Park Avenue West

When complete, Park Avenue West will be Oregon's first high-rise building to combine office, retail and residential condominiums. The project incorporates regional materials with an emphasis on durability, recycled content and future adaptability. With these sustainability features, Portland's third tallest building is shaping up to be among its greenest.

Project Highlights

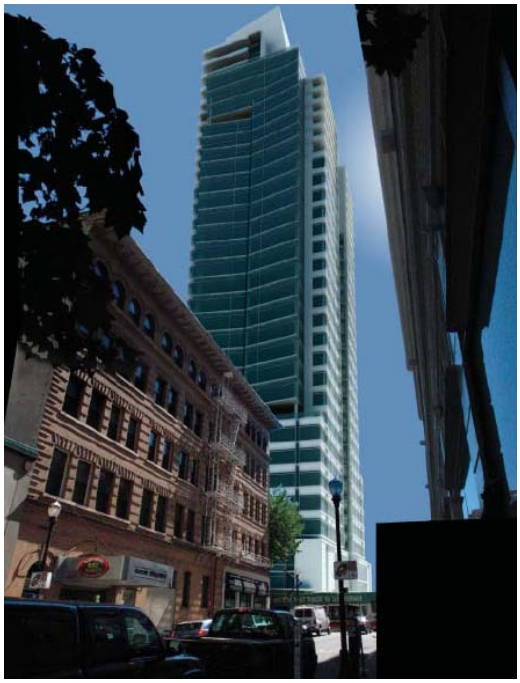
- **Geoexchange feasibility study**
- **Sustainable wood products evaluation**
- **Urban ecology opportunities assessment**
- **LEED Platinum certification**

Portfolio Contents

Final Report

Energy Trust of Oregon
Portland Water Bureau — From Forest to Faucet
Environmental Services
Bureau of Planning and Sustainability — Innovation. Collaboration. Practical Solutions.
City of Portland, Oregon
Sam Adams, Mayor • Susan Anderson, Director

Park Avenue West Tower



Green Investment Fund GIF RFP-08
Final Report
July 2009

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EXECUTIVE SUMMARY

The Park Avenue West Tower project (PAWT) is a 474,000-sf mixed-use project owned by TMT Development located in the heart of downtown Portland, Oregon. PAWT was awarded a Green Investment Fund (GIF) grant by the City of Portland in the 2008 grant cycle (NOTE: *The PAWT project is currently under redesign. For this report, the project is described in the context of the original design as proposed in the February 2008 GIF RFP response and by which geoexchange feasibility was evaluated.*). The 33-story project replaces a surface parking lot on a half-block (20,000-sf) and the program includes (as proposed in the February 2008 RFP response) office, retail, residential, underground parking and a small plaza. The Green Investment Fund is a competitive grant program that supports highly innovative and comprehensive green building projects in the City of Portland. The grant was awarded to PAWT in support of the project's comprehensive green building approach and, specifically, the preliminary feasibility evaluation of an on-site geoexchange system. The grant was pursued when the project was at 25% Design Development and during early discussions about including a geoexchange system in the project.

Preliminary research and assessment of the primary influencing variables on geoexchange feasibility such as subsurface conditions, regulatory context, technical requirements and cost suggested that a geoexchange system was a viable energy efficiency strategy for PAWT. There are a few precedent geoexchange projects in the downtown area that have generally functioned well and significantly decreased building energy use. Energy efficiency projects in Oregon can access an array of incentive options at hand ranging from grants to tax credits. Further, a basic evaluation of system options demonstrated that geoexchange would likely create a significant reduction in PAWT's space conditioning-related energy demand. These conditions provided enough surety to work to integrate the system into the project's design documents, which subsequently surfaced multiple challenges.

PAWT's program and location, while desirable from a sustainability standpoint (dense, mixed use, underground parking, adjacent to MAX light rail, etc.), yielded unforeseen issues that threatened to cause overly burdensome scheduling delays and capital investment. Specifically, PAWT is located on a half-size city block and meeting the technical requirements for a viably-sized geoexchange system required portions of the system to be located on the neighboring block. Crossing property lines and the right of way created additional fees, applications, financing challenges and capital investments and also hindered an already aggressive construction schedule. For these reasons, the feasibility evaluation stopped prior to the drilling of a test well. The test well would have enabled field testing of on-site subsurface conditions and was anticipated to cost approximately $1 million. The test well also would have been incorporated into the final system if the field test results were assuring.

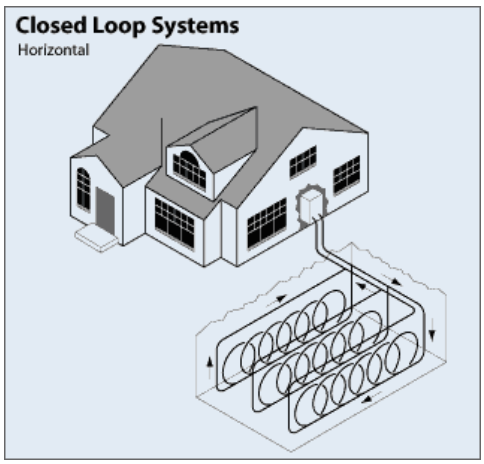
Geoexchange systems can be a viable strategy to reduce space conditioning-related energy consumption in downtown buildings when planning and expertise are integrated early in the design process. Preliminary, expert evaluation prior to design development can help to identify spatial and technical factors that can inform building and site design decisions. Further, it can also help to reveal multi-jurisdictional regulatory, permitting and other necessary approvals that impact project schedule. Identifying these issues early when

design is more readily influenced could make them less costly to address; allow integration of their temporal impacts into the project schedule; and, support a more efficient execution of the evaluation, design and approval process. An early, integrated approach and financial incentives are two key influencing factors on the viability of geoexchange system.

GEOEXCHANGE OVERVIEW

Geoexchange systems rely on the relatively constant temperature of the earth to deliver and reject heat to and from buildings and can significantly increasing the efficiency of space conditioning. With Geoexchange, the earth's natural heat is tapped by employing a series of belowground pipes, called a loop, installed in the soil or submersed in a pond or lake. A fluid circulating in the loop absorbs the earth's heat in winter and carries it to the building. Indoor geothermal heat pumps then concentrate the heat and release it at a higher temperature inside the building. In summer, the process is reversed, as excess heat is drawn from the building, expelled to the loop, and absorbed by the earth. The Geoexchange system provides cooling in much the same way that a refrigerator keeps its contents cool, by drawing heat from the interior, not by injecting cold.

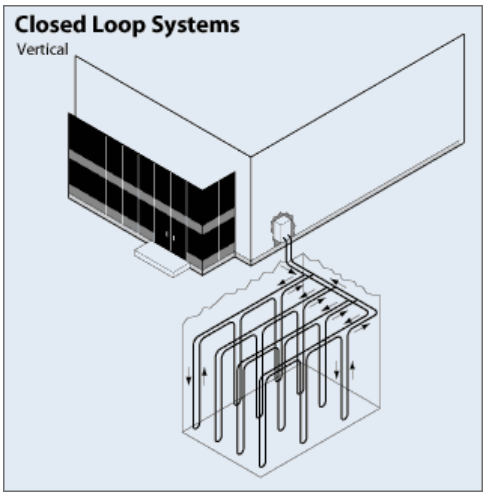
Closed Loop Systems



Horizontal closed-loop (source: cogeneration.net)

Horizontal, closed ground loop configurations are often the most economical to install when adequate space is available and the soil allows contractors to dig trenches easily. A series of parallel pipes are laid out in trenches below the frost line, 3 to 6 feet below the ground surface. Typically, about 400 to 600 feet of pipe are installed per ton of heating and cooling capacity (1 ton = 12,000Btu/hour). The pipe may be coiled into the shape of a "slinky" in order to fit more pipe into a given trench area. The trench is then carefully backfilled to make sure no sharp rocks or debris damage the pipe. New horizontal boring machines can allow loops to be installed under existing buildings or parking lots.

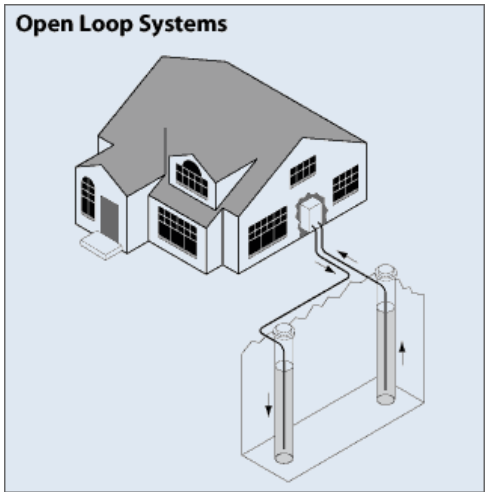
Vertical closed ground loop configurations are preferable for buildings with large heating and cooling loads, when the earth is rocky close to the surface, or for applications where space is limited. Contractors bore vertical holes in the ground 150 to 450 feet deep. Each hole contains a single loop of pipe with a U-bend at the bottom. After the pipe is inserted, the hole is backfilled or grouted. Each vertical pipe is then connected to a horizontal pipe, which is also concealed underground. The horizontal pipe then carries fluid to and from the geothermal heat pump(s). Vertical loops usually require less piping than horizontal loops because the earth deeper down is alternating cooler in summer and warmer in winter.



Vertical closed-loop (source: cogeneration.net)

Open Loop Systems

Open loop configurations are used less frequently, but may be employed cost-effectively if groundwater is plentiful. Open loop systems are the simplest to install and have been used successfully for decades in areas where local codes permit. The significant parameters that need to be evaluated when considering an open loop geothermal well system include: depth to water, porosity, specific yield, hydraulic conductivity, specific capacity, and what type of aquifer conditions are present (i.e., confined, unconfined, etc.). In this type of system, groundwater from an aquifer is piped directly from the well to the building, where it transfers its heat to a geothermal heat pump. After it leaves the building, the water is pumped back into the same aquifer via a second well — called a discharge well — located at a suitable distance from the first. This system requires a sand settlement water storage tank and filtration system requiring regular maintenance. (Source: Liepe, Dr. Paul C., Environmental Design + Construction Magazine, *January 16, 2001, available (as of 5/2009):* http://www.edcmag.com/Articles/Feature_Article/6786869a47697010VgnVCM100000f932a8c0____).



Open loop (source: cogeneration.net)

Design of open loop geothermal well systems requires detailed knowledge of the local hydrogeology and an understanding of the hydraulics involved with the piping and heat exchange portion of the system. The most critical aspect of the design involves the aquifer system from which groundwater is being withdrawn from and recharged to. Since the wells are the key to tapping and utilizing the groundwater, they need to be carefully sized and located. When designing these types of wells the usual aquifer parameters such as porosity, hydraulic conductivity, transmissivity, storativity and aquifer thickness, are sought out through research of published works about the local area, obtaining data from nearby existing wells or through conducting actual field tests. Conducting actual field tests is the most preferred and accurate method to obtain data specific to the project, but it can economically infeasible especially for smaller projects such as residential applications.

Other critical design criteria in open loop systems that can be investigated with field tests include water quality, depth to water, formation porosity (amount of open cell space created by material comprising aquifer), hydraulic conductivity (aquifer's ability to transmit water) and specific capacity (well efficiency).

Hybrid Systems

A hybrid system that combines geoexchange with a conventional boiler or cooling tower can be most cost effective when a building's heating and cooling requirements are substantially different. In a hybrid system, contractors size the ground loop in order to meet either the building's heating load or its cooling load, whichever is smaller. Depending upon the need, additional heating or cooling requirements beyond the

capacity of the geoexchange system are provided by a boiler (if the building's heating load is high) and / or a cooling tower (if the cooling load is high). A hybrid system uses a smaller loop than would otherwise be necessary, thus reducing the initial installation cost. A hybrid variation is the night evaporative system, in which cooling towers are used at night to expel excess heat that builds up in the loop as a result of heavy daytime use of the geoexchange system. This prevents the temperature of the fluid in the loop from losing its efficiency as a heat sink. Such systems may be ideal in climates where the days are unusually hot but the nights are cool, or where time-of-use rates are available from the local utility.

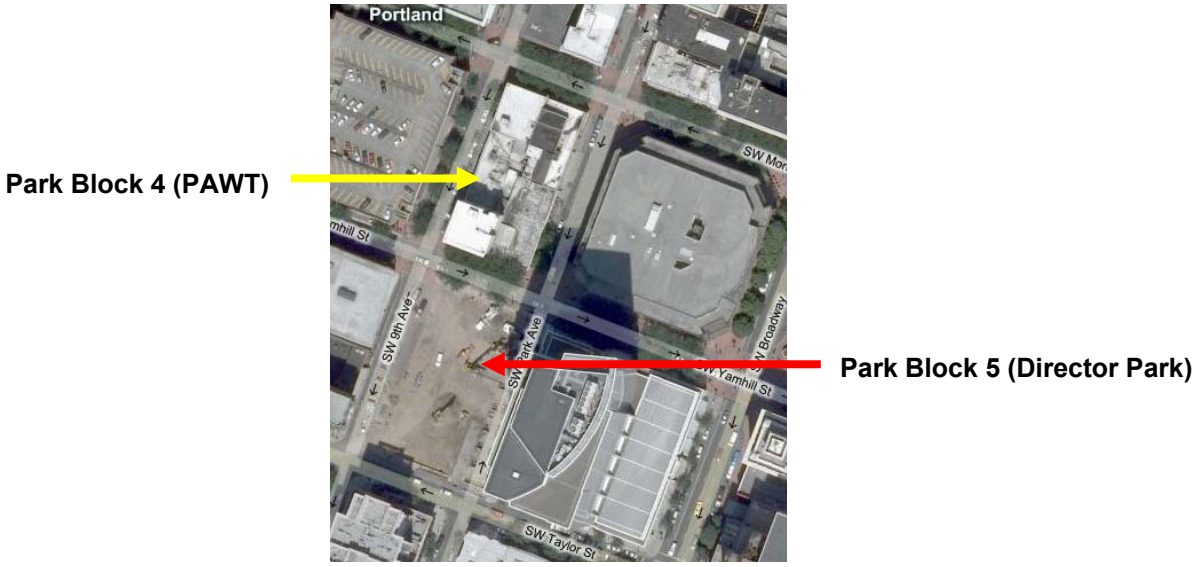
(Source: Boyce, Paul K. P.E. and Fitzsimmons, Doreen., Open Loop Geothermal Well Systems on Long Island, PW Grosser Consulting, available (as of 7/2009) http://www.geo.sunysb.edu/lig/Conferences/abstracts-03/boyce.htm):

PARK AVENUE WEST TOWER & GEOEXCHANGE – PRELIMINARY FEASIBILITY ASSESSMENT

Project Overview

Park Avenue West Tower (PAWT) was originally designed (at the time of the GIF award and the geoexchange evaluation) as a 33-story, 474,000 square foot mixed use building located on Park Block 4 bound by SW Yamhill Street, SW 9th Avenue, SW Morrison Street and Park Avenue, respectively in downtown Portland, Oregon. The original design included 6-stories of underground parking, 2-stories of retail, 20-stories of commercial office and 10-stories of for-sale condominium units. The building is located on a half-sized block 20,000-sf in area (.46 acres) and the building footprint is approximately 18,600-sf.

Park Block 5 neighbors PAWT to the south and was owned by TMT Development (TMT). TMT donated the surface development rights to the City of Portland to develop a public park that extends the greater South Park Blocks. TMT retained the subsurface rights and used this area to create additional underground parking capacity for the Fox Tower, directly adjacent and east of Park Block 5.



PAWT is TMT Development's first LEED project and the owner pursues a Platinum level of certification. In addition to the inherent and significant sustainability performance benefits of the project location's, the project will take a comprehensive green building approach to include onsite stormwater management, local and safe materials, water use reduction and energy efficiency among other strategies. Geoexchange was one of many potential measures identified to contribute to the project's sustainability and LEED performance.

Precedent Geoexchange Projects in Portland

Two precedent projects in the immediate area were examined to help estimate subsurface conditions at the PAWT project site, learn what approaches have been used downtown and to identify and avoid prospective issues experience by these projects.

Equitable Building, Portland (1948)
The Equitable Building system used two deep wells for supply from different aquifers (Troutdale gravel aquifer - upper = 150' deep at 195 GPM at 63 degrees) and one deep well for discharge (Columbia River basalt aquifer below it was 510' deep with 450 GPM at 57 degrees). This is no longer allowed – supply/discharge must be from same aquifer due to possible cross-contamination. The system also used surface discharge "pump and dump" which is also no longer allowed- projects must discharge in the supply aquifer. A rejection well was installed at a later date to make the system code compliant. The system reduced building energy use by 40% and worked very well for 50 years. The owner recently installed traditional air chillers (700-ton capacity) and decommissioned the system because the new (code complying) rejection well not adequately absorbing volume of water discharged. The City of Portland would have allowed discharge of "fresh water" into Willamette River but an underground pipe across Naito Parkway was not allowed. All equipment is still in place for inspection. The conclusion is that the reinjection well was not sized to align with the project's discharge volume and absorption rate limit of the Columbia aquifer.

PSU College of Engineering (2003)
The PSU College of Engineering system uses three wells (1 of which was added at a later date): one supply at 240' (Troutdale gravel aquifer), one supply at 130' and 1 (recently added) for injection discharge at 710' (Columbia river basalt aquifer). The supply water temperature is approximately 55 degrees and the building realizes 30-40% energy savings achieved, which exceeded expectations. The sedimentation filtration tank was 50% undersized which is causing multiple maintenance problems. Large GPM rates stir-up large quantities of aquifer sediment and, as a result, filter maintenance has greatly increased. There are multiple design and installation methodologies to help mitigate these problems that were not incorporated. The conclusion is that the supply well(s) sedimentation filtration tank system was 50% undersized and is causing on-going maintenance problems. The entire system cost was about $1 million (not including offsetting costs, i.e., cooling tower, boiler, etc).

Context - Subsurface Conditions
The PAWT project rests above the Troutdale gravel and the Columbia basalt aquifers and lower level 6 was estimated to be about 10-15 feet above the groundwater table, which is approximately 85 feet below the surface of neighboring Park Block 5. The Troutdale aquifer lies above the Columbia aquifer and is gravely in composition due to historical flood deposits. Temperatures in the Troutdale aquifer at 195 feet are approximately 63F. The underlying Columbia aquifer is composed of basalt and maintains temperatures closer to 55F.

For PAWT, it was recommended that the project use the deeper Columbia River basalt aquifer (500-700 feet) because it has less restrictive usage (Troutdale is a drinking water source), little flow variation (Willamette River Influence) and typically greater flow rates. An optimistic supply of 800-1000 gallons per minute (GPM), per well was identified. It is generally more difficult to recharge groundwater than to remove it, thus a coarse medium with a high percentage of void spaces lends itself more readily to diffusion of

reinjected water from an open loop geoexchange system. Most local open loop geothermal well systems are installed in the Troutdale and Columbia River aquifers.

Context – Regulations, Permits & Requirements

Permits required from the State of Oregon included a permanent water-rights permit from the Oregon Water Resources Department (due to "beneficial use" of water for thermal exchange) and an underground injection control (UIC) permit from the Oregon Department of Environmental Quality. Reinjection must occur in the same aquifer as the supply well by law. The UIC permit can up to 2 years to obtain but expediting options exist that can decrease this to 6 months. A temporary permit can be obtained first if a flow rate and peak heating and cooling analysis can show that the system will not detrimentally change or impact aquifer conditions.

If any of the system's wells are located outside the building envelope, the well(s) are required to be 50' from any sanitary or storm lines. If inside envelope there is no clearance required; however, the supply well needs to be located upstream and discharge well downstream if the direction of the flow is known. If the flow direction is not known, supply and return wells should be separated a minimum of 150'.

Proposed System Configuration

Based on assumptions about local aquifer conditions and water supply, the PAWT project proposed an open-loop, hybrid geoexchange configuration that would supply approximately 50% of heating and cooling through the geoexchange system with the remainder made up by a downsized cooling tower. The PAWT program was mostly comprised of office and retail which typically require a much greater volume of cooling than heating. It was assumed that the proposed configuration (described below) would reduce heating and cooling related energy by 40%.

The following is a general description of the proposed configuration:

The condenser water loop peak load at full buildout is 2,500 GPM. A hybrid geothermal system supplies a portion of this demand from geothermal wells, while the remainder is served by traditional cooling towers for peak loads. a) 1,200-gpm geothermal wells (extraction/injection) would handle 80 percent of the annual loads at full buildout and 50 percent of the peak loads at partial early occupancy (office, retail). b) 1,300 GPM would be served by a cooling tower. Boilers and cooling tower would be downsized and future ones shown (it wasn't anticipated for them to ever be needed, but it mitigated risk of undersupply).

The geoexchange system stood to significantly increase the efficiency of the residential watersource heat pumps as well as provide a highly efficient cooling source in the retail and office spaces. The two core building-level energy efficiency measures that would enable the efficiency gains of the geoexchange loop were the heat pumps and the system's heat exchanger:

Geothermal Heat Exchanger

This geothermal or ground water heat exchanger would serve the hydronic condenser loop in the building.

The geothermal loop would act as a heat sink in the warm summer months with the building's HVAC system dumping excess heat into the ground water. In the winter, the loop would act as a heat source with the stored heat being extracted. The presence of a geothermal heat loop in conjunction with high efficiency residential heat pumps leads to significant energy savings which help offset the substantial first cost.

A commercial ground-water source heat exchange loop:	
Total System Installed Cost:	$1,500,000
BETC Tax Credit	$500,000
GIF	$125,000
Energy Trust Rebate	$100,000
Early Rent Revenue	TBD
Boiler/Cooling Tower Reduction	$300,000
NET COST:	$475,000

Anticipated Costs and Incentives (October 2008)

The source of savings for this energy efficiency measure (EEM) is a large reduction in cooling and heating due to the increased efficiency of the water-source heat pumps:

Energy Savings		Cost Savings			
Annual Gas Savings, therm	Annual Electricity Savings, kWh	Annual Gas Savings, $	Annual Electricity Savings, $	Incremental Cost, $	Simple Payback, Years
7,146	687,473	$7,742	$45,854	$475,000	8.9

Anticipated Savings (October 2008)

Residential Heat Pumps

This measure determines the energy savings from switching from air-to-air to to high efficiency water source heat pumps (WSHPs) in the residential units. The basis of design for this EEM is the ClimateMaster Tranquility series of heat pumps. These heat pumps are characterized by very high efficiency, two-stage scroll compressors and ECM fan motors which can run over 50% more efficiently than standard motors. As a point of comparison, the following table represents the ClimateMaster Tranquility heat pump efficiencies as compared to an Oregon Code heat pump:

	Cooling EER	COP Rating
Oregon Code Baseline WSHP	12	4.2
ClimateMaster Tranquility	16	5.2

The cost for this measure is determined from previous project estimates:

	Quanity		Cost/Unit		Cost
ClimateMaster Tranquility WSHP	65	X	$1,600	=	$104,000
OR Code Baseline WSHP	65	X	$1,100	=	$71,500
			Incremental Cost:		$ 32,500

Anticipated Costs (October 2008)

The primary source of savings for this EEM is the reduced space cooling demand. A secondary source of savings is seen in the lower fan and pump energy usage due to the improved efficiency of the WSHP fan motors.

Energy Savings		Cost Savings			
Annual Gas Savings, therm	Annual Electricity Savings, kWh	Annual Gas Savings, $	Annual Electricity Savings, $	Incremental Cost, $	Simple Payback, Years
241	193,360	$274	$10,325	$32,500	3.1

Anticipated Savings (October 2008)

(Source: Interface Engineering, Park Avenue West Tower Final Energy Analysis Report, October 2008)

To further increase energy savings, a thermal management option of setting up separate aquifer storage zones in the subsurface for hot and cold water was also discussed. In the summer, waste water from the chillers can be injected into a specific aquifer and stored (the subsurface has very good insulation properties so the water stays relatively hot). Come winter, the hot water could be pulled back out at approximately 15 to 20F degrees warmer than ambient groundwater temperatures thus decreasing heating equipment demand. A separate aquifer could be used to store the cooled water generated during the winter for use next summer. The only additional cost is in constructing dual-purpose wells (wells you can inject into as well as pump out of). For PAWT, this translated to the cost of two more pumps and controls.

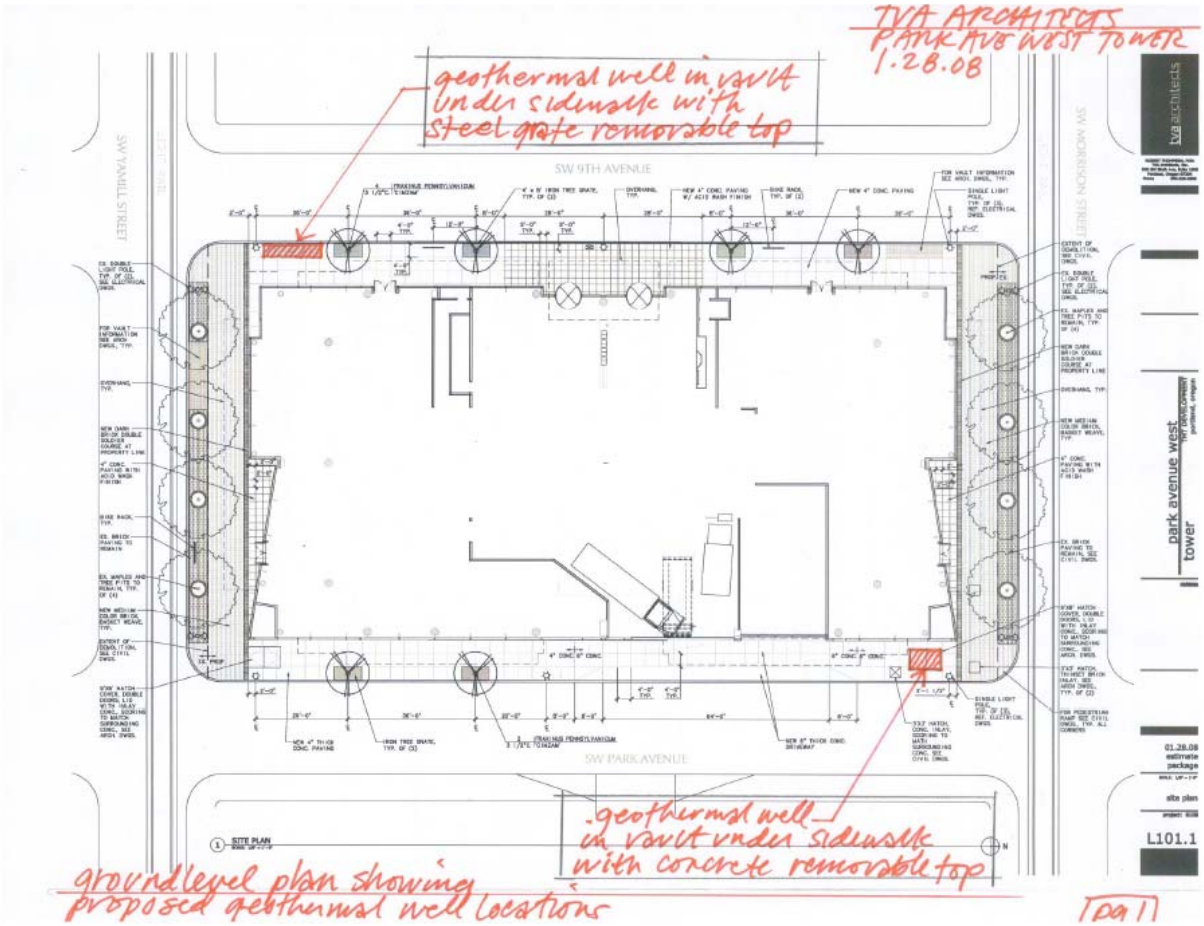
Anticipated Benefits

Early estimates anticipated that the geoexchange configuration would be approximately 40% more efficient than a baseline, code-compliant space conditioning system and save $100,000/year in related operating costs. Other anticipated benefits included downsized boilers, earlier occupancy (realized rent) for lower floors connected to the system, increased total building energy savings and additional energy-related LEED points (Source: Interface Engineering, *Memorandum: Hybrid Geothermal Heat Exchange Feasibility*, January 8, 2008). In addition to the GIF grant, the project also anticipated additional financial incentives from Energy Trust of Oregon and State of Oregon's Business Energy Tax Credit programs in support of evaluation and achievement of the project's anticipated energy performance (Interface Engineering, Park Avenue West Tower Energy Analysis Report, October 2008).

PAWT & GEOEXCHANGE – INTEGRATION OF GEOEXCHANGE INTO PROJECT DESIGN

The preliminary feasibility evaluation showed promise for the inclusion of a geoexchange system into the project. However, several challenges arose when the team initiated more in-depth logistical and technical evaluation of how the system could be integrated into the project design.

The proposed design that evolved from the preliminary evaluation included two 250 feet deep supply wells in the Troutdale aquifer at 500-600GPM each and two 700 feet deep 500-600GPM each discharge wells in the Columbia aquifer. Wells needed to be spaced a minimum of 200 feet apart and the initial approach was to locate the supply wells on the high side of the site at the corner of Yamhill and 9th Avenue. and the discharge wells at the low point of the site at the corner of Morrison and SW Park Avenue as indicated below:



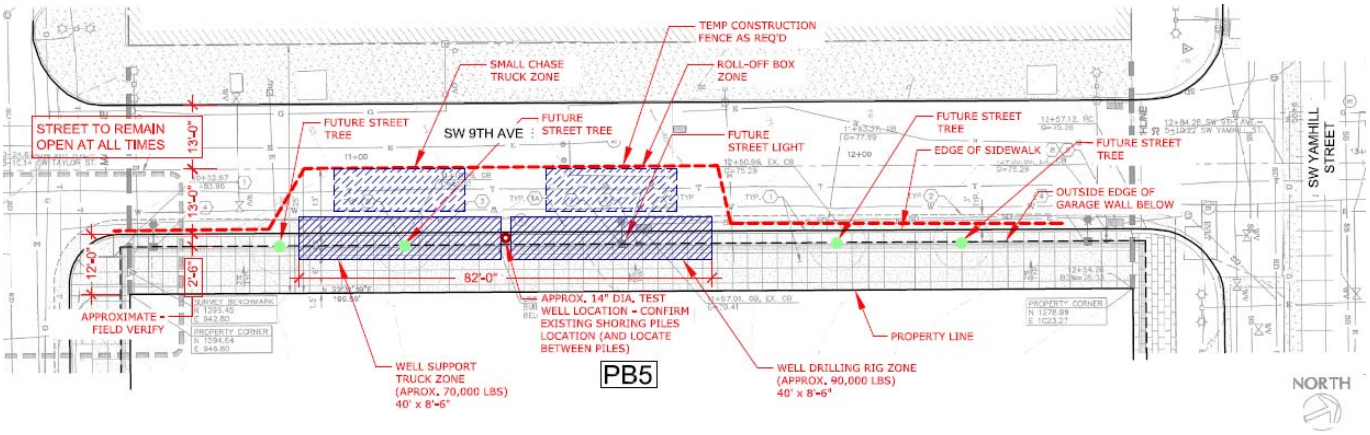
Initially proposed well locations

The wells were located outside of the excavation for the six levels of underground parking for PAWT due to anticipated 6-8 week project schedule impact if the wells were located inside excavation area. In addition to the schedule concerns, it was determined the wells could be located within the garage due to limited overhead clearance required for future maintenance. At this stage it was believed that any schedule impacts would be negligible if well excavation was located outside of building site.

As well location planning continued and became more detailed and discussions with well excavation contractors began, it became apparent that establishing wells adjacent to the building site would be more difficult than initially anticipated. Staging and spoils removal require a significant footprint and access to allow for drilling rig and centrifugal spoils containers. The drilling equipment weights would weigh in at over 160,000 lbs. and requires a staging area, with street access, of 82' x 20'. Providing drill rigs at proposed location on the corners of the site would have interfered with the MAX Light Rail line and vehicular and pedestrian access on both Yamhill and Morrison Streets.

In addition to the staging area issues, there were restrictions on the structural loading that could be supported by the shoring walls of the garage excavation. The drill rigs and spoils containers could not be supported by the shoring walls unless the staging area and equipment was moved further off the wall line. This only exacerbated the interference with MAX light rail line and vehicular and pedestrian access. At this point, the team explored options for moving the staging area to locations along SW Park and SW Ninth Avenues to minimize conflicts at the corner locations. This direction proved problematic in terms of the impact on the garage excavation staging and construction and ultimate schedule impact.

It became apparent that the test well construction on the Park Avenue West Tower site was not an option and the design team began brainstorming alternate test well locations. TMT Development owns below-grade land rights on the adjacent Park Block 5 site, home of the recently completed Fox Tower Parking Garage expansion with plans to connect this site to the Park Avenue West Tower site through a tunnel below SW Yamhill Street. The surface land rights of Park Block 5 were donated by TMT Development to Portland Parks and Recreation. So while the actual site could not be used for the wells, the design team explored options for locating the wells in the right-of-way (ROW) adjacent to Park Block 5. Two of the final wells would be located within the public right-of-way on the east side of Ninth Avenue adjacent to Park Block 5 approximately midblock between Yamhill and Taylor. These would be the initial test wells, which would be converted to permanent supply wells pending test results. The well heads, including pumping equipment, would be located in a vault below the sidewalk inside the curb line on 9th Street. The vault lid would remain accessible for maintenance, but could be set below sidewalk level to allow the park sidewalk paving to run uninterrupted.



Proposed well location at adjacent PB5

The supply piping would run direct from the vertical wells into the west wall of the existing below-grade parking structure on Park Block 5 and run through the garage and either:

a. route the well supply piping through a new tunnel into the Park Avenue West Tower below-grade parking structure; thereby reducing the necessary encroachment into the public right-of-way; OR,
b. route the well water piping below SW Yamhill Street ROW under a franchise agreement with Portland Department of Transportation (PDOT).

PDOT indicated that the Franchise Agreement process was a lengthy and complicated and that it would require a $5,000 application fee and a $10,000 annual maintenance fee. The geoexchange system was anticipated to generate proportionately minimal additional annual operating revenue for the owner and after considering the initial capital cost expenditure, it was determined that these incumbent fee costs made this option financially unviable.

PDOT would however approve a plan to run piping through the garage with a minor easement granted for the well, well access lid, and portion of pipe from the well into garage. Portland Parks and Recreation's schedule of construction for the Director Park (PB5) required the proposed well location be moved from the corner of SW Ninth Ave and Taylor Street to the opposite corner at SW Yamhill Street to avoid conflicts with ongoing park construction which would delay the test well. It appeared we were close to a solution when it was learned that the State of Oregon Water Resources Department (OWRD) concerns with well locations in public ROWs could be pacified with a letter of authorization from PDOT allowing the water rights process to proceed.

Further complications due to separate financing of the two adjacent properties precluded such an arrangement ultimately forcing the decision to abandon the geothermal system.

Due to these challenges, the geoexchange system was deemed unviable for the project and the feasibility analysis ended. The next stage in analysis would have included the drilling of a test well to learn the actual subsurface conditions, hydrologic flow rates of the two underlying aquifers and to inform system design. The test well was anticipated to cost approximately $1 million, and would have been functional in the final system if the well results yielded promising results.

CONCLUSION

Geoexchange is a proven means to achieve significant energy savings in buildings but requires early and thorough due diligence to be successfully integrated in high-rise building projects, particularly in dense urban areas. Spatial requirements are a strong driver in the creation of viable system configurations for projects with significant heating and/or cooling demand. For PAWT, this led to a series of multi-jurisdictional permitting, fee and on-site technical requirements that added capital and operational costs to the project. These requirements to make the system viable also yielded scheduling delays, which subsequently increase loan carrying costs and delay rent realization. Earlier execution of the preliminary feasibility assessment may have allowed sufficient time to integrate a geoexchange system into the design and have related discussions with approval agencies at a more impressionable stage in the project. This may have also created the opportunity to more readily integrate the evaluation, design, approvals and construction of the system into the project schedule.

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