009
 Prepared By: S.Birrell
 Mhr: rate: \$85.00 /hr avg labour rate
 Construction factor: 1.3 construction, inflation factor

Scenario 5

Feasibility Estimate
DDI IN-BLDG HEX

Description	No.	unit	Material		Labour		TOTAL
			cost	factored \$	mhrs	mhr cost	

Lift Station Expansion for Waste HEX

Mobilization/Demobilization	0 LS			\$0.00			\$0.00
Building construction	416.5		\$450.00	\$243,652.50			\$243,652.50
overhead monorail	1 LS		\$10,000.00	\$13,000.00		\$0.00	\$13,000.00
Heating (elec heat) @ 30 btuh/ft2 = 4 kW - UH	3 ea		\$1,000.00	\$3,900.00	5	\$1,275.00	\$5,175.00
fencing	0 LS		\$20,000.00	\$0.00	0	\$0.00	\$0.00
property (City sells to utility)	0 LS		\$150,000.00	\$0.00	0	\$0.00	\$0.00
power to building	0 LS		\$60,000.00	\$0.00		\$0.00	\$0.00

\$261,827.50

Pump & HEX in Lift Stn

Waste Heat Exchanger	1 ea		\$201,300.00	\$261,690.00	200	\$17,000.00	\$278,690.00
HEX injection pump (lead/lag)	2 ea		\$14,600.00	\$37,960.00	80	\$13,600.00	\$51,560.00
Expansion Tank	1 ea		\$700.00	\$910.00	8	\$680.00	\$1,590.00
Temperature Indicators	6 ea		\$75.00	\$585.00	1	\$510.00	\$1,095.00
Pressure Indicators	6 ea		\$75.00	\$585.00	1	\$510.00	\$1,095.00
Control valve & bypass piping	1 LS		\$5,000.00	\$6,500.00		\$0.00	\$6,500.00
Trenching/Backfill for cold side GWS/R to pump	820 ft		\$39.80	\$42,422.85	0	\$0.00	\$42,422.85
Insulated buried piping for cold side	1640 ft		\$41.00	\$87,412.00	0	\$0.00	\$87,412.00
Cold & hot side added piping within bldg	2 LS		\$8,000.00	\$20,800.00	100	\$17,000.00	\$37,800.00
Cold & hot side piping Insulation within bldg	2 LS		\$4,000.00	\$10,400.00		\$0.00	\$10,400.00
Controls	1 LS		\$4,800.00	\$6,240.00		\$0.00	\$6,240.00
O&M	1 LS		\$7,500.00	\$9,750.00		\$0.00	\$9,750.00
Tie in at WBN DES	1 LS		\$2,500.00	\$3,250.00		\$0.00	\$3,250.00
Bypass sewage inside pumphouse	1 LS		\$5,000.00	\$6,500.00		\$0.00	\$6,500.00

\$683,242.35

Added and Offset costs

Increased sewage pumping costs	15 HP		\$7,125.00	\$138,937.50		\$0.00	\$138,937.50
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sub-total **\$945,070**

contingency 20% \$189,014

Total - construction **\$1,134,084**

Engineering 10% \$113,408

TOTAL **\$1,247,492**

*This opinion of probable cost is conditional to the following: No taxes included, built in 2010, competitive tender with minimum 3 valid bids.

Project: **Whistle Bend Neighbourhood Geoexchange**
 FSC No: 2008-4300
 Date Prepared: June 3, 2009
 Prepared By: S.Birrell
 Mhr: rate: \$85.00 /hr avg labour rate
 Construction factor: 1.3 construction, inflation factor

Scenario 3

Feasibility Estimate
DDI IN-BLDG HEX

Description	No.	unit	Material		Labour		TOTAL
			cost	factored \$	mhrs	mhr cost	

Lift Station Expansion for Waste HEX

Mobilization/Demobilization	0 LS			\$0.00			\$0.00
Building construction	237.6		\$450.00	\$138,996.00			\$138,996.00
overhead monorail	1 LS		\$10,000.00	\$13,000.00		\$0.00	\$13,000.00
Heating (elec heat) @ 30 btuh/ft2 = 4 kW - UH	3 ea		\$1,000.00	\$3,900.00	5	\$1,275.00	\$5,175.00
fencing	0 LS		\$20,000.00	\$0.00	0	\$0.00	\$0.00
property (City sells to utility)	0 LS		\$150,000.00	\$0.00	0	\$0.00	\$0.00
power to building	0 LS		\$60,000.00	\$0.00		\$0.00	\$0.00

\$157,171.00

Pump & HEX in Lift Stn

Waste Heat Exchanger	1 ea		\$113,960.00	\$148,148.00	200	\$17,000.00	\$165,148.00
HEX injection pump (lead/lag)	2 ea		\$8,000.00	\$20,800.00	60	\$10,200.00	\$31,000.00
Expansion Tank	1 ea		\$700.00	\$910.00	8	\$680.00	\$1,590.00
Temperature Indicators	6 ea		\$75.00	\$585.00	1	\$510.00	\$1,095.00
Pressure Indicators	6 ea		\$75.00	\$585.00	1	\$510.00	\$1,095.00
Control valve & bypass piping	1 LS		\$5,000.00	\$6,500.00		\$0.00	\$6,500.00
Trenching/Backfill for cold side GWS/R to pump	820 ft		\$39.80	\$42,422.85	0	\$0.00	\$42,422.85
Insulated buried piping for cold side	1640 ft		\$41.00	\$87,412.00	0	\$0.00	\$87,412.00
Cold & hot side added piping within bldg	2 LS		\$8,000.00	\$20,800.00	100	\$17,000.00	\$37,800.00
Cold & hot side piping Insulation within bldg	2 LS		\$4,000.00	\$10,400.00		\$0.00	\$10,400.00
Controls	1 LS		\$4,800.00	\$6,240.00		\$0.00	\$6,240.00
O&M	1 LS		\$7,500.00	\$9,750.00		\$0.00	\$9,750.00
Tie in at WBN DES	1 LS		\$2,500.00	\$3,250.00		\$0.00	\$3,250.00
Bypass sewage inside pumphouse	1 LS		\$5,000.00	\$6,500.00		\$0.00	\$6,500.00

\$429,702.85

Added and Offset costs

Increased sewage pumping costs	5 HP		\$3,000.00	\$19,500.00		\$0.00	\$19,500.00
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sub-total **\$586,874**

contingency 20% \$117,375

Total - construction **\$704,249**

Engineering 10% \$70,425

TOTAL **\$774,673**

*This opinion of probable cost is conditional to the following: No taxes included, built in 2010, competitive tender with minimum 3 valid bids.

Project: **Whistle Bend Neighbourhood Geoexchange**
 FSC No: 2008-4300
 Date Prepared: June 3, 2009
 Prepared By: S.Birrell
 Mhr: rate: \$85.00 /hr avg labour rate
 Construction factor: 1.3 construction, inflation factor

Scenarios 1 , 2 & 4

Feasibility Estimate

DDI IN-BLDG HEX

Description	No.	unit	Material		Labour		TOTAL
			cost	factored \$	mhrs	mhr cost	

Lift Station Expansion for Waste HEX

Mobilization/Demobilization	0 LS			\$0.00			\$0.00
Building construction	237.6		\$450.00	\$138,996.00			\$138,996.00
overhead monorail	1 LS		\$10,000.00	\$13,000.00		\$0.00	\$13,000.00
Heating (elec heat) @ 30 btuh/ft2 = 4 kW - UH	3 ea		\$1,000.00	\$3,900.00	5	\$1,275.00	\$5,175.00
fencing	0 LS		\$20,000.00	\$0.00	0	\$0.00	\$0.00
property (City sells to utility)	0 LS		\$150,000.00	\$0.00	0	\$0.00	\$0.00
power to building	0 LS		\$60,000.00	\$0.00		\$0.00	\$0.00

\$157,171.00

Pump & HEX in Lift Stn

Waste Heat Exchanger	1 ea		\$95,700.00	\$124,410.00	200	\$17,000.00	\$141,410.00
HEX injection pump (lead/lag)	2 ea		\$6,000.00	\$15,600.00	60	\$10,200.00	\$25,800.00
Expansion Tank	1 ea		\$700.00	\$910.00	8	\$680.00	\$1,590.00
Temperature Indicators	6 ea		\$75.00	\$585.00	1	\$510.00	\$1,095.00
Pressure Indicators	6 ea		\$75.00	\$585.00	1	\$510.00	\$1,095.00
Control valve & bypass piping	1 LS		\$5,000.00	\$6,500.00		\$0.00	\$6,500.00
Trenching/Backfill for cold side GWS/R to pump	820 ft		\$39.80	\$42,422.85	0	\$0.00	\$42,422.85
Insulated buried piping for cold side	1640 ft		\$41.00	\$87,412.00	0	\$0.00	\$87,412.00
Cold & hot side added piping within bldg	2 LS		\$8,000.00	\$20,800.00	100	\$17,000.00	\$37,800.00
Cold & hot side piping Insulation within bldg	2 LS		\$4,000.00	\$10,400.00		\$0.00	\$10,400.00
Controls	1 LS		\$4,800.00	\$6,240.00		\$0.00	\$6,240.00
O&M	1 LS		\$7,500.00	\$9,750.00		\$0.00	\$9,750.00
Tie in at WBN DES	1 LS		\$2,500.00	\$3,250.00		\$0.00	\$3,250.00
Bypass sewage inside pumphouse	1 LS		\$5,000.00	\$6,500.00		\$0.00	\$6,500.00

\$400,764.85

Added and Offset costs

Increased sewage pumping costs	5 HP		\$3,000.00	\$19,500.00		\$0.00	\$19,500.00
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sub-total **\$557,936**

contingency 20% \$111,587

Total - construction **\$669,523**

Engineering 10% \$66,952

TOTAL **\$736,475**

*This opinion of probable cost is conditional to the following: No taxes included, built in 2010, competitive tender with minimum 3 valid bids.

Project: **Whistle Bend Neighbourhood Geoexchange**
FSC No: 2008-4300
Date Prepared: June 3, 2009
Prepared By: S.Birrell

Feasibility Estimate

SUMMARY

Scenario	Total Cost	Life - yrs.	Maintenance (over life)
1	\$ 736,475	15	\$ 12,000
2	\$ 736,475	15	\$ 12,000
3	\$ 774,673	15	\$ 12,000
4	\$ 736,475	15	\$ 12,000
5	\$ 1,247,492	15	\$ 12,000
6	\$ 1,304,120	15	\$ 12,000
6 Rab	\$ 1,180,956	50	unknown
PC	\$ 2,555,201	15	\$ 12,000

Note: Scenario 6 with the Rabtherm heat exchanger is not suitable for scenarios 1 - 4 with lower sewage flow rates, nor for the PC heat recovery as it would require sewage pipeline retrofit.

*This opinion of probable cost is conditional to the following:

No taxes included, built in 2010, competitive tender with minimum 3 valid bids.

APPENDIX C

APPENDIX C PROJECTED ANNUAL CASH FLOWS FOR EACH EVALUATION SCENARIO

TABLE 6.3: PROJECTED ANNUAL CASH FLOWS FOR NEAR OPTIMUM HYBRID COMBINATION OF EACH EVALUATION SCENARIO
SCENARIO 1 (NO SEWER HEAT RECOVERY) PROJECTED ANNUAL CASH FLOWS (IN MILLION DOLLARS).

	Projected District Energy Revenue					Projected District System Costs					
Year	Customer Avoided Fuel Oil Cost	Customer Heat Pump Electricity Cost	Commercial Customer Heat Pump Electric Demand Charges	Gross District Energy Sales Income	Fuel Oil Consumption for Peaking Boiler	District Circulating Pump Electricity	Boiler Maintenance	District Infrastructure Maintenance & Management	Sewer Heat Recovery Heat Exchanger Maintenance	Total District System Expenses	Projected Annual Cash Flow
2012	\$0.10	\$0.02	\$0.000	\$0.07	\$0.00	\$0.002	\$0.001	\$0.065	\$0.000	\$0.07	-\$0.003
2013	\$0.21	\$0.05	\$0.001	\$0.14	\$0.00	\$0.005	\$0.001	\$0.067	\$0.000	\$0.08	\$0.07
2014	\$0.33	\$0.07	\$0.001	\$0.22	\$0.01	\$0.007	\$0.002	\$0.068	\$0.000	\$0.09	\$0.13
2015	\$0.46	\$0.10	\$0.002	\$0.31	\$0.03	\$0.010	\$0.003	\$0.069	\$0.000	\$0.11	\$0.20
2016	\$0.60	\$0.13	\$0.002	\$0.40	\$0.05	\$0.014	\$0.004	\$0.071	\$0.000	\$0.14	\$0.26
2017	\$0.62	\$0.17	\$0.003	\$0.39	\$0.09	\$0.017	\$0.004	\$0.072	\$0.000	\$0.18	\$0.21
2018	\$0.65	\$0.17	\$0.003	\$0.41	\$0.09	\$0.017	\$0.004	\$0.074	\$0.000	\$0.19	\$0.22
2019	\$0.67	\$0.17	\$0.003	\$0.43	\$0.10	\$0.017	\$0.004	\$0.075	\$0.000	\$0.19	\$0.24
2020	\$0.70	\$0.17	\$0.003	\$0.45	\$0.10	\$0.018	\$0.004	\$0.077	\$0.000	\$0.20	\$0.25
2021	\$0.73	\$0.18	\$0.003	\$0.47	\$0.10	\$0.018	\$0.004	\$0.078	\$0.000	\$0.20	\$0.27
2022	\$0.76	\$0.18	\$0.003	\$0.50	\$0.11	\$0.018	\$0.004	\$0.080	\$0.000	\$0.21	\$0.29
2023	\$0.79	\$0.18	\$0.003	\$0.52	\$0.11	\$0.019	\$0.004	\$0.081	\$0.000	\$0.22	\$0.30
2024	\$0.82	\$0.19	\$0.003	\$0.54	\$0.11	\$0.019	\$0.004	\$0.083	\$0.000	\$0.22	\$0.32
2025	\$0.85	\$0.19	\$0.003	\$0.57	\$0.12	\$0.020	\$0.005	\$0.085	\$0.000	\$0.23	\$0.34
2026	\$0.88	\$0.20	\$0.004	\$0.60	\$0.12	\$0.020	\$0.005	\$0.086	\$0.000	\$0.23	\$0.37
2027	\$0.92	\$0.20	\$0.004	\$0.62	\$0.12	\$0.020	\$0.005	\$0.088	\$0.000	\$0.24	\$0.39
2028	\$0.96	\$0.20	\$0.004	\$0.65	\$0.13	\$0.021	\$0.005	\$0.090	\$0.000	\$0.24	\$0.41
2029	\$0.99	\$0.21	\$0.004	\$0.68	\$0.13	\$0.021	\$0.005	\$0.092	\$0.000	\$0.25	\$0.43
2030	\$1.03	\$0.21	\$0.004	\$0.71	\$0.14	\$0.022	\$0.005	\$0.093	\$0.000	\$0.26	\$0.45
2031	\$1.08	\$0.22	\$0.004	\$0.75	\$0.15	\$0.022	\$0.005	\$0.095	\$0.000	\$0.27	\$0.48
2032	\$1.12	\$0.22	\$0.004	\$0.78	\$0.15	\$0.023	\$0.005	\$0.097	\$0.000	\$0.28	\$0.51
2033	\$1.16	\$0.23	\$0.004	\$0.82	\$0.16	\$0.023	\$0.005	\$0.099	\$0.000	\$0.28	\$0.53
2034	\$1.21	\$0.23	\$0.004	\$0.85	\$0.16	\$0.024	\$0.005	\$0.101	\$0.000	\$0.29	\$0.56
2035	\$1.26	\$0.24	\$0.004	\$0.89	\$0.16	\$0.024	\$0.006	\$0.103	\$0.000	\$0.30	\$0.59
2036	\$1.31	\$0.24	\$0.004	\$0.93	\$0.17	\$0.025	\$0.006	\$0.105	\$0.000	\$0.31	\$0.62
2037	\$1.36	\$0.25	\$0.004	\$0.97	\$0.18	\$0.025	\$0.006	\$0.107	\$0.000	\$0.32	\$0.66
2038	\$1.42	\$0.25	\$0.004	\$1.02	\$0.19	\$0.026	\$0.006	\$0.109	\$0.000	\$0.33	\$0.69
2039	\$1.47	\$0.26	\$0.005	\$1.06	\$0.20	\$0.026	\$0.006	\$0.112	\$0.000	\$0.34	\$0.73
2040	\$1.53	\$0.26	\$0.005	\$1.11	\$0.20	\$0.027	\$0.006	\$0.114	\$0.000	\$0.35	\$0.76
2041	\$1.59	\$0.26	\$0.005	\$1.16	\$0.21	\$0.027	\$0.006	\$0.116	\$0.000	\$0.36	\$0.80
2042	\$1.66	\$0.27	\$0.005	\$1.22	\$0.22	\$0.027	\$0.006	\$0.118	\$0.000	\$0.37	\$0.84
2043	\$1.72	\$0.27	\$0.005	\$1.27	\$0.23	\$0.028	\$0.007	\$0.121	\$0.000	\$0.38	\$0.89

	Projected District Energy Revenue					Projected District System Costs					
Year	Customer Avoided Fuel Oil Cost	Customer Heat Pump Electricity Cost	Commercial Customer Heat Pump Electric Demand Charges	Gross District Energy Sales Income	Fuel Oil Consumption for Peaking Boiler	District Circulating Pump Electricity	Boiler Maintenance	District Infrastructure Maintenance & Management	Sewer Heat Recovery Heat Exchanger Maintenance	Total District System Expenses	Projected Annual Cash Flow
2044	\$1.79	\$0.28	\$0.005	\$1.33	\$0.23	\$0.028	\$0.007	\$0.123	\$0.000	\$0.39	\$0.93
2045	\$1.86	\$0.29	\$0.005	\$1.39	\$0.25	\$0.029	\$0.007	\$0.126	\$0.000	\$0.41	\$0.98
2046	\$1.94	\$0.29	\$0.005	\$1.45	\$0.26	\$0.030	\$0.007	\$0.128	\$0.000	\$0.42	\$1.02
2047	\$2.01	\$0.30	\$0.005	\$1.51	\$0.26	\$0.030	\$0.007	\$0.131	\$0.000	\$0.43	\$1.08
2048	\$2.09	\$0.30	\$0.005	\$1.58	\$0.28	\$0.031	\$0.007	\$0.133	\$0.000	\$0.45	\$1.13
2049	\$2.18	\$0.31	\$0.006	\$1.65	\$0.29	\$0.031	\$0.007	\$0.136	\$0.000	\$0.46	\$1.18
2050	\$2.27	\$0.32	\$0.006	\$1.72	\$0.30	\$0.032	\$0.008	\$0.139	\$0.000	\$0.48	\$1.24
2051	\$2.36	\$0.32	\$0.006	\$1.79	\$0.31	\$0.033	\$0.008	\$0.141	\$0.000	\$0.49	\$1.30
2052	\$2.45	\$0.33	\$0.006	\$1.87	\$0.32	\$0.033	\$0.008	\$0.144	\$0.000	\$0.51	\$1.36
2053	\$2.55	\$0.33	\$0.006	\$1.95	\$0.34	\$0.034	\$0.008	\$0.147	\$0.000	\$0.53	\$1.43
2054	\$2.65	\$0.34	\$0.006	\$2.04	\$0.35	\$0.035	\$0.008	\$0.150	\$0.000	\$0.54	\$1.50
2055	\$2.76	\$0.35	\$0.006	\$2.13	\$0.37	\$0.035	\$0.008	\$0.153	\$0.000	\$0.56	\$1.56
2056	\$2.87	\$0.36	\$0.006	\$2.22	\$0.38	\$0.036	\$0.008	\$0.156	\$0.000	\$0.58	\$1.64
2057	\$2.98	\$0.36	\$0.007	\$2.32	\$0.39	\$0.037	\$0.009	\$0.159	\$0.000	\$0.59	\$1.72
2058	\$3.10	\$0.37	\$0.007	\$2.41	\$0.40	\$0.038	\$0.009	\$0.163	\$0.000	\$0.61	\$1.81
2059	\$3.22	\$0.38	\$0.007	\$2.52	\$0.41	\$0.039	\$0.009	\$0.166	\$0.000	\$0.63	\$1.89
2060	\$3.35	\$0.39	\$0.007	\$2.62	\$0.43	\$0.039	\$0.009	\$0.169	\$0.000	\$0.65	\$1.98
2061	\$3.49	\$0.39	\$0.007	\$2.74	\$0.45	\$0.040	\$0.009	\$0.172	\$0.000	\$0.67	\$2.07



SCENARIO 1 (WITH SEWER HEAT RECOVERY) PROJECTED ANNUAL CASH FLOWS (IN MILLION DOLLARS).

	Projected District Energy Revenue					Projected District System Costs					
Year	Customer Avoided Fuel Oil Cost	Customer Heat Pump Electricity Cost	Commercial Customer Heat Pump Electric Demand Charges	Gross District Energy Sales Income	Fuel Oil Consumption for Peaking Boiler	District Circulating Pump Electricity	Boiler Maintenance	District Infrastructure Maintenance & Management	Sewer Heat Recovery Heat Exchanger Maintenance	Total District System Expenses	Projected Annual Cash Flow
2012	\$0.10	\$0.02	\$0.000	\$0.07	\$0.00	\$0.003	\$0.001	\$0.065	\$0.000	\$0.07	-\$0.005
2013	\$0.21	\$0.05	\$0.001	\$0.14	\$0.01	\$0.005	\$0.002	\$0.067	\$0.000	\$0.08	\$0.06
2014	\$0.33	\$0.07	\$0.001	\$0.22	\$0.01	\$0.008	\$0.002	\$0.068	\$0.000	\$0.09	\$0.13
2015	\$0.46	\$0.10	\$0.002	\$0.31	\$0.03	\$0.010	\$0.003	\$0.069	\$0.001	\$0.11	\$0.20
2016	\$0.60	\$0.13	\$0.002	\$0.41	\$0.04	\$0.013	\$0.004	\$0.071	\$0.001	\$0.13	\$0.28
2017	\$0.62	\$0.16	\$0.003	\$0.40	\$0.06	\$0.016	\$0.004	\$0.072	\$0.001	\$0.16	\$0.24
2018	\$0.65	\$0.16	\$0.003	\$0.42	\$0.06	\$0.016	\$0.004	\$0.074	\$0.001	\$0.15	\$0.26
2019	\$0.67	\$0.16	\$0.003	\$0.44	\$0.06	\$0.017	\$0.004	\$0.075	\$0.001	\$0.15	\$0.28
2020	\$0.70	\$0.17	\$0.003	\$0.46	\$0.06	\$0.017	\$0.004	\$0.077	\$0.001	\$0.15	\$0.30
2021	\$0.73	\$0.17	\$0.003	\$0.48	\$0.06	\$0.017	\$0.004	\$0.078	\$0.001	\$0.16	\$0.33
2022	\$0.76	\$0.17	\$0.004	\$0.50	\$0.06	\$0.018	\$0.005	\$0.080	\$0.001	\$0.16	\$0.34
2023	\$0.79	\$0.18	\$0.003	\$0.53	\$0.06	\$0.018	\$0.005	\$0.081	\$0.001	\$0.16	\$0.36
2024	\$0.82	\$0.18	\$0.004	\$0.55	\$0.06	\$0.018	\$0.005	\$0.083	\$0.001	\$0.17	\$0.38
2025	\$0.85	\$0.18	\$0.003	\$0.58	\$0.06	\$0.019	\$0.005	\$0.085	\$0.001	\$0.17	\$0.41
2026	\$0.88	\$0.19	\$0.004	\$0.61	\$0.07	\$0.019	\$0.005	\$0.086	\$0.001	\$0.18	\$0.43
2027	\$0.92	\$0.19	\$0.004	\$0.63	\$0.07	\$0.019	\$0.005	\$0.088	\$0.257	\$0.44	\$0.20
2028	\$0.96	\$0.19	\$0.004	\$0.66	\$0.07	\$0.020	\$0.005	\$0.090	\$0.001	\$0.19	\$0.48
2029	\$0.99	\$0.20	\$0.004	\$0.69	\$0.07	\$0.020	\$0.005	\$0.092	\$0.001	\$0.19	\$0.50
2030	\$1.03	\$0.20	\$0.004	\$0.73	\$0.08	\$0.020	\$0.005	\$0.093	\$0.001	\$0.20	\$0.53
2031	\$1.08	\$0.20	\$0.004	\$0.76	\$0.08	\$0.021	\$0.005	\$0.095	\$0.001	\$0.20	\$0.56
2032	\$1.12	\$0.21	\$0.004	\$0.79	\$0.08	\$0.021	\$0.005	\$0.097	\$0.001	\$0.21	\$0.59
2033	\$1.16	\$0.21	\$0.004	\$0.83	\$0.08	\$0.022	\$0.006	\$0.099	\$0.001	\$0.21	\$0.62
2034	\$1.21	\$0.22	\$0.004	\$0.87	\$0.08	\$0.022	\$0.006	\$0.101	\$0.001	\$0.21	\$0.65
2035	\$1.26	\$0.22	\$0.004	\$0.91	\$0.09	\$0.023	\$0.006	\$0.103	\$0.001	\$0.22	\$0.69
2036	\$1.31	\$0.23	\$0.004	\$0.95	\$0.09	\$0.023	\$0.006	\$0.105	\$0.001	\$0.22	\$0.72
2037	\$1.36	\$0.23	\$0.004	\$0.99	\$0.09	\$0.023	\$0.006	\$0.107	\$0.001	\$0.23	\$0.76
2038	\$1.42	\$0.23	\$0.004	\$1.04	\$0.09	\$0.024	\$0.006	\$0.109	\$0.001	\$0.23	\$0.80
2039	\$1.47	\$0.24	\$0.005	\$1.08	\$0.10	\$0.024	\$0.006	\$0.112	\$0.001	\$0.24	\$0.84
2040	\$1.53	\$0.24	\$0.005	\$1.13	\$0.10	\$0.025	\$0.006	\$0.114	\$0.001	\$0.25	\$0.88
2041	\$1.59	\$0.25	\$0.006	\$1.18	\$0.11	\$0.025	\$0.007	\$0.116	\$0.001	\$0.26	\$0.92
2042	\$1.66	\$0.25	\$0.006	\$1.23	\$0.11	\$0.026	\$0.007	\$0.118	\$0.346	\$0.61	\$0.62

	Projected District Energy Revenue					Projected District System Costs					
Year	Customer Avoided Fuel Oil Cost	Customer Heat Pump Electricity Cost	Commercial Customer Heat Pump Electric Demand Charges	Gross District Energy Sales Income	Fuel Oil Consumption for Peaking Boiler	District Circulating Pump Electricity	Boiler Maintenance	District Infrastructure Maintenance & Management	Sewer Heat Recovery Heat Exchanger Maintenance	Total District System Expenses	Projected Annual Cash Flow
2043	\$1.72	\$0.26	\$0.005	\$1.29	\$0.11	\$0.026	\$0.007	\$0.121	\$0.001	\$0.27	\$1.02
2044	\$1.79	\$0.26	\$0.006	\$1.34	\$0.12	\$0.027	\$0.007	\$0.123	\$0.002	\$0.27	\$1.07
2045	\$1.86	\$0.27	\$0.005	\$1.40	\$0.12	\$0.027	\$0.007	\$0.126	\$0.002	\$0.29	\$1.12
2046	\$1.94	\$0.27	\$0.007	\$1.46	\$0.13	\$0.028	\$0.007	\$0.128	\$0.002	\$0.29	\$1.17
2047	\$2.01	\$0.28	\$0.008	\$1.52	\$0.13	\$0.029	\$0.007	\$0.131	\$0.002	\$0.30	\$1.22
2048	\$2.09	\$0.29	\$0.005	\$1.59	\$0.14	\$0.029	\$0.008	\$0.133	\$0.002	\$0.31	\$1.28
2049	\$2.18	\$0.29	\$0.006	\$1.66	\$0.15	\$0.030	\$0.008	\$0.136	\$0.002	\$0.32	\$1.34
2050	\$2.27	\$0.30	\$0.006	\$1.74	\$0.16	\$0.030	\$0.008	\$0.139	\$0.002	\$0.33	\$1.40
2051	\$2.36	\$0.30	\$0.006	\$1.81	\$0.16	\$0.031	\$0.008	\$0.141	\$0.002	\$0.34	\$1.47
2052	\$2.45	\$0.31	\$0.006	\$1.89	\$0.17	\$0.031	\$0.008	\$0.144	\$0.002	\$0.35	\$1.54
2053	\$2.55	\$0.31	\$0.006	\$1.97	\$0.17	\$0.032	\$0.008	\$0.147	\$0.002	\$0.36	\$1.61
2054	\$2.65	\$0.32	\$0.008	\$2.06	\$0.18	\$0.033	\$0.008	\$0.150	\$0.002	\$0.37	\$1.68
2055	\$2.76	\$0.33	\$0.006	\$2.15	\$0.19	\$0.033	\$0.009	\$0.153	\$0.002	\$0.38	\$1.76
2056	\$2.87	\$0.33	\$0.006	\$2.24	\$0.19	\$0.034	\$0.009	\$0.156	\$0.002	\$0.39	\$1.85
2057	\$2.98	\$0.34	\$0.007	\$2.34	\$0.20	\$0.035	\$0.009	\$0.159	\$0.002	\$0.40	\$1.94
2058	\$3.10	\$0.35	\$0.010	\$2.43	\$0.20	\$0.036	\$0.009	\$0.163	\$0.002	\$0.41	\$2.02
2059	\$3.22	\$0.35	\$0.008	\$2.54	\$0.21	\$0.036	\$0.009	\$0.166	\$0.002	\$0.42	\$2.12
2060	\$3.35	\$0.36	\$0.007	\$2.65	\$0.21	\$0.037	\$0.010	\$0.169	\$0.002	\$0.43	\$2.22
2061	\$3.49	\$0.37	\$0.009	\$2.76	\$0.22	\$0.038	\$0.010	\$0.172	\$0.002	\$0.44	\$2.32



SCENARIO 2 (NO SEWER HEAT RECOVERY) PROJECTED ANNUAL CASH FLOWS (IN MILLION DOLLARS).

	Projected District Energy Revenue				Projected District System Costs							
Year	Customer Avoided Fuel Oil Cost	Customer Heat Pump Electricity Cost	Commercial Customer Heat Pump Electric Demand Charges	Gross District Energy Sales Income	Fuel Oil Consumption for Peaking Boiler	District Circulating Pump Electricity	Boiler Maintenance	District Infrastructure Maintenance & Management	Sewer Heat Recovery Heat Exchanger Maintenance	Total District System Expenses	Projected Annual Cash Flow	
2013	\$0.15	\$0.03	\$0.000	\$0.10	\$0.00	\$0.003	\$0.001	\$0.13	\$0.000	\$0.14	-\$0.035	
2014	\$0.31	\$0.06	\$0.000	\$0.21	\$0.00	\$0.006	\$0.002	\$0.13	\$0.000	\$0.14	\$0.07	
2015	\$0.48	\$0.10	\$0.000	\$0.33	\$0.01	\$0.010	\$0.002	\$0.13	\$0.000	\$0.16	\$0.17	
2016	\$0.66	\$0.14	\$0.000	\$0.46	\$0.03	\$0.014	\$0.003	\$0.14	\$0.000	\$0.19	\$0.27	
2017	\$0.86	\$0.14	\$0.000	\$0.63	\$0.03	\$0.014	\$0.004	\$0.14	\$0.000	\$0.19	\$0.44	
2018	\$0.90	\$0.19	\$0.000	\$0.62	\$0.07	\$0.019	\$0.004	\$0.14	\$0.000	\$0.24	\$0.38	
2019	\$0.93	\$0.19	\$0.000	\$0.65	\$0.08	\$0.019	\$0.004	\$0.14	\$0.000	\$0.24	\$0.40	
2020	\$0.97	\$0.24	\$0.000	\$0.63	\$0.13	\$0.024	\$0.004	\$0.15	\$0.000	\$0.31	\$0.32	
2021	\$1.01	\$0.24	\$0.000	\$0.66	\$0.14	\$0.024	\$0.004	\$0.15	\$0.000	\$0.32	\$0.34	
2022	\$1.05	\$0.25	\$0.000	\$0.70	\$0.15	\$0.025	\$0.004	\$0.15	\$0.000	\$0.33	\$0.37	
2023	\$1.09	\$0.25	\$0.000	\$0.73	\$0.15	\$0.025	\$0.005	\$0.16	\$0.000	\$0.34	\$0.39	
2024	\$1.13	\$0.26	\$0.000	\$0.76	\$0.16	\$0.026	\$0.005	\$0.16	\$0.000	\$0.35	\$0.41	
2025	\$1.18	\$0.26	\$0.001	\$0.80	\$0.17	\$0.026	\$0.005	\$0.16	\$0.000	\$0.36	\$0.44	
2026	\$1.23	\$0.27	\$0.001	\$0.84	\$0.17	\$0.027	\$0.005	\$0.17	\$0.000	\$0.37	\$0.47	
2027	\$1.28	\$0.27	\$0.001	\$0.88	\$0.18	\$0.027	\$0.005	\$0.17	\$0.000	\$0.38	\$0.50	
2028	\$1.33	\$0.28	\$0.001	\$0.92	\$0.18	\$0.028	\$0.005	\$0.17	\$0.000	\$0.39	\$0.53	
2029	\$1.38	\$0.28	\$0.001	\$0.96	\$0.19	\$0.028	\$0.005	\$0.18	\$0.000	\$0.40	\$0.56	
2030	\$1.43	\$0.29	\$0.001	\$1.00	\$0.19	\$0.029	\$0.005	\$0.18	\$0.000	\$0.41	\$0.60	
2031	\$1.49	\$0.29	\$0.001	\$1.05	\$0.20	\$0.029	\$0.005	\$0.18	\$0.000	\$0.41	\$0.64	
2032	\$1.55	\$0.30	\$0.001	\$1.10	\$0.20	\$0.030	\$0.005	\$0.19	\$0.000	\$0.42	\$0.68	
2033	\$1.61	\$0.30	\$0.001	\$1.15	\$0.21	\$0.030	\$0.006	\$0.19	\$0.000	\$0.43	\$0.72	
2034	\$1.68	\$0.31	\$0.001	\$1.20	\$0.21	\$0.031	\$0.006	\$0.19	\$0.000	\$0.45	\$0.76	
2035	\$1.75	\$0.32	\$0.001	\$1.26	\$0.22	\$0.032	\$0.006	\$0.20	\$0.000	\$0.45	\$0.80	
2036	\$1.82	\$0.33	\$0.001	\$1.31	\$0.24	\$0.033	\$0.006	\$0.20	\$0.000	\$0.48	\$0.83	
2037	\$1.89	\$0.33	\$0.001	\$1.36	\$0.26	\$0.033	\$0.006	\$0.21	\$0.000	\$0.50	\$0.86	
2038	\$1.96	\$0.34	\$0.001	\$1.42	\$0.27	\$0.035	\$0.006	\$0.21	\$0.000	\$0.53	\$0.90	
2039	\$2.04	\$0.35	\$0.001	\$1.48	\$0.29	\$0.035	\$0.006	\$0.22	\$0.000	\$0.55	\$0.94	
2040	\$2.12	\$0.36	\$0.001	\$1.55	\$0.31	\$0.036	\$0.006	\$0.22	\$0.000	\$0.57	\$0.98	
2041	\$2.21	\$0.37	\$0.001	\$1.62	\$0.32	\$0.037	\$0.006	\$0.22	\$0.000	\$0.59	\$1.03	
2042	\$2.30	\$0.37	\$0.001	\$1.69	\$0.33	\$0.038	\$0.007	\$0.23	\$0.000	\$0.61	\$1.09	
2043	\$2.39	\$0.38	\$0.001	\$1.77	\$0.35	\$0.038	\$0.007	\$0.23	\$0.000	\$0.63	\$1.14	
2044	\$2.48	\$0.39	\$0.001	\$1.85	\$0.36	\$0.039	\$0.007	\$0.24	\$0.000	\$0.65	\$1.20	



	Projected District Energy Revenue				Projected District System Costs						
Year	Customer Avoided Fuel Oil Cost	Customer Heat Pump Electricity Cost	Commercial Customer Heat Pump Electric Demand Charges	Gross District Energy Sales Income	Fuel Oil Consumption for Peaking Boiler	District Circulating Pump Electricity	Boiler Maintenance	District Infrastructure Maintenance & Management	Sewer Heat Recovery Heat Exchanger Maintenance	Total District System Expenses	Projected Annual Cash Flow
2045	\$2.58	\$0.39	\$0.001	\$1.93	\$0.37	\$0.040	\$0.007	\$0.24	\$0.000	\$0.66	\$1.27
2046	\$2.69	\$0.40	\$0.001	\$2.02	\$0.38	\$0.040	\$0.007	\$0.25	\$0.000	\$0.68	\$1.34
2047	\$2.79	\$0.41	\$0.001	\$2.11	\$0.40	\$0.041	\$0.007	\$0.25	\$0.000	\$0.70	\$1.41
2048	\$2.91	\$0.42	\$0.001	\$2.20	\$0.40	\$0.042	\$0.007	\$0.26	\$0.000	\$0.71	\$1.49
2049	\$3.02	\$0.42	\$0.001	\$2.30	\$0.42	\$0.042	\$0.008	\$0.26	\$0.000	\$0.73	\$1.57
2050	\$3.14	\$0.43	\$0.001	\$2.40	\$0.43	\$0.043	\$0.008	\$0.27	\$0.000	\$0.75	\$1.65
2051	\$3.27	\$0.44	\$0.001	\$2.51	\$0.44	\$0.044	\$0.008	\$0.27	\$0.000	\$0.76	\$1.74
2052	\$3.40	\$0.45	\$0.001	\$2.61	\$0.46	\$0.045	\$0.008	\$0.28	\$0.000	\$0.79	\$1.82
2053	\$3.54	\$0.45	\$0.001	\$2.73	\$0.48	\$0.045	\$0.008	\$0.28	\$0.000	\$0.81	\$1.91
2054	\$3.68	\$0.46	\$0.001	\$2.85	\$0.49	\$0.046	\$0.008	\$0.29	\$0.000	\$0.84	\$2.01
2055	\$3.82	\$0.47	\$0.001	\$2.97	\$0.50	\$0.047	\$0.009	\$0.30	\$0.000	\$0.85	\$2.12
2056	\$3.98	\$0.48	\$0.001	\$3.10	\$0.52	\$0.048	\$0.009	\$0.30	\$0.000	\$0.88	\$2.22
2057	\$4.14	\$0.49	\$0.001	\$3.24	\$0.54	\$0.049	\$0.009	\$0.31	\$0.000	\$0.90	\$2.34
2058	\$4.30	\$0.50	\$0.001	\$3.37	\$0.55	\$0.050	\$0.009	\$0.31	\$0.000	\$0.92	\$2.45
2059	\$4.47	\$0.51	\$0.001	\$3.51	\$0.58	\$0.051	\$0.009	\$0.32	\$0.000	\$0.96	\$2.55
2060	\$4.65	\$0.52	\$0.001	\$3.66	\$0.61	\$0.052	\$0.009	\$0.33	\$0.000	\$1.00	\$2.67
2061	\$4.84	\$0.54	\$0.001	\$3.82	\$0.67	\$0.054	\$0.010	\$0.33	\$0.000	\$1.07	\$2.75
2062	\$5.03	\$0.56	\$0.001	\$3.97	\$0.72	\$0.056	\$0.010	\$0.34	\$0.000	\$1.13	\$2.84



SCENARIO 2 (WITH SEWER HEAT RECOVERY) PROJECTED ANNUAL CASH FLOWS (IN MILLION DOLLARS).												
	Projected District Energy Revenue							Projected District System Costs				
Year	Customer Avoided Fuel Oil Cost	Customer Heat Pump Electricity Cost	Commercial Customer Heat Pump Electric Demand Charges	Gross District Energy Sales Income	Fuel Oil Consumption for Peaking Boiler	District Circulating Pump Electricity	Boiler Maintenance	District Infrastructure Maintenance & Management	Sewer Heat Recovery Heat Exchanger Maintenance	Total District System Expenses	Projected Annual Cash Flow	
2013	\$0.15	\$0.02	\$0.000	\$0.12	\$0.00	\$0.002	\$0.001	\$0.13	\$0.000	\$0.13	-\$0.014	
2014	\$0.31	\$0.03	\$0.000	\$0.24	\$0.00	\$0.003	\$0.001	\$0.13	\$0.000	\$0.14	\$0.11	
2015	\$0.48	\$0.07	\$0.000	\$0.36	\$0.01	\$0.007	\$0.002	\$0.13	\$0.000	\$0.15	\$0.21	
2016	\$0.66	\$0.11	\$0.000	\$0.49	\$0.02	\$0.011	\$0.003	\$0.14	\$0.001	\$0.18	\$0.31	
2017	\$0.86	\$0.15	\$0.000	\$0.63	\$0.05	\$0.015	\$0.004	\$0.14	\$0.001	\$0.21	\$0.42	
2018	\$0.90	\$0.15	\$0.000	\$0.66	\$0.05	\$0.015	\$0.004	\$0.14	\$0.001	\$0.21	\$0.45	
2019	\$0.93	\$0.19	\$0.000	\$0.65	\$0.08	\$0.019	\$0.004	\$0.14	\$0.001	\$0.25	\$0.40	
2020	\$0.97	\$0.19	\$0.000	\$0.68	\$0.08	\$0.019	\$0.004	\$0.15	\$0.001	\$0.25	\$0.42	
2021	\$1.01	\$0.24	\$0.001	\$0.67	\$0.12	\$0.024	\$0.004	\$0.15	\$0.001	\$0.30	\$0.36	
2022	\$1.05	\$0.25	\$0.000	\$0.70	\$0.12	\$0.025	\$0.004	\$0.15	\$0.001	\$0.30	\$0.39	
2023	\$1.09	\$0.25	\$0.000	\$0.73	\$0.12	\$0.025	\$0.004	\$0.16	\$0.001	\$0.31	\$0.42	
2024	\$1.13	\$0.25	\$0.001	\$0.77	\$0.12	\$0.025	\$0.005	\$0.16	\$0.001	\$0.31	\$0.46	
2025	\$1.18	\$0.26	\$0.001	\$0.80	\$0.12	\$0.026	\$0.005	\$0.16	\$0.001	\$0.32	\$0.49	
2026	\$1.23	\$0.26	\$0.001	\$0.84	\$0.12	\$0.026	\$0.005	\$0.17	\$0.001	\$0.32	\$0.52	
2027	\$1.28	\$0.27	\$0.001	\$0.88	\$0.12	\$0.027	\$0.005	\$0.17	\$0.001	\$0.33	\$0.55	
2028	\$1.33	\$0.27	\$0.001	\$0.92	\$0.13	\$0.027	\$0.005	\$0.17	\$0.257	\$0.59	\$0.33	
2029	\$1.38	\$0.28	\$0.001	\$0.96	\$0.13	\$0.028	\$0.005	\$0.18	\$0.001	\$0.34	\$0.62	
2030	\$1.43	\$0.28	\$0.001	\$1.01	\$0.14	\$0.028	\$0.005	\$0.18	\$0.001	\$0.35	\$0.66	
2031	\$1.49	\$0.29	\$0.001	\$1.06	\$0.14	\$0.029	\$0.005	\$0.18	\$0.001	\$0.36	\$0.70	
2032	\$1.55	\$0.29	\$0.001	\$1.10	\$0.15	\$0.029	\$0.005	\$0.19	\$0.001	\$0.37	\$0.74	
2033	\$1.61	\$0.30	\$0.001	\$1.15	\$0.15	\$0.030	\$0.005	\$0.19	\$0.001	\$0.37	\$0.78	
2034	\$1.68	\$0.30	\$0.001	\$1.21	\$0.15	\$0.030	\$0.006	\$0.19	\$0.001	\$0.38	\$0.82	
2035	\$1.75	\$0.31	\$0.001	\$1.26	\$0.16	\$0.031	\$0.006	\$0.20	\$0.001	\$0.39	\$0.87	
2036	\$1.82	\$0.32	\$0.001	\$1.32	\$0.16	\$0.032	\$0.006	\$0.20	\$0.001	\$0.41	\$0.91	
2037	\$1.89	\$0.32	\$0.001	\$1.37	\$0.17	\$0.033	\$0.006	\$0.21	\$0.001	\$0.42	\$0.95	
2038	\$1.96	\$0.33	\$0.001	\$1.44	\$0.18	\$0.033	\$0.006	\$0.21	\$0.001	\$0.44	\$1.00	
2039	\$2.04	\$0.34	\$0.001	\$1.50	\$0.19	\$0.034	\$0.006	\$0.22	\$0.001	\$0.45	\$1.05	
2040	\$2.12	\$0.34	\$0.001	\$1.57	\$0.20	\$0.035	\$0.006	\$0.22	\$0.001	\$0.47	\$1.10	
2041	\$2.21	\$0.35	\$0.001	\$1.64	\$0.22	\$0.035	\$0.006	\$0.22	\$0.001	\$0.48	\$1.15	
2042	\$2.30	\$0.36	\$0.001	\$1.71	\$0.22	\$0.036	\$0.006	\$0.23	\$0.001	\$0.49	\$1.22	
2043	\$2.39	\$0.37	\$0.001	\$1.78	\$0.23	\$0.037	\$0.007	\$0.23	\$0.346	\$0.85	\$0.93	
2044	\$2.48	\$0.37	\$0.001	\$1.86	\$0.24	\$0.037	\$0.007	\$0.24	\$0.001	\$0.52	\$1.34	
2045	\$2.58	\$0.38	\$0.001	\$1.94	\$0.25	\$0.038	\$0.007	\$0.24	\$0.002	\$0.53	\$1.41	



	Projected District Energy Revenue					Projected District System Costs					
Year	Customer Avoided Fuel Oil Cost	Customer Heat Pump Electricity Cost	Commercial Customer Heat Pump Electric Demand Charges	Gross District Energy Sales Income	Fuel Oil Consumption for Peaking Boiler	District Circulating Pump Electricity	Boiler Maintenance	District Infrastructure Maintenance & Management	Sewer Heat Recovery Heat Exchanger Maintenance	Total District System Expenses	Projected Annual Cash Flow
2046	\$2.69	\$0.39	\$0.001	\$2.03	\$0.25	\$0.039	\$0.007	\$0.25	\$0.002	\$0.55	\$1.48
2047	\$2.79	\$0.40	\$0.001	\$2.12	\$0.26	\$0.040	\$0.007	\$0.25	\$0.002	\$0.56	\$1.55
2048	\$2.91	\$0.40	\$0.001	\$2.21	\$0.27	\$0.040	\$0.007	\$0.26	\$0.002	\$0.58	\$1.64
2049	\$3.02	\$0.41	\$0.001	\$2.31	\$0.28	\$0.041	\$0.007	\$0.26	\$0.002	\$0.59	\$1.71
2050	\$3.14	\$0.42	\$0.001	\$2.41	\$0.30	\$0.042	\$0.008	\$0.27	\$0.002	\$0.61	\$1.79
2051	\$3.27	\$0.43	\$0.001	\$2.51	\$0.31	\$0.043	\$0.008	\$0.27	\$0.002	\$0.63	\$1.88
2052	\$3.40	\$0.43	\$0.001	\$2.62	\$0.32	\$0.044	\$0.008	\$0.28	\$0.002	\$0.65	\$1.97
2053	\$3.54	\$0.44	\$0.001	\$2.74	\$0.33	\$0.044	\$0.008	\$0.28	\$0.002	\$0.67	\$2.07
2054	\$3.68	\$0.45	\$0.001	\$2.86	\$0.34	\$0.045	\$0.008	\$0.29	\$0.002	\$0.69	\$2.17
2055	\$3.82	\$0.46	\$0.001	\$2.98	\$0.35	\$0.046	\$0.008	\$0.30	\$0.002	\$0.70	\$2.28
2056	\$3.98	\$0.47	\$0.001	\$3.11	\$0.36	\$0.047	\$0.009	\$0.30	\$0.002	\$0.72	\$2.39
2057	\$4.14	\$0.48	\$0.001	\$3.24	\$0.37	\$0.048	\$0.009	\$0.31	\$0.002	\$0.73	\$2.51
2058	\$4.30	\$0.49	\$0.001	\$3.38	\$0.38	\$0.049	\$0.009	\$0.31	\$0.002	\$0.76	\$2.63
2059	\$4.47	\$0.50	\$0.001	\$3.53	\$0.40	\$0.050	\$0.009	\$0.32	\$0.002	\$0.78	\$2.74
2060	\$4.65	\$0.51	\$0.001	\$3.68	\$0.41	\$0.051	\$0.009	\$0.33	\$0.002	\$0.80	\$2.88
2061	\$4.84	\$0.52	\$0.001	\$3.84	\$0.43	\$0.052	\$0.009	\$0.33	\$0.002	\$0.83	\$3.01
2062	\$5.03	\$0.53	\$0.001	\$4.00	\$0.45	\$0.053	\$0.010	\$0.34	\$0.002	\$0.85	\$3.15



SCENARIO 3 (NO SEWER HEAT RECOVERY) PROJECTED ANNUAL CASH FLOWS (IN MILLION DOLLARS).

	Projected District Energy Revenue					Projected District System Costs					
Year	Customer Avoided Fuel Oil Cost	Customer Heat Pump Electricity Cost	Commercial Customer Heat Pump Electric Demand Charges	Gross District Energy Sales Income	Fuel Oil Consumption for Peaking Boiler	District Circulating Pump Electricity	Boiler Maintenance	District Infrastructure Maintenance & Management	Sewer Heat Recovery Heat Exchanger Maintenance	Total District System Expenses	Projected Annual Cash Flow
2012	\$0.25	\$0.04	\$0.000	\$0.19	\$0.00	\$0.004	\$0.001	\$0.22	\$0.000	\$0.22	-\$0.032
2013	\$0.52	\$0.07	\$0.001	\$0.39	\$0.00	\$0.007	\$0.002	\$0.22	\$0.000	\$0.23	\$0.16
2014	\$0.81	\$0.13	\$0.001	\$0.60	\$0.00	\$0.013	\$0.003	\$0.22	\$0.000	\$0.24	\$0.36
2015	\$1.12	\$0.19	\$0.002	\$0.82	\$0.01	\$0.019	\$0.004	\$0.23	\$0.000	\$0.26	\$0.56
2016	\$1.46	\$0.26	\$0.003	\$1.05	\$0.03	\$0.026	\$0.006	\$0.23	\$0.000	\$0.30	\$0.75
2017	\$1.52	\$0.29	\$0.003	\$1.07	\$0.06	\$0.030	\$0.006	\$0.24	\$0.000	\$0.33	\$0.74
2018	\$1.58	\$0.34	\$0.003	\$1.08	\$0.09	\$0.035	\$0.006	\$0.24	\$0.000	\$0.37	\$0.70
2019	\$1.64	\$0.35	\$0.004	\$1.12	\$0.10	\$0.035	\$0.006	\$0.25	\$0.000	\$0.38	\$0.74
2020	\$1.71	\$0.40	\$0.004	\$1.13	\$0.14	\$0.040	\$0.006	\$0.25	\$0.000	\$0.44	\$0.69
2021	\$1.78	\$0.41	\$0.004	\$1.18	\$0.15	\$0.041	\$0.006	\$0.26	\$0.000	\$0.45	\$0.73
2022	\$1.85	\$0.42	\$0.004	\$1.24	\$0.15	\$0.042	\$0.006	\$0.26	\$0.000	\$0.47	\$0.77
2023	\$1.92	\$0.43	\$0.004	\$1.30	\$0.16	\$0.043	\$0.006	\$0.27	\$0.000	\$0.48	\$0.82
2024	\$2.00	\$0.43	\$0.004	\$1.36	\$0.16	\$0.044	\$0.006	\$0.27	\$0.000	\$0.49	\$0.87
2025	\$2.08	\$0.44	\$0.004	\$1.42	\$0.17	\$0.045	\$0.007	\$0.28	\$0.000	\$0.50	\$0.92
2026	\$2.16	\$0.45	\$0.004	\$1.49	\$0.18	\$0.046	\$0.007	\$0.28	\$0.000	\$0.51	\$0.98
2027	\$2.25	\$0.46	\$0.005	\$1.56	\$0.18	\$0.046	\$0.007	\$0.29	\$0.000	\$0.52	\$1.04
2028	\$2.34	\$0.47	\$0.005	\$1.63	\$0.18	\$0.047	\$0.007	\$0.30	\$0.000	\$0.53	\$1.10
2029	\$2.43	\$0.48	\$0.005	\$1.70	\$0.19	\$0.048	\$0.007	\$0.30	\$0.000	\$0.55	\$1.16
2030	\$2.53	\$0.49	\$0.005	\$1.78	\$0.19	\$0.049	\$0.007	\$0.31	\$0.000	\$0.56	\$1.22
2031	\$2.63	\$0.50	\$0.005	\$1.86	\$0.20	\$0.050	\$0.007	\$0.31	\$0.000	\$0.57	\$1.29
2032	\$2.73	\$0.51	\$0.005	\$1.95	\$0.21	\$0.051	\$0.008	\$0.32	\$0.000	\$0.58	\$1.36
2033	\$2.84	\$0.52	\$0.005	\$2.04	\$0.21	\$0.052	\$0.008	\$0.33	\$0.000	\$0.60	\$1.44
2034	\$2.96	\$0.53	\$0.005	\$2.13	\$0.21	\$0.053	\$0.008	\$0.33	\$0.000	\$0.61	\$1.52
2035	\$3.07	\$0.54	\$0.005	\$2.22	\$0.22	\$0.054	\$0.008	\$0.34	\$0.000	\$0.63	\$1.60
2036	\$3.20	\$0.55	\$0.005	\$2.32	\$0.24	\$0.056	\$0.008	\$0.35	\$0.000	\$0.65	\$1.67
2037	\$3.33	\$0.57	\$0.006	\$2.42	\$0.26	\$0.057	\$0.008	\$0.35	\$0.000	\$0.68	\$1.74
2038	\$3.46	\$0.58	\$0.006	\$2.53	\$0.27	\$0.058	\$0.009	\$0.36	\$0.000	\$0.70	\$1.82
2039	\$3.60	\$0.59	\$0.006	\$2.64	\$0.29	\$0.060	\$0.009	\$0.37	\$0.000	\$0.73	\$1.92
2040	\$3.74	\$0.60	\$0.006	\$2.76	\$0.30	\$0.061	\$0.009	\$0.38	\$0.000	\$0.75	\$2.01
2041	\$3.89	\$0.61	\$0.006	\$2.88	\$0.32	\$0.062	\$0.009	\$0.38	\$0.000	\$0.77	\$2.11
2042	\$4.05	\$0.62	\$0.006	\$3.01	\$0.33	\$0.063	\$0.009	\$0.39	\$0.000	\$0.79	\$2.22
2043	\$4.21	\$0.63	\$0.006	\$3.15	\$0.34	\$0.064	\$0.009	\$0.40	\$0.000	\$0.81	\$2.33



	Projected District Energy Revenue					Projected District System Costs					
Year	Customer Avoided Fuel Oil Cost	Customer Heat Pump Electricity Cost	Commercial Customer Heat Pump Electric Demand Charges	Gross District Energy Sales Income	Fuel Oil Consumption for Peaking Boiler	District Circulating Pump Electricity	Boiler Maintenance	District Infrastructure Maintenance & Management	Sewer Heat Recovery Heat Exchanger Maintenance	Total District System Expenses	Projected Annual Cash Flow
2044	\$4.38	\$0.65	\$0.006	\$3.28	\$0.35	\$0.065	\$0.010	\$0.41	\$0.000	\$0.84	\$2.45
2045	\$4.55	\$0.66	\$0.006	\$3.43	\$0.37	\$0.067	\$0.010	\$0.42	\$0.000	\$0.86	\$2.57
2046	\$4.73	\$0.67	\$0.007	\$3.58	\$0.38	\$0.068	\$0.010	\$0.42	\$0.000	\$0.88	\$2.70
2047	\$4.92	\$0.68	\$0.007	\$3.74	\$0.39	\$0.069	\$0.010	\$0.43	\$0.000	\$0.90	\$2.84
2048	\$5.12	\$0.70	\$0.007	\$3.90	\$0.40	\$0.070	\$0.010	\$0.44	\$0.000	\$0.92	\$2.98
2049	\$5.32	\$0.71	\$0.007	\$4.07	\$0.42	\$0.072	\$0.011	\$0.45	\$0.000	\$0.95	\$3.12
2050	\$5.54	\$0.73	\$0.007	\$4.25	\$0.44	\$0.073	\$0.011	\$0.46	\$0.000	\$0.98	\$3.27
2051	\$5.76	\$0.74	\$0.007	\$4.44	\$0.45	\$0.075	\$0.011	\$0.47	\$0.000	\$1.00	\$3.44
2052	\$5.99	\$0.75	\$0.007	\$4.63	\$0.46	\$0.076	\$0.011	\$0.48	\$0.000	\$1.02	\$3.61
2053	\$6.23	\$0.77	\$0.008	\$4.83	\$0.46	\$0.077	\$0.012	\$0.49	\$0.000	\$1.04	\$3.79
2054	\$6.48	\$0.78	\$0.008	\$5.04	\$0.47	\$0.079	\$0.012	\$0.50	\$0.000	\$1.06	\$3.98
2055	\$6.74	\$0.80	\$0.008	\$5.26	\$0.49	\$0.080	\$0.012	\$0.51	\$0.000	\$1.09	\$4.17
2056	\$7.01	\$0.81	\$0.008	\$5.49	\$0.50	\$0.082	\$0.012	\$0.52	\$0.000	\$1.11	\$4.38
2057	\$7.29	\$0.83	\$0.008	\$5.72	\$0.51	\$0.083	\$0.012	\$0.53	\$0.000	\$1.13	\$4.59
2058	\$7.58	\$0.84	\$0.008	\$5.97	\$0.52	\$0.085	\$0.013	\$0.54	\$0.000	\$1.16	\$4.81
2059	\$7.88	\$0.86	\$0.009	\$6.22	\$0.55	\$0.087	\$0.013	\$0.55	\$0.000	\$1.20	\$5.02
2060	\$8.20	\$0.89	\$0.009	\$6.48	\$0.58	\$0.089	\$0.013	\$0.56	\$0.000	\$1.24	\$5.24
2061	\$8.52	\$0.91	\$0.009	\$6.75	\$0.63	\$0.092	\$0.013	\$0.57	\$0.000	\$1.31	\$5.45



SCENARIO 3 (WITH SEWER HEAT RECOVERY) PROJECTED ANNUAL CASH FLOWS (IN MILLION DOLLARS).

Year	Projected District Energy Revenue					Projected District System Costs					Projected Annual Cash Flow
	Customer Avoided Fuel Oil Cost	Customer Heat Pump Electricity Cost	Commercial Customer Heat Pump Electric Demand Charges	Gross District Energy Sales Income	Fuel Oil Consumption for Peaking Boiler	District Circulating Pump Electricity	Boiler Maintenance	District Infrastructure Maintenance & Management	Sewer Heat Recovery Heat Exchanger Maintenance	Total District System Expenses	
2012	\$0.25	\$0.04	\$0.000	\$0.18	\$0.000	\$0.004	\$0.001	\$0.22	\$0.000	\$0.22	-\$0.037
2013	\$0.52	\$0.08	\$0.001	\$0.38	\$0.000	\$0.008	\$0.002	\$0.22	\$0.000	\$0.23	\$0.15
2014	\$0.81	\$0.14	\$0.001	\$0.59	\$0.000	\$0.014	\$0.002	\$0.22	\$0.000	\$0.24	\$0.34
2015	\$1.12	\$0.20	\$0.002	\$0.80	\$0.005	\$0.021	\$0.003	\$0.23	\$0.001	\$0.26	\$0.54
2016	\$1.46	\$0.27	\$0.003	\$1.04	\$0.018	\$0.027	\$0.004	\$0.23	\$0.001	\$0.28	\$0.75
2017	\$1.52	\$0.30	\$0.003	\$1.06	\$0.024	\$0.030	\$0.004	\$0.24	\$0.001	\$0.30	\$0.76
2018	\$1.58	\$0.34	\$0.003	\$1.07	\$0.032	\$0.035	\$0.004	\$0.24	\$0.001	\$0.32	\$0.76
2019	\$1.64	\$0.35	\$0.004	\$1.13	\$0.028	\$0.035	\$0.004	\$0.25	\$0.001	\$0.32	\$0.81
2020	\$1.71	\$0.39	\$0.004	\$1.14	\$0.039	\$0.039	\$0.005	\$0.25	\$0.001	\$0.34	\$0.81
2021	\$1.78	\$0.39	\$0.004	\$1.20	\$0.034	\$0.040	\$0.005	\$0.26	\$0.001	\$0.34	\$0.86
2022	\$1.85	\$0.40	\$0.004	\$1.26	\$0.030	\$0.040	\$0.005	\$0.26	\$0.001	\$0.34	\$0.92
2023	\$1.92	\$0.40	\$0.004	\$1.32	\$0.027	\$0.041	\$0.005	\$0.27	\$0.001	\$0.34	\$0.98
2024	\$2.00	\$0.41	\$0.004	\$1.39	\$0.025	\$0.041	\$0.005	\$0.27	\$0.001	\$0.35	\$1.04
2025	\$2.08	\$0.41	\$0.004	\$1.45	\$0.023	\$0.042	\$0.005	\$0.28	\$0.001	\$0.35	\$1.10
2026	\$2.16	\$0.42	\$0.004	\$1.52	\$0.022	\$0.042	\$0.005	\$0.28	\$0.001	\$0.36	\$1.16
2027	\$2.25	\$0.43	\$0.005	\$1.59	\$0.021	\$0.043	\$0.005	\$0.29	\$0.299	\$0.66	\$0.93
2028	\$2.34	\$0.43	\$0.005	\$1.66	\$0.020	\$0.044	\$0.005	\$0.30	\$0.001	\$0.37	\$1.30
2029	\$2.43	\$0.44	\$0.005	\$1.74	\$0.019	\$0.045	\$0.005	\$0.30	\$0.001	\$0.37	\$1.37
2030	\$2.53	\$0.45	\$0.005	\$1.82	\$0.018	\$0.045	\$0.006	\$0.31	\$0.001	\$0.38	\$1.44
2031	\$2.63	\$0.46	\$0.005	\$1.91	\$0.017	\$0.046	\$0.006	\$0.31	\$0.001	\$0.38	\$1.52
2032	\$2.73	\$0.46	\$0.005	\$1.99	\$0.016	\$0.047	\$0.006	\$0.32	\$0.001	\$0.39	\$1.60
2033	\$2.84	\$0.47	\$0.005	\$2.08	\$0.015	\$0.048	\$0.006	\$0.33	\$0.001	\$0.40	\$1.69
2034	\$2.96	\$0.48	\$0.005	\$2.18	\$0.015	\$0.048	\$0.006	\$0.33	\$0.001	\$0.40	\$1.77
2035	\$3.07	\$0.49	\$0.005	\$2.27	\$0.016	\$0.049	\$0.006	\$0.34	\$0.001	\$0.41	\$1.86
2036	\$3.20	\$0.50	\$0.005	\$2.37	\$0.017	\$0.050	\$0.006	\$0.35	\$0.001	\$0.42	\$1.95
2037	\$3.33	\$0.51	\$0.006	\$2.48	\$0.019	\$0.051	\$0.006	\$0.35	\$0.001	\$0.43	\$2.05
2038	\$3.46	\$0.52	\$0.006	\$2.59	\$0.021	\$0.053	\$0.007	\$0.36	\$0.001	\$0.44	\$2.14
2039	\$3.60	\$0.53	\$0.006	\$2.70	\$0.023	\$0.054	\$0.007	\$0.37	\$0.001	\$0.45	\$2.25
2040	\$3.74	\$0.54	\$0.006	\$2.82	\$0.027	\$0.055	\$0.007	\$0.38	\$0.001	\$0.47	\$2.35
2041	\$3.89	\$0.55	\$0.006	\$2.94	\$0.028	\$0.056	\$0.007	\$0.38	\$0.001	\$0.48	\$2.47
2042	\$4.05	\$0.56	\$0.006	\$3.07	\$0.029	\$0.057	\$0.007	\$0.39	\$0.402	\$0.89	\$2.19
2043	\$4.21	\$0.57	\$0.006	\$3.21	\$0.030	\$0.058	\$0.007	\$0.40	\$0.001	\$0.50	\$2.71
2044	\$4.38	\$0.58	\$0.006	\$3.35	\$0.030	\$0.059	\$0.007	\$0.41	\$0.002	\$0.51	\$2.84



	Projected District Energy Revenue					Projected District System Costs					
Year	Customer Avoided Fuel Oil Cost	Customer Heat Pump Electricity Cost	Commercial Customer Heat Pump Electric Demand Charges	Gross District Energy Sales Income	Fuel Oil Consumption for Peaking Boiler	District Circulating Pump Electricity	Boiler Maintenance	District Infrastructure Maintenance & Management	Sewer Heat Recovery Heat Exchanger Maintenance	Total District System Expenses	Projected Annual Cash Flow
2045	\$4.55	\$0.59	\$0.006	\$3.50	\$0.030	\$0.060	\$0.008	\$0.42	\$0.002	\$0.51	\$2.98
2046	\$4.73	\$0.60	\$0.007	\$3.65	\$0.031	\$0.061	\$0.008	\$0.42	\$0.002	\$0.52	\$3.12
2047	\$4.92	\$0.62	\$0.007	\$3.81	\$0.030	\$0.062	\$0.008	\$0.43	\$0.002	\$0.53	\$3.27
2048	\$5.12	\$0.63	\$0.007	\$3.97	\$0.030	\$0.063	\$0.008	\$0.44	\$0.002	\$0.54	\$3.43
2049	\$5.32	\$0.64	\$0.007	\$4.15	\$0.031	\$0.065	\$0.008	\$0.45	\$0.002	\$0.55	\$3.59
2050	\$5.54	\$0.65	\$0.007	\$4.32	\$0.031	\$0.066	\$0.008	\$0.46	\$0.002	\$0.57	\$3.76
2051	\$5.76	\$0.67	\$0.007	\$4.51	\$0.032	\$0.067	\$0.008	\$0.47	\$0.002	\$0.58	\$3.93
2052	\$5.99	\$0.68	\$0.007	\$4.70	\$0.032	\$0.069	\$0.009	\$0.48	\$0.002	\$0.59	\$4.12
2053	\$6.23	\$0.69	\$0.008	\$4.91	\$0.033	\$0.070	\$0.009	\$0.49	\$0.002	\$0.60	\$4.31
2054	\$6.48	\$0.70	\$0.008	\$5.12	\$0.033	\$0.071	\$0.009	\$0.50	\$0.002	\$0.61	\$4.51
2055	\$6.74	\$0.72	\$0.008	\$5.34	\$0.032	\$0.072	\$0.009	\$0.51	\$0.002	\$0.62	\$4.72
2056	\$7.01	\$0.73	\$0.008	\$5.57	\$0.032	\$0.074	\$0.009	\$0.52	\$0.002	\$0.63	\$4.94
2057	\$7.29	\$0.74	\$0.008	\$5.81	\$0.032	\$0.075	\$0.010	\$0.53	\$0.002	\$0.64	\$5.16
2058	\$7.58	\$0.75	\$0.008	\$6.06	\$0.031	\$0.076	\$0.010	\$0.54	\$0.002	\$0.66	\$5.40
2059	\$7.88	\$0.77	\$0.009	\$6.32	\$0.032	\$0.078	\$0.010	\$0.55	\$0.002	\$0.67	\$5.65
2060	\$8.20	\$0.79	\$0.009	\$6.58	\$0.034	\$0.079	\$0.010	\$0.56	\$0.002	\$0.68	\$5.90
2061	\$8.52	\$0.80	\$0.009	\$6.86	\$0.037	\$0.081	\$0.010	\$0.57	\$0.002	\$0.70	\$6.16



SCENARIO 4 (NO SEWER HEAT RECOVERY) PROJECTED ANNUAL CASH FLOWS (IN MILLION DOLLARS).

	Projected District Energy Revenue					Projected District System Costs					
Year	Customer Avoided Fuel Oil Cost	Customer Heat Pump Electricity Cost	Commercial Customer Heat Pump Electric Demand Charges	Gross District Energy Sales Income	Fuel Oil Consumption for Peaking Boiler	District Circulating Pump Electricity	Boiler Maintenance	District Infrastructure Maintenance & Management	Sewer Heat Recovery Heat Exchanger Maintenance	Total District System Expenses	Projected Annual Cash Flow
2023	\$0.15	\$0.04	\$0.000	\$0.10	\$0.01	\$0.004	\$0.001	\$0.14	\$0.000	\$0.15	-\$0.055
2024	\$0.32	\$0.08	\$0.001	\$0.20	\$0.01	\$0.008	\$0.002	\$0.14	\$0.000	\$0.17	\$0.04
2025	\$0.49	\$0.12	\$0.002	\$0.32	\$0.04	\$0.012	\$0.003	\$0.15	\$0.000	\$0.20	\$0.12
2026	\$0.68	\$0.16	\$0.004	\$0.45	\$0.07	\$0.017	\$0.005	\$0.15	\$0.000	\$0.24	\$0.20
2027	\$0.89	\$0.21	\$0.007	\$0.58	\$0.12	\$0.021	\$0.006	\$0.15	\$0.000	\$0.30	\$0.28
2028	\$0.92	\$0.21	\$0.008	\$0.61	\$0.19	\$0.022	\$0.006	\$0.15	\$0.000	\$0.37	\$0.24
2029	\$0.96	\$0.21	\$0.009	\$0.64	\$0.19	\$0.022	\$0.006	\$0.16	\$0.000	\$0.38	\$0.26
2030	\$1.00	\$0.22	\$0.009	\$0.67	\$0.20	\$0.023	\$0.006	\$0.16	\$0.000	\$0.39	\$0.28
2031	\$1.04	\$0.22	\$0.009	\$0.70	\$0.21	\$0.023	\$0.006	\$0.16	\$0.000	\$0.40	\$0.30
2032	\$1.08	\$0.23	\$0.009	\$0.73	\$0.22	\$0.024	\$0.006	\$0.17	\$0.000	\$0.42	\$0.32
2033	\$1.12	\$0.23	\$0.009	\$0.77	\$0.23	\$0.024	\$0.006	\$0.17	\$0.000	\$0.43	\$0.34
2034	\$1.17	\$0.24	\$0.009	\$0.80	\$0.24	\$0.025	\$0.007	\$0.17	\$0.000	\$0.44	\$0.36
2035	\$1.21	\$0.24	\$0.010	\$0.84	\$0.24	\$0.025	\$0.007	\$0.18	\$0.000	\$0.45	\$0.39
2036	\$1.26	\$0.25	\$0.010	\$0.88	\$0.25	\$0.026	\$0.007	\$0.18	\$0.000	\$0.47	\$0.41
2037	\$1.31	\$0.25	\$0.010	\$0.92	\$0.26	\$0.026	\$0.007	\$0.18	\$0.000	\$0.48	\$0.44
2038	\$1.36	\$0.26	\$0.010	\$0.96	\$0.27	\$0.027	\$0.007	\$0.19	\$0.000	\$0.49	\$0.47
2039	\$1.42	\$0.26	\$0.010	\$1.01	\$0.28	\$0.027	\$0.007	\$0.19	\$0.000	\$0.51	\$0.50
2040	\$1.48	\$0.27	\$0.011	\$1.05	\$0.30	\$0.028	\$0.007	\$0.20	\$0.000	\$0.53	\$0.53
2041	\$1.54	\$0.27	\$0.011	\$1.10	\$0.31	\$0.028	\$0.008	\$0.20	\$0.000	\$0.54	\$0.56
2042	\$1.60	\$0.27	\$0.011	\$1.15	\$0.32	\$0.029	\$0.008	\$0.20	\$0.000	\$0.56	\$0.59
2043	\$1.66	\$0.28	\$0.011	\$1.20	\$0.33	\$0.029	\$0.008	\$0.21	\$0.000	\$0.58	\$0.62
2044	\$1.73	\$0.29	\$0.011	\$1.26	\$0.34	\$0.030	\$0.008	\$0.21	\$0.000	\$0.59	\$0.66
2045	\$1.80	\$0.29	\$0.012	\$1.31	\$0.35	\$0.030	\$0.008	\$0.22	\$0.000	\$0.60	\$0.71
2046	\$1.87	\$0.30	\$0.012	\$1.37	\$0.35	\$0.031	\$0.008	\$0.22	\$0.000	\$0.61	\$0.76
2047	\$1.94	\$0.30	\$0.012	\$1.43	\$0.36	\$0.032	\$0.009	\$0.22	\$0.000	\$0.63	\$0.80
2048	\$2.02	\$0.31	\$0.012	\$1.49	\$0.38	\$0.032	\$0.009	\$0.23	\$0.000	\$0.65	\$0.85
2049	\$2.10	\$0.32	\$0.013	\$1.56	\$0.39	\$0.033	\$0.009	\$0.23	\$0.000	\$0.66	\$0.90
2050	\$2.18	\$0.32	\$0.013	\$1.63	\$0.40	\$0.034	\$0.009	\$0.24	\$0.000	\$0.68	\$0.95
2051	\$2.27	\$0.33	\$0.013	\$1.70	\$0.42	\$0.034	\$0.009	\$0.24	\$0.000	\$0.71	\$0.99
2052	\$2.36	\$0.34	\$0.013	\$1.78	\$0.44	\$0.035	\$0.009	\$0.25	\$0.000	\$0.73	\$1.05
2053	\$2.46	\$0.34	\$0.014	\$1.85	\$0.45	\$0.036	\$0.010	\$0.25	\$0.000	\$0.75	\$1.11
2054	\$2.56	\$0.35	\$0.014	\$1.94	\$0.47	\$0.036	\$0.010	\$0.26	\$0.000	\$0.77	\$1.16
2055	\$2.66	\$0.36	\$0.014	\$2.02	\$0.49	\$0.037	\$0.010	\$0.26	\$0.000	\$0.80	\$1.22



	Projected District Energy Revenue				Projected District System Costs						
Year	Customer Avoided Fuel Oil Cost	Customer Heat Pump Electricity Cost	Commercial Customer Heat Pump Electric Demand Charges	Gross District Energy Sales Income	Fuel Oil Consumption for Peaking Boiler	District Circulating Pump Electricity	Boiler Maintenance	District Infrastructure Maintenance & Management	Sewer Heat Recovery Heat Exchanger Maintenance	Total District System Expenses	Projected Annual Cash Flow
2056	\$2.76	\$0.37	\$0.015	\$2.11	\$0.52	\$0.038	\$0.010	\$0.27	\$0.000	\$0.83	\$1.27
2057	\$2.88	\$0.37	\$0.015	\$2.20	\$0.54	\$0.039	\$0.010	\$0.27	\$0.000	\$0.86	\$1.34
2058	\$2.99	\$0.38	\$0.015	\$2.30	\$0.57	\$0.040	\$0.011	\$0.28	\$0.000	\$0.90	\$1.40
2059	\$3.11	\$0.39	\$0.015	\$2.40	\$0.60	\$0.040	\$0.011	\$0.29	\$0.000	\$0.93	\$1.46
2060	\$3.23	\$0.40	\$0.016	\$2.50	\$0.62	\$0.041	\$0.011	\$0.29	\$0.000	\$0.96	\$1.54
2061	\$3.36	\$0.40	\$0.016	\$2.61	\$0.65	\$0.042	\$0.011	\$0.30	\$0.000	\$1.00	\$1.61
2062	\$3.50	\$0.41	\$0.016	\$2.72	\$0.67	\$0.043	\$0.012	\$0.30	\$0.000	\$1.03	\$1.69
2063	\$3.64	\$0.42	\$0.017	\$2.84	\$0.70	\$0.043	\$0.012	\$0.31	\$0.000	\$1.07	\$1.77
2064	\$3.78	\$0.43	\$0.017	\$2.96	\$0.73	\$0.044	\$0.012	\$0.31	\$0.000	\$1.10	\$1.86
2065	\$3.93	\$0.43	\$0.017	\$3.09	\$0.76	\$0.045	\$0.012	\$0.32	\$0.000	\$1.14	\$1.95
2066	\$4.09	\$0.44	\$0.018	\$3.22	\$0.79	\$0.046	\$0.012	\$0.33	\$0.000	\$1.18	\$2.04
2067	\$4.26	\$0.45	\$0.018	\$3.36	\$0.82	\$0.047	\$0.013	\$0.33	\$0.000	\$1.21	\$2.15
2068	\$4.43	\$0.46	\$0.018	\$3.51	\$0.84	\$0.048	\$0.013	\$0.34	\$0.000	\$1.25	\$2.26
2069	\$4.60	\$0.47	\$0.019	\$3.65	\$0.86	\$0.049	\$0.013	\$0.35	\$0.000	\$1.27	\$2.38
2070	\$4.79	\$0.48	\$0.019	\$3.81	\$0.88	\$0.050	\$0.014	\$0.35	\$0.000	\$1.30	\$2.51
2071	\$4.98	\$0.49	\$0.020	\$3.97	\$0.91	\$0.051	\$0.014	\$0.36	\$0.000	\$1.33	\$2.64
2072	\$5.18	\$0.50	\$0.020	\$4.14	\$0.94	\$0.052	\$0.014	\$0.37	\$0.000	\$1.37	\$2.77



SCENARIO 4 (WITH SEWER HEAT RECOVERY) PROJECTED ANNUAL CASH FLOWS (IN MILLION DOLLARS).

	Projected District Energy Revenue					Projected District System Costs					
Year	Customer Avoided Fuel Oil Cost	Customer Heat Pump Electricity Cost	Commercial Customer Heat Pump Electric Demand Charges	Gross District Energy Sales Income	Fuel Oil Consumption for Peaking Boiler	District Circulating Pump Electricity	Boiler Maintenance	District Infrastructure Maintenance & Management	Sewer Heat Recovery Heat Exchanger Maintenance	Total District System Expenses	Projected Annual Cash Flow
2023	\$0.15	\$0.01	\$0.000	\$0.13	\$0.000	\$0.001	\$0.001	\$0.14	\$0.000	\$0.14	-\$0.017
2024	\$0.32	\$0.04	\$0.000	\$0.25	\$0.000	\$0.004	\$0.002	\$0.14	\$0.000	\$0.15	\$0.10
2025	\$0.49	\$0.08	\$0.000	\$0.37	\$0.000	\$0.008	\$0.003	\$0.15	\$0.001	\$0.16	\$0.21
2026	\$0.68	\$0.13	\$0.000	\$0.48	\$0.000	\$0.013	\$0.005	\$0.15	\$0.001	\$0.17	\$0.31
2027	\$0.89	\$0.20	\$0.000	\$0.59	\$0.000	\$0.020	\$0.006	\$0.15	\$0.001	\$0.18	\$0.41
2028	\$0.92	\$0.21	\$0.001	\$0.62	\$0.000	\$0.021	\$0.006	\$0.15	\$0.001	\$0.18	\$0.44
2029	\$0.96	\$0.21	\$0.001	\$0.65	\$0.000	\$0.021	\$0.006	\$0.16	\$0.001	\$0.19	\$0.47
2030	\$1.00	\$0.21	\$0.001	\$0.68	\$0.000	\$0.021	\$0.006	\$0.16	\$0.001	\$0.19	\$0.49
2031	\$1.04	\$0.22	\$0.001	\$0.72	\$0.000	\$0.022	\$0.006	\$0.16	\$0.001	\$0.19	\$0.52
2032	\$1.08	\$0.22	\$0.001	\$0.75	\$0.000	\$0.022	\$0.006	\$0.17	\$0.001	\$0.20	\$0.55
2033	\$1.12	\$0.22	\$0.001	\$0.78	\$0.000	\$0.023	\$0.006	\$0.17	\$0.001	\$0.20	\$0.58
2034	\$1.17	\$0.23	\$0.001	\$0.82	\$0.000	\$0.023	\$0.007	\$0.17	\$0.001	\$0.20	\$0.61
2035	\$1.21	\$0.23	\$0.003	\$0.86	\$0.006	\$0.024	\$0.007	\$0.18	\$0.001	\$0.21	\$0.64
2036	\$1.26	\$0.24	\$0.005	\$0.89	\$0.037	\$0.024	\$0.007	\$0.18	\$0.314	\$0.56	\$0.33
2037	\$1.31	\$0.24	\$0.007	\$0.93	\$0.093	\$0.025	\$0.007	\$0.18	\$0.001	\$0.31	\$0.62
2038	\$1.36	\$0.24	\$0.008	\$0.98	\$0.164	\$0.025	\$0.007	\$0.19	\$0.001	\$0.39	\$0.59
2039	\$1.42	\$0.25	\$0.010	\$1.02	\$0.249	\$0.026	\$0.007	\$0.19	\$0.001	\$0.48	\$0.54
2040	\$1.48	\$0.25	\$0.011	\$1.07	\$0.240	\$0.026	\$0.007	\$0.20	\$0.001	\$0.47	\$0.59
2041	\$1.54	\$0.26	\$0.011	\$1.11	\$0.236	\$0.027	\$0.008	\$0.20	\$0.001	\$0.47	\$0.64
2042	\$1.60	\$0.27	\$0.011	\$1.16	\$0.235	\$0.028	\$0.008	\$0.20	\$0.001	\$0.48	\$0.69
2043	\$1.66	\$0.27	\$0.011	\$1.21	\$0.233	\$0.028	\$0.008	\$0.21	\$0.002	\$0.48	\$0.73
2044	\$1.73	\$0.28	\$0.011	\$1.27	\$0.234	\$0.029	\$0.008	\$0.21	\$0.002	\$0.48	\$0.78
2045	\$1.80	\$0.28	\$0.012	\$1.32	\$0.238	\$0.029	\$0.008	\$0.22	\$0.002	\$0.49	\$0.83
2046	\$1.87	\$0.29	\$0.012	\$1.38	\$0.245	\$0.030	\$0.008	\$0.22	\$0.002	\$0.51	\$0.88
2047	\$1.94	\$0.29	\$0.012	\$1.44	\$0.252	\$0.031	\$0.009	\$0.22	\$0.002	\$0.52	\$0.92
2048	\$2.02	\$0.30	\$0.012	\$1.51	\$0.254	\$0.031	\$0.009	\$0.23	\$0.002	\$0.52	\$0.98
2049	\$2.10	\$0.31	\$0.013	\$1.57	\$0.260	\$0.032	\$0.009	\$0.23	\$0.002	\$0.54	\$1.04
2050	\$2.18	\$0.31	\$0.013	\$1.64	\$0.270	\$0.032	\$0.009	\$0.24	\$0.002	\$0.55	\$1.09
2051	\$2.27	\$0.32	\$0.013	\$1.71	\$0.280	\$0.033	\$0.009	\$0.24	\$0.422	\$0.99	\$0.73
2052	\$2.36	\$0.33	\$0.013	\$1.79	\$0.286	\$0.034	\$0.009	\$0.25	\$0.002	\$0.58	\$1.21
2053	\$2.46	\$0.33	\$0.014	\$1.87	\$0.296	\$0.035	\$0.010	\$0.25	\$0.002	\$0.60	\$1.27
2054	\$2.56	\$0.34	\$0.014	\$1.95	\$0.308	\$0.035	\$0.010	\$0.26	\$0.002	\$0.61	\$1.34



Year	Projected District Energy Revenue				Projected District System Costs						Projected Annual Cash Flow
	Customer Avoided Fuel Oil Cost	Customer Heat Pump Electricity Cost	Commercial Customer Heat Pump Electric Demand Charges	Gross District Energy Sales Income	Fuel Oil Consumption for Peaking Boiler	District Circulating Pump Electricity	Boiler Maintenance	District Infrastructure Maintenance & Management	Sewer Heat Recovery Heat Exchanger Maintenance	Total District System Expenses	
2055	\$2.66	\$0.34	\$0.014	\$2.03	\$0.326	\$0.036	\$0.010	\$0.26	\$0.002	\$0.64	\$1.40
2056	\$2.76	\$0.35	\$0.015	\$2.12	\$0.339	\$0.037	\$0.010	\$0.27	\$0.002	\$0.66	\$1.47
2057	\$2.88	\$0.36	\$0.015	\$2.22	\$0.352	\$0.037	\$0.010	\$0.27	\$0.002	\$0.68	\$1.54
2058	\$2.99	\$0.36	\$0.015	\$2.31	\$0.370	\$0.038	\$0.011	\$0.28	\$0.002	\$0.70	\$1.61
2059	\$3.11	\$0.37	\$0.015	\$2.41	\$0.389	\$0.039	\$0.011	\$0.29	\$0.002	\$0.73	\$1.69
2060	\$3.23	\$0.38	\$0.016	\$2.52	\$0.407	\$0.039	\$0.011	\$0.29	\$0.002	\$0.75	\$1.77
2061	\$3.36	\$0.38	\$0.016	\$2.63	\$0.430	\$0.040	\$0.011	\$0.30	\$0.002	\$0.78	\$1.85
2062	\$3.50	\$0.39	\$0.016	\$2.74	\$0.446	\$0.041	\$0.011	\$0.30	\$0.002	\$0.80	\$1.94
2063	\$3.64	\$0.40	\$0.017	\$2.86	\$0.470	\$0.042	\$0.012	\$0.31	\$0.002	\$0.83	\$2.02
2064	\$3.78	\$0.41	\$0.017	\$2.98	\$0.490	\$0.043	\$0.012	\$0.31	\$0.002	\$0.86	\$2.12
2065	\$3.93	\$0.42	\$0.017	\$3.11	\$0.512	\$0.043	\$0.012	\$0.32	\$0.002	\$0.89	\$2.22
2066	\$4.09	\$0.43	\$0.018	\$3.24	\$0.525	\$0.045	\$0.012	\$0.33	\$0.568	\$1.48	\$1.76
2067	\$4.26	\$0.44	\$0.018	\$3.37	\$0.544	\$0.046	\$0.013	\$0.33	\$0.002	\$0.94	\$2.44
2068	\$4.43	\$0.45	\$0.018	\$3.52	\$0.559	\$0.047	\$0.013	\$0.34	\$0.002	\$0.96	\$2.55
2069	\$4.60	\$0.46	\$0.019	\$3.67	\$0.573	\$0.048	\$0.013	\$0.35	\$0.003	\$0.98	\$2.68
2070	\$4.79	\$0.47	\$0.019	\$3.82	\$0.591	\$0.049	\$0.013	\$0.35	\$0.003	\$1.01	\$2.81
2071	\$4.98	\$0.48	\$0.020	\$3.98	\$0.610	\$0.050	\$0.014	\$0.36	\$0.003	\$1.04	\$2.95
2072	\$5.18	\$0.48	\$0.020	\$4.16	\$0.624	\$0.050	\$0.014	\$0.37	\$0.003	\$1.06	\$3.10

	Projected District Energy Revenue					Projected District System Costs					
Year	Customer Avoided Fuel Oil Cost	Customer Heat Pump Electricity Cost	Commercial Customer Heat Pump Electric Demand Charges	Gross District Energy Sales Income	Fuel Oil Consumption for Peaking Boiler	District Circulating Pump Electricity	Boiler Maintenance	District Infrastructure Maintenance & Management	Sewer Heat Recovery Heat Exchanger Maintenance	Total District System Expenses	Projected Annual Cash Flow
2044	\$11.55	\$1.70	\$0.014	\$8.68	\$0.70	\$0.17	\$0.014	\$1.25	\$0.000	\$2.14	\$6.55
2045	\$12.01	\$1.73	\$0.014	\$9.06	\$0.72	\$0.17	\$0.015	\$1.28	\$0.000	\$2.19	\$6.87
2046	\$12.49	\$1.77	\$0.014	\$9.46	\$0.76	\$0.18	\$0.015	\$1.30	\$0.000	\$2.25	\$7.20
2047	\$12.99	\$1.81	\$0.014	\$9.87	\$0.79	\$0.18	\$0.015	\$1.33	\$0.000	\$2.32	\$7.55
2048	\$13.51	\$1.86	\$0.015	\$10.29	\$0.82	\$0.19	\$0.016	\$1.36	\$0.000	\$2.38	\$7.91
2049	\$14.05	\$1.90	\$0.015	\$10.73	\$0.86	\$0.19	\$0.016	\$1.38	\$0.000	\$2.45	\$8.28
2050	\$14.62	\$1.94	\$0.015	\$11.20	\$0.90	\$0.20	\$0.016	\$1.41	\$0.000	\$2.52	\$8.67
2051	\$15.20	\$1.99	\$0.016	\$11.68	\$0.94	\$0.20	\$0.017	\$1.44	\$0.000	\$2.60	\$9.08
2052	\$15.81	\$2.03	\$0.016	\$12.18	\$0.98	\$0.21	\$0.017	\$1.47	\$0.000	\$2.67	\$9.50
2053	\$16.44	\$2.08	\$0.016	\$12.70	\$1.02	\$0.21	\$0.017	\$1.50	\$0.000	\$2.75	\$9.95
2054	\$17.10	\$2.12	\$0.017	\$13.25	\$1.06	\$0.21	\$0.018	\$1.53	\$0.000	\$2.82	\$10.43
2055	\$17.78	\$2.16	\$0.017	\$13.82	\$1.10	\$0.22	\$0.018	\$1.56	\$0.000	\$2.90	\$10.93
2056	\$18.49	\$2.21	\$0.017	\$14.42	\$1.13	\$0.22	\$0.018	\$1.59	\$0.000	\$2.96	\$11.46
2057	\$19.23	\$2.25	\$0.018	\$15.05	\$1.16	\$0.23	\$0.019	\$1.62	\$0.000	\$3.02	\$12.02
2058	\$20.00	\$2.29	\$0.018	\$15.70	\$1.18	\$0.23	\$0.019	\$1.65	\$0.000	\$3.09	\$12.61
2059	\$20.80	\$2.32	\$0.018	\$16.38	\$1.20	\$0.23	\$0.019	\$1.69	\$0.000	\$3.14	\$13.24
2060	\$21.64	\$2.36	\$0.019	\$17.09	\$1.23	\$0.24	\$0.020	\$1.72	\$0.000	\$3.21	\$13.89
2061	\$22.50	\$2.40	\$0.019	\$17.83	\$1.26	\$0.24	\$0.020	\$1.76	\$0.000	\$3.28	\$14.56



SCENARIO 5 (WITH SEWER HEAT RECOVERY) PROJECTED ANNUAL CASH FLOWS (IN MILLION DOLLARS).

	Projected District Energy Revenue					Projected District System Costs					
Year	Customer Avoided Fuel Oil Cost	Customer Heat Pump Electricity Cost	Commercial Customer Heat Pump Electric Demand Charges	Gross District Energy Sales Income	Fuel Oil Consumption for Peaking Boiler	District Circulating Pump Electricity	Boiler Maintenance	District Infrastructure Maintenance & Management	Sewer Heat Recovery Heat Exchanger Maintenance	Total District System Expenses	Projected Annual Cash Flow
2012	\$0.10	\$0.04	\$0.000	\$0.05	\$0.00	\$0.00	\$0.001	\$0.49	\$0.001	\$0.49	-\$0.45
2013	\$0.37	\$0.09	\$0.001	\$0.24	\$0.00	\$0.01	\$0.001	\$0.50	\$0.002	\$0.51	-\$0.27
2014	\$0.65	\$0.16	\$0.001	\$0.43	\$0.00	\$0.02	\$0.002	\$0.51	\$0.002	\$0.53	-\$0.10
2015	\$0.96	\$0.22	\$0.002	\$0.64	\$0.00	\$0.02	\$0.003	\$0.52	\$0.003	\$0.55	\$0.09
2016	\$1.29	\$0.29	\$0.002	\$0.87	\$0.01	\$0.03	\$0.003	\$0.53	\$0.004	\$0.57	\$0.29
2017	\$1.72	\$0.33	\$0.003	\$1.21	\$0.01	\$0.03	\$0.004	\$0.60	\$0.005	\$0.66	\$0.55
2018	\$1.99	\$0.39	\$0.003	\$1.40	\$0.02	\$0.04	\$0.005	\$0.61	\$0.006	\$0.68	\$0.72
2019	\$2.28	\$0.44	\$0.004	\$1.61	\$0.04	\$0.04	\$0.006	\$0.62	\$0.007	\$0.72	\$0.89
2020	\$2.60	\$0.54	\$0.004	\$1.80	\$0.07	\$0.05	\$0.007	\$0.64	\$0.008	\$0.78	\$1.02
2021	\$2.93	\$0.60	\$0.005	\$2.03	\$0.10	\$0.06	\$0.007	\$0.65	\$0.010	\$0.83	\$1.21
2022	\$3.05	\$0.67	\$0.005	\$2.07	\$0.13	\$0.07	\$0.008	\$0.71	\$0.011	\$0.93	\$1.15
2023	\$3.33	\$0.73	\$0.006	\$2.25	\$0.16	\$0.07	\$0.009	\$0.72	\$0.012	\$0.98	\$1.27
2024	\$3.62	\$0.79	\$0.006	\$2.47	\$0.20	\$0.08	\$0.010	\$0.74	\$0.013	\$1.04	\$1.43
2025	\$3.93	\$0.84	\$0.007	\$2.70	\$0.23	\$0.08	\$0.011	\$0.75	\$0.014	\$1.09	\$1.60
2026	\$4.27	\$0.89	\$0.007	\$2.94	\$0.27	\$0.09	\$0.012	\$0.77	\$0.016	\$1.16	\$1.79
2027	\$4.88	\$0.94	\$0.008	\$3.44	\$0.31	\$0.10	\$0.013	\$0.90	\$0.017	\$1.33	\$2.11
2028	\$5.35	\$1.00	\$0.008	\$3.81	\$0.36	\$0.10	\$0.014	\$0.91	\$0.019	\$1.41	\$2.40
2029	\$5.85	\$1.07	\$0.009	\$4.18	\$0.42	\$0.11	\$0.016	\$0.93	\$0.020	\$1.50	\$2.69
2030	\$6.38	\$1.14	\$0.009	\$4.59	\$0.48	\$0.11	\$0.017	\$0.95	\$0.022	\$1.59	\$3.00
2031	\$6.94	\$1.21	\$0.010	\$5.02	\$0.55	\$0.12	\$0.018	\$0.97	\$0.023	\$1.68	\$3.34
2032	\$7.22	\$1.29	\$0.010	\$5.19	\$0.62	\$0.13	\$0.018	\$0.99	\$0.025	\$1.78	\$3.41
2033	\$7.50	\$1.37	\$0.011	\$5.37	\$0.70	\$0.14	\$0.019	\$1.01	\$0.027	\$1.90	\$3.48
2034	\$7.80	\$1.40	\$0.011	\$5.62	\$0.72	\$0.14	\$0.019	\$1.03	\$0.028	\$1.94	\$3.68
2035	\$8.12	\$1.42	\$0.011	\$5.87	\$0.74	\$0.14	\$0.020	\$1.05	\$0.030	\$1.98	\$3.89
2036	\$8.44	\$1.45	\$0.012	\$6.14	\$0.76	\$0.15	\$0.020	\$1.07	\$0.032	\$2.03	\$4.11
2037	\$8.78	\$1.48	\$0.012	\$6.41	\$0.78	\$0.15	\$0.020	\$1.09	\$0.034	\$2.07	\$4.34
2038	\$9.13	\$1.50	\$0.013	\$6.70	\$0.81	\$0.15	\$0.021	\$1.11	\$0.036	\$2.13	\$4.57
2039	\$9.49	\$1.53	\$0.012	\$7.00	\$0.84	\$0.15	\$0.021	\$1.14	\$0.038	\$2.19	\$4.81
2040	\$9.87	\$1.57	\$0.013	\$7.31	\$0.87	\$0.16	\$0.022	\$1.16	\$0.040	\$2.25	\$5.06
2041	\$10.27	\$1.60	\$0.016	\$7.63	\$0.91	\$0.16	\$0.022	\$1.18	\$0.043	\$2.32	\$5.31
2042	\$10.68	\$1.63	\$0.013	\$7.96	\$0.94	\$0.16	\$0.022	\$1.21	\$0.045	\$2.38	\$5.58
2043	\$11.11	\$1.67	\$0.014	\$8.31	\$0.99	\$0.17	\$0.023	\$1.23	\$0.047	\$2.45	\$5.86



Year	Projected District Energy Revenue				Projected District System Costs						Projected Annual Cash Flow
	Customer Avoided Fuel Oil Cost	Customer Heat Pump Electricity Cost	Commercial Customer Heat Pump Electric Demand Charges	Gross District Energy Sales Income	Fuel Oil Consumption for Peaking Boiler	District Circulating Pump Electricity	Boiler Maintenance	District Infrastructure Maintenance & Management	Sewer Heat Recovery Heat Exchanger Maintenance	Total District System Expenses	
2044	\$11.55	\$1.70	\$0.019	\$8.68	\$1.03	\$0.17	\$0.023	\$1.25	\$0.050	\$2.53	\$6.15
2045	\$12.01	\$1.75	\$0.018	\$9.05	\$1.07	\$0.18	\$0.024	\$1.28	\$0.052	\$2.61	\$6.44
2046	\$12.49	\$1.79	\$0.014	\$9.44	\$1.11	\$0.18	\$0.024	\$1.30	\$0.055	\$2.67	\$6.77
2047	\$12.99	\$1.81	\$0.014	\$9.87	\$1.15	\$0.18	\$0.025	\$1.33	\$0.058	\$2.75	\$7.12
2048	\$13.51	\$1.85	\$0.015	\$10.30	\$1.20	\$0.19	\$0.025	\$1.36	\$0.060	\$2.83	\$7.47
2049	\$14.05	\$1.89	\$0.021	\$10.74	\$1.25	\$0.19	\$0.026	\$1.38	\$0.063	\$2.92	\$7.82
2050	\$14.62	\$1.92	\$0.016	\$11.22	\$1.29	\$0.19	\$0.026	\$1.41	\$0.066	\$2.99	\$8.23
2051	\$15.20	\$1.96	\$0.020	\$11.71	\$1.34	\$0.20	\$0.027	\$1.44	\$0.069	\$3.07	\$8.63
2052	\$15.81	\$1.99	\$0.020	\$12.22	\$1.38	\$0.20	\$0.027	\$1.47	\$0.072	\$3.15	\$9.07
2053	\$16.44	\$2.02	\$0.021	\$12.75	\$1.44	\$0.20	\$0.028	\$1.50	\$0.076	\$3.24	\$9.51
2054	\$17.10	\$2.07	\$0.017	\$13.31	\$1.49	\$0.21	\$0.028	\$1.53	\$0.079	\$3.34	\$9.97
2055	\$17.78	\$2.10	\$0.017	\$13.89	\$1.53	\$0.21	\$0.029	\$1.56	\$0.082	\$3.41	\$10.47
2056	\$18.49	\$2.14	\$0.017	\$14.49	\$1.57	\$0.22	\$0.030	\$1.59	\$0.086	\$3.49	\$11.00
2057	\$19.23	\$2.17	\$0.018	\$15.12	\$1.62	\$0.22	\$0.030	\$1.62	\$0.090	\$3.58	\$11.54
2058	\$20.00	\$2.22	\$0.021	\$15.76	\$1.67	\$0.22	\$0.031	\$1.65	\$0.093	\$3.67	\$12.09
2059	\$20.80	\$2.27	\$0.019	\$16.44	\$1.72	\$0.23	\$0.031	\$1.69	\$0.097	\$3.77	\$12.67
2060	\$21.64	\$2.31	\$0.027	\$17.14	\$1.79	\$0.23	\$0.032	\$1.72	\$0.101	\$3.88	\$13.26
2061	\$22.50	\$2.36	\$0.022	\$17.87	\$1.88	\$0.24	\$0.033	\$1.76	\$0.106	\$4.02	\$13.85



SCENARIO 6 (NO SEWER HEAT RECOVERY) PROJECTED ANNUAL CASH FLOWS (IN MILLION DOLLARS).

Year	Projected District Energy Revenue				Projected District System Costs						Projected Annual Cash Flow
	Customer Avoided Fuel Oil Cost	Customer Heat Pump Electricity Cost	Commercial Customer Heat Pump Electric Demand Charges	Gross District Energy Sales Income	Fuel Oil Consumption for Peaking Boiler	District Circulating Pump Electricity	Boiler Maintenance	District Infrastructure Maintenance & Management	Sewer Heat Recovery Heat Exchanger Maintenance	Total District System Expenses	
2012	\$0.10	\$0.05	\$0.000	\$0.05	\$0.00	\$0.00	\$0.001	\$0.57	\$0.000	\$0.57	-\$0.53
2013	\$0.37	\$0.10	\$0.001	\$0.23	\$0.00	\$0.01	\$0.001	\$0.58	\$0.000	\$0.59	-\$0.37
2014	\$0.65	\$0.17	\$0.001	\$0.42	\$0.00	\$0.02	\$0.002	\$0.59	\$0.000	\$0.61	-\$0.19
2015	\$0.96	\$0.24	\$0.002	\$0.63	\$0.00	\$0.02	\$0.002	\$0.60	\$0.000	\$0.63	\$0.00
2016	\$1.29	\$0.31	\$0.003	\$0.85	\$0.00	\$0.03	\$0.003	\$0.62	\$0.000	\$0.65	\$0.20
2017	\$1.90	\$0.35	\$0.003	\$1.36	\$0.00	\$0.03	\$0.003	\$0.74	\$0.000	\$0.78	\$0.59
2018	\$2.38	\$0.39	\$0.003	\$1.74	\$0.00	\$0.04	\$0.004	\$0.76	\$0.000	\$0.80	\$0.94
2019	\$2.89	\$0.49	\$0.004	\$2.11	\$0.00	\$0.05	\$0.005	\$0.77	\$0.000	\$0.82	\$1.29
2020	\$3.44	\$0.63	\$0.005	\$2.46	\$0.01	\$0.06	\$0.005	\$0.79	\$0.000	\$0.87	\$1.59
2021	\$4.02	\$0.74	\$0.006	\$2.87	\$0.03	\$0.07	\$0.006	\$0.80	\$0.000	\$0.92	\$1.96
2022	\$4.18	\$0.87	\$0.007	\$2.89	\$0.08	\$0.09	\$0.007	\$0.87	\$0.000	\$1.04	\$1.86
2023	\$4.51	\$1.00	\$0.007	\$3.05	\$0.15	\$0.10	\$0.008	\$0.88	\$0.000	\$1.14	\$1.91
2024	\$4.85	\$1.07	\$0.008	\$3.29	\$0.21	\$0.11	\$0.009	\$0.90	\$0.000	\$1.22	\$2.06
2025	\$5.21	\$1.14	\$0.009	\$3.54	\$0.28	\$0.11	\$0.009	\$0.92	\$0.000	\$1.32	\$2.22
2026	\$5.59	\$1.21	\$0.009	\$3.81	\$0.35	\$0.12	\$0.010	\$0.94	\$0.000	\$1.42	\$2.39
2027	\$6.26	\$1.28	\$0.010	\$4.34	\$0.43	\$0.13	\$0.011	\$1.07	\$0.000	\$1.64	\$2.70
2028	\$6.79	\$1.36	\$0.010	\$4.74	\$0.52	\$0.14	\$0.012	\$1.09	\$0.000	\$1.76	\$2.98
2029	\$7.34	\$1.44	\$0.011	\$5.16	\$0.61	\$0.15	\$0.013	\$1.11	\$0.000	\$1.88	\$3.27
2030	\$7.93	\$1.53	\$0.011	\$5.60	\$0.71	\$0.15	\$0.014	\$1.13	\$0.000	\$2.02	\$3.58
2031	\$8.55	\$1.62	\$0.012	\$6.07	\$0.83	\$0.16	\$0.015	\$1.16	\$0.000	\$2.16	\$3.91
2032	\$8.90	\$1.71	\$0.013	\$6.29	\$0.94	\$0.17	\$0.015	\$1.18	\$0.000	\$2.31	\$3.98
2033	\$9.25	\$1.80	\$0.013	\$6.51	\$1.07	\$0.18	\$0.016	\$1.20	\$0.000	\$2.47	\$4.05
2034	\$9.62	\$1.83	\$0.013	\$6.81	\$1.11	\$0.18	\$0.016	\$1.23	\$0.000	\$2.54	\$4.28
2035	\$10.01	\$1.87	\$0.014	\$7.12	\$1.14	\$0.19	\$0.016	\$1.25	\$0.000	\$2.60	\$4.53
2036	\$10.41	\$1.90	\$0.014	\$7.45	\$1.17	\$0.19	\$0.017	\$1.28	\$0.000	\$2.66	\$4.80
2037	\$10.82	\$1.93	\$0.014	\$7.80	\$1.21	\$0.19	\$0.017	\$1.30	\$0.000	\$2.72	\$5.08
2038	\$11.26	\$1.96	\$0.015	\$8.16	\$1.25	\$0.20	\$0.017	\$1.33	\$0.000	\$2.79	\$5.37
2039	\$11.71	\$1.99	\$0.015	\$8.53	\$1.29	\$0.20	\$0.018	\$1.36	\$0.000	\$2.86	\$5.67
2040	\$12.17	\$2.02	\$0.015	\$8.92	\$1.33	\$0.20	\$0.018	\$1.38	\$0.000	\$2.94	\$5.98
2041	\$12.66	\$2.06	\$0.015	\$9.32	\$1.38	\$0.21	\$0.018	\$1.41	\$0.000	\$3.01	\$6.31
2042	\$13.17	\$2.09	\$0.016	\$9.74	\$1.43	\$0.21	\$0.019	\$1.44	\$0.000	\$3.09	\$6.65
2043	\$13.69	\$2.13	\$0.016	\$10.18	\$1.49	\$0.21	\$0.019	\$1.47	\$0.000	\$3.19	\$6.98

Year	Projected District Energy Revenue					Projected District System Costs					Projected Annual Cash Flow
	Customer Avoided Fuel Oil Cost	Customer Heat Pump Electricity Cost	Commercial Customer Heat Pump Electric Demand Charges	Gross District Energy Sales Income	Fuel Oil Consumption for Peaking Boiler	District Circulating Pump Electricity	Boiler Maintenance	District Infrastructure Maintenance & Management	Sewer Heat Recovery Heat Exchanger Maintenance	Total District System Expenses	
2044	\$14.24	\$2.17	\$0.016	\$10.63	\$1.55	\$0.22	\$0.020	\$1.50	\$0.000	\$3.29	\$7.34
2045	\$14.81	\$2.22	\$0.017	\$11.09	\$1.62	\$0.22	\$0.020	\$1.53	\$0.000	\$3.39	\$7.70
2046	\$15.40	\$2.27	\$0.017	\$11.58	\$1.70	\$0.23	\$0.020	\$1.56	\$0.000	\$3.50	\$8.07
2047	\$16.02	\$2.32	\$0.017	\$12.08	\$1.77	\$0.23	\$0.021	\$1.59	\$0.000	\$3.62	\$8.46
2048	\$16.66	\$2.38	\$0.018	\$12.60	\$1.86	\$0.24	\$0.021	\$1.62	\$0.000	\$3.74	\$8.86
2049	\$17.33	\$2.43	\$0.018	\$13.15	\$1.95	\$0.24	\$0.022	\$1.65	\$0.000	\$3.87	\$9.28
2050	\$18.02	\$2.49	\$0.018	\$13.71	\$2.04	\$0.25	\$0.022	\$1.69	\$0.000	\$4.00	\$9.71
2051	\$18.74	\$2.54	\$0.019	\$14.30	\$2.14	\$0.26	\$0.022	\$1.72	\$0.000	\$4.14	\$10.17
2052	\$19.49	\$2.60	\$0.019	\$14.92	\$2.23	\$0.26	\$0.023	\$1.75	\$0.000	\$4.27	\$10.65
2053	\$20.27	\$2.66	\$0.020	\$15.56	\$2.33	\$0.27	\$0.023	\$1.79	\$0.000	\$4.41	\$11.16
2054	\$21.08	\$2.72	\$0.020	\$16.24	\$2.43	\$0.27	\$0.024	\$1.82	\$0.000	\$4.55	\$11.69
2055	\$21.92	\$2.77	\$0.020	\$16.94	\$2.52	\$0.28	\$0.024	\$1.86	\$0.000	\$4.69	\$12.25
2056	\$22.80	\$2.83	\$0.021	\$17.67	\$2.61	\$0.28	\$0.025	\$1.90	\$0.000	\$4.81	\$12.86
2057	\$23.71	\$2.88	\$0.021	\$18.44	\$2.69	\$0.29	\$0.025	\$1.94	\$0.000	\$4.94	\$13.50
2058	\$24.66	\$2.93	\$0.022	\$19.24	\$2.77	\$0.30	\$0.026	\$1.97	\$0.000	\$5.06	\$14.18
2059	\$25.65	\$2.98	\$0.022	\$20.08	\$2.83	\$0.30	\$0.026	\$2.01	\$0.000	\$5.18	\$14.90
2060	\$26.67	\$3.03	\$0.022	\$20.95	\$2.89	\$0.31	\$0.027	\$2.05	\$0.000	\$5.28	\$15.67
2061	\$27.74	\$3.08	\$0.023	\$21.86	\$2.97	\$0.31	\$0.027	\$2.10	\$0.000	\$5.40	\$16.46



SCENARIO 6 (WITH SEWER HEAT RECOVERY) PROJECTED ANNUAL CASH FLOWS (IN MILLION DOLLARS).

	Projected District Energy Revenue					Projected District System Costs					
Year	Customer Avoided Fuel Oil Cost	Customer Heat Pump Electricity Cost	Commercial Customer Heat Pump Electric Demand Charges	Gross District Energy Sales Income	Fuel Oil Consumption for Peaking Boiler	District Circulating Pump Electricity	Boiler Maintenance	District Infrastructure Maintenance & Management	Sewer Heat Recovery Heat Exchanger Maintenance	Total District System Expenses	Projected Annual Cash Flow
2012	\$0.10	\$0.05	\$0.000	\$0.05	\$0.00	\$0.00	\$0.000	\$0.57	\$0.001	\$0.58	-\$0.53
2013	\$0.37	\$0.11	\$0.001	\$0.22	\$0.00	\$0.01	\$0.001	\$0.58	\$0.002	\$0.59	-\$0.37
2014	\$0.65	\$0.18	\$0.001	\$0.41	\$0.00	\$0.02	\$0.001	\$0.59	\$0.002	\$0.61	-\$0.21
2015	\$0.96	\$0.25	\$0.002	\$0.62	\$0.00	\$0.02	\$0.001	\$0.60	\$0.003	\$0.63	-\$0.02
2016	\$1.29	\$0.32	\$0.002	\$0.84	\$0.00	\$0.03	\$0.002	\$0.62	\$0.004	\$0.65	\$0.19
2017	\$1.90	\$0.36	\$0.003	\$1.35	\$0.00	\$0.04	\$0.002	\$0.74	\$0.005	\$0.78	\$0.57
2018	\$2.38	\$0.40	\$0.003	\$1.74	\$0.00	\$0.04	\$0.003	\$0.76	\$0.006	\$0.81	\$0.93
2019	\$2.89	\$0.49	\$0.004	\$2.11	\$0.00	\$0.05	\$0.003	\$0.77	\$0.007	\$0.83	\$1.28
2020	\$3.44	\$0.61	\$0.005	\$2.48	\$0.00	\$0.06	\$0.003	\$0.79	\$0.008	\$0.86	\$1.62
2021	\$4.02	\$0.71	\$0.006	\$2.90	\$0.00	\$0.07	\$0.004	\$0.80	\$0.010	\$0.89	\$2.02
2022	\$4.18	\$0.82	\$0.006	\$2.94	\$0.00	\$0.08	\$0.004	\$0.87	\$0.011	\$0.96	\$1.97
2023	\$4.51	\$0.94	\$0.007	\$3.11	\$0.00	\$0.09	\$0.005	\$0.88	\$0.012	\$0.99	\$2.11
2024	\$4.85	\$1.01	\$0.008	\$3.35	\$0.00	\$0.10	\$0.005	\$0.90	\$0.013	\$1.02	\$2.33
2025	\$5.21	\$1.07	\$0.009	\$3.61	\$0.01	\$0.11	\$0.006	\$0.92	\$0.014	\$1.06	\$2.55
2026	\$5.59	\$1.14	\$0.009	\$3.89	\$0.02	\$0.11	\$0.007	\$0.94	\$0.016	\$1.09	\$2.79
2027	\$6.26	\$1.21	\$0.010	\$4.42	\$0.03	\$0.12	\$0.007	\$1.07	\$0.017	\$1.25	\$3.17
2028	\$6.79	\$1.28	\$0.010	\$4.82	\$0.05	\$0.13	\$0.008	\$1.09	\$0.602	\$1.88	\$2.94
2029	\$7.34	\$1.37	\$0.011	\$5.23	\$0.07	\$0.14	\$0.008	\$1.11	\$0.020	\$1.35	\$3.88
2030	\$7.93	\$1.45	\$0.011	\$5.67	\$0.09	\$0.15	\$0.009	\$1.13	\$0.022	\$1.40	\$4.27
2031	\$8.55	\$1.54	\$0.012	\$6.14	\$0.12	\$0.16	\$0.010	\$1.16	\$0.023	\$1.47	\$4.68
2032	\$8.90	\$1.64	\$0.013	\$6.36	\$0.15	\$0.16	\$0.010	\$1.18	\$0.025	\$1.53	\$4.82
2033	\$9.25	\$1.73	\$0.013	\$6.58	\$0.20	\$0.17	\$0.010	\$1.20	\$0.027	\$1.61	\$4.97
2034	\$9.62	\$1.77	\$0.013	\$6.88	\$0.21	\$0.18	\$0.010	\$1.23	\$0.028	\$1.65	\$5.22
2035	\$10.01	\$1.80	\$0.014	\$7.19	\$0.23	\$0.18	\$0.010	\$1.25	\$0.030	\$1.70	\$5.49
2036	\$10.41	\$1.84	\$0.014	\$7.51	\$0.24	\$0.19	\$0.011	\$1.28	\$0.032	\$1.75	\$5.77
2037	\$10.82	\$1.87	\$0.014	\$7.85	\$0.25	\$0.19	\$0.011	\$1.30	\$0.034	\$1.79	\$6.06
2038	\$11.26	\$1.91	\$0.015	\$8.21	\$0.27	\$0.19	\$0.011	\$1.33	\$0.036	\$1.83	\$6.37
2039	\$11.71	\$1.94	\$0.015	\$8.58	\$0.28	\$0.20	\$0.011	\$1.36	\$0.038	\$1.89	\$6.69
2040	\$12.17	\$1.98	\$0.015	\$8.97	\$0.29	\$0.20	\$0.012	\$1.38	\$0.040	\$1.92	\$7.04
2041	\$12.66	\$2.01	\$0.015	\$9.37	\$0.31	\$0.20	\$0.012	\$1.41	\$0.043	\$1.97	\$7.39
2042	\$13.17	\$2.05	\$0.016	\$9.78	\$0.32	\$0.21	\$0.012	\$1.44	\$0.045	\$2.02	\$7.76
2043	\$13.69	\$2.09	\$0.016	\$10.22	\$0.34	\$0.21	\$0.012	\$1.47	\$0.832	\$2.86	\$7.36



	Projected District Energy Revenue					Projected District System Costs					
Year	Customer Avoided Fuel Oil Cost	Customer Heat Pump Electricity Cost	Commercial Customer Heat Pump Electric Demand Charges	Gross District Energy Sales Income	Fuel Oil Consumption for Peaking Boiler	District Circulating Pump Electricity	Boiler Maintenance	District Infrastructure Maintenance & Management	Sewer Heat Recovery Heat Exchanger Maintenance	Total District System Expenses	Projected Annual Cash Flow
2044	\$14.24	\$2.13	\$0.016	\$10.67	\$0.34	\$0.21	\$0.012	\$1.50	\$0.050	\$2.12	\$8.55
2045	\$14.81	\$2.17	\$0.017	\$11.14	\$0.36	\$0.22	\$0.013	\$1.53	\$0.052	\$2.17	\$8.97
2046	\$15.40	\$2.22	\$0.017	\$11.63	\$0.38	\$0.22	\$0.013	\$1.56	\$0.055	\$2.22	\$9.40
2047	\$16.02	\$2.27	\$0.017	\$12.13	\$0.39	\$0.23	\$0.013	\$1.59	\$0.058	\$2.28	\$9.86
2048	\$16.66	\$2.32	\$0.018	\$12.66	\$0.40	\$0.23	\$0.014	\$1.62	\$0.060	\$2.33	\$10.33
2049	\$17.33	\$2.37	\$0.018	\$13.21	\$0.42	\$0.24	\$0.014	\$1.65	\$0.063	\$2.39	\$10.82
2050	\$18.02	\$2.42	\$0.018	\$13.78	\$0.44	\$0.24	\$0.014	\$1.69	\$0.066	\$2.45	\$11.33
2051	\$18.74	\$2.47	\$0.019	\$14.38	\$0.46	\$0.25	\$0.014	\$1.72	\$0.069	\$2.51	\$11.86
2052	\$19.49	\$2.53	\$0.019	\$15.00	\$0.48	\$0.25	\$0.015	\$1.75	\$0.072	\$2.57	\$12.42
2053	\$20.27	\$2.58	\$0.020	\$15.64	\$0.50	\$0.26	\$0.015	\$1.79	\$0.076	\$2.64	\$13.00
2054	\$21.08	\$2.63	\$0.020	\$16.32	\$0.51	\$0.27	\$0.015	\$1.82	\$0.079	\$2.70	\$13.62
2055	\$21.92	\$2.69	\$0.020	\$17.02	\$0.54	\$0.27	\$0.016	\$1.86	\$0.082	\$2.77	\$14.26
2056	\$22.80	\$2.74	\$0.021	\$17.76	\$0.55	\$0.28	\$0.016	\$1.90	\$0.086	\$2.82	\$14.94
2057	\$23.71	\$2.79	\$0.021	\$18.53	\$0.57	\$0.28	\$0.016	\$1.94	\$0.090	\$2.89	\$15.64
2058	\$24.66	\$2.85	\$0.022	\$19.33	\$0.58	\$0.29	\$0.016	\$1.97	\$0.093	\$2.95	\$16.38
2059	\$25.65	\$2.90	\$0.022	\$20.16	\$0.60	\$0.29	\$0.017	\$2.01	\$0.097	\$3.02	\$17.14
2060	\$26.67	\$2.95	\$0.022	\$21.03	\$0.62	\$0.30	\$0.017	\$2.05	\$0.101	\$3.09	\$17.94
2061	\$27.74	\$3.00	\$0.023	\$21.94	\$0.63	\$0.30	\$0.017	\$2.10	\$0.106	\$3.15	\$18.79

