MEMORANDUM

Date:	July 21, 2020	Project Number:	865.06.55
To:	Plumas Unified School District 1446 East Main Street Quincy, CA 95971 Attn: Kevin Nolen/CRM Group		
From:	Michael Leacox / Darcy Hinkley		
Subject:	Quincy JSHS Ground Source Heat Exchange System Feasibility Study		

Dear Mr. Nolan:

NCE is pleased to present this memorandum to CRM Group on behalf of the Plumas Unified School District (PUSD) that presents an estimate of probable costs to construct a ground source heat exchange system at the Quincy Junior/Senior High School (QJSH). NCE understands that PUSD is considering three different options to replace their existing HVAC system including a ground source heat exchange system, and a biomass or propane-fired boiler(s). To support this effort, we brought Ainsworth Associates Mechanical Engineers onto our team to support the evaluation of both horizontal and vertical ground loop options while NCE guided and prepared the civil engineering estimates for installation. NCE's scope of work was to look at the cost of installation of the ground source heat exchange equipment only and it is understood by PUSD that additional evaluations may be required to fully assess the overall cost of installing the system.

BACKGROUND

The existing mechanical system at QJSH is comprised of two diesel fired boilers that serve a heating hot water system. The boilers are nearing the end of their useful life and QJSH is considering replacing the system with a ground source heat exchange system. Ground source heat exchange systems circulate water or a water/antifreeze solution in a loop from underground to a heat pump to heat and cool. In order to heat and cool the QJSH using a ground source heat exchange system a large amount of land would be needed to install the loops in a horizontal or vertical configuration.

Adjacent to the main part of the school is an approximately 10- to 11-acre area that supports the athletic fields that serve QJSH. The athletic fields consist of a football field, two softball fields and a baseball field. The athletic fields at QJSH have poor drainage that leads to ponding water during both winter rains and summer irrigation. NCE performed an alternatives assessment to look at options to address the drainage issues and concluded that the alternative with the best outcome was to remove the athletic fields appurtenances, regrade the fields and re-install the athletic field equipment. Concurrently, PUSD is considering using the athletic fields at QJSH as the location for potential ground-source heat exchange system which would be installed prior to regrading. Accordingly, the appropriate sequencing would be to design the field layout and

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grades to include both the ground exchange heat system to avoid equipment conflicts, re-grade the field, followed by installation of the ground exchange heat system and then the athletic equipment.

As part of the drainage alternative assessment NCE drilled and logged 14 shallow borings and installed two piezometers to 10 feet. The soil data, and depth to water and groundwater temperatures measurements, were used to support the evaluation of the ground exchange system assessment.

METHODS

NCE conducted a literature search to ensure geothermal exchange systems operate efficiently in the Quincy area. The primary factors that influence the effectiveness and efficiency of a ground source heat exchange system include thermal conductivity, thermal diffusivity, saturation, and subsurface temperature. Thermal conductivity refers to soil/rock's ability to conduct heat. The higher the thermal conductivity the better the soil/rock conducts heat. Thermal diffusivity is the rate at which heat transfer occurs. The higher the thermal diffusivity the faster heat transfers to the soil/rock. Saturation is the amount of water in the pore space of the soil with more saturated material having greater thermal conductivity.

Ainsworth Associates then used estimated building loads for QJSH and conservative estimates of the thermal conductivity, thermal diffusivity, saturation, and subsurface temperature to estimate the amount of horizontal and vertical piping necessary to heat and cool the facilities with ground loop design software. Ainsworth also developed an estimate of probable costs to install the vertical ground source heat exchange system based on previous work. A copy of Ainsworth's evaluation is included as Attachment 1. NCE prepared an estimate of probable costs to install the horizontal system based on Ainsworth's estimate of horizontal piping needed. The estimates included costs for mobilization, excavation, bracing and shoring of the excavation, dewatering, and backfill/compaction. A copy of NCE's estimate is included as Attachment 2

RESULTS

The literature research indicated ground exchange heat pump systems have worked efficiently in the Quincy area and can be effective in reducing energy consumption. According to *Assessment of California's Low Temperature Geothermal Resources: Geothermal Heat Pump Efficiencies by Region* prepared by the California Energy Commission, geothermal heat pump systems can reduce energy consumption by approximately 50% in the Quincy area when compared to conventional HVAC systems.

To estimate the thermal conductivity and diffusivity at the Site the boring logs from the drainage alternatives for the Athletic Fields at Quincy JSHS were examined. These boring logs indicate shallow soils in the Athletic Fields are generally fine-grained, ranging from clay to sandy silt. Saturated soil is beneficial to the geothermal heat exchange process. Groundwater at the site is very shallow and ranges from 4.43 to 6.61-feet below ground surface indicating the geoloops would be in saturated soil. The literature research indicates thermal conductivities for saturated clay range from 0.5 to 1.3 $\frac{BTU}{hr-ft-°F}$ and thermal diffusivities range from 0.24 to 0.63 $\frac{ft^2}{day}$. The thermal conductivities and diffusivities from previous Ainsworth experience were also considered when developing the estimate for QJSH.

The assumptions used were as follows:

- Thermal Conductivity = 0.8 $\frac{BTU}{hr-ft-°F}$
- Thermal Diffusivity = 0.55 $\frac{ft^2}{day}$
- Average Ground Temperature = 62 °F

Based on these assumptions and an estimated 673 kBtus/hr of heating required, 4,600 feet of 1-inch diameter HDPE piping as 36-inch slinky loops in 10-foot deep trenches would be needed to adequately heat the facility. This could be installed as ten 460-foot trenches. If cooling were to be included, based on an assumed building load of 210 tons, 18,720 feet of the slinky loop piping would be needed to heat and cool the facility. This could be installed as 32 trenches that are 585-feet long. There is sufficient space available within the athletic fields for either option.

To install the ground loops in vertical boreholes, 150 boreholes 150-feet deep spaced 30-feet on center would be required to heat the facility and 252 boreholes 300-feet deep spaced 30-feet on center would be required to heat and cool the facility. There is sufficient space available within the athletic fields for either vertical option as well.

Rough order of magnitude costs also were developed based to install the horizontal and vertical geoloop options and are summarized in the table below.

Table 1: Estimated Geoloop Installation Costs

Type of Ground Loop	System Served	Trenching/Boreholes	Geoloop Cost	Trenching Cost	Total Cost
Horizontal	Heating	4,600 feet trenching	$150,000	$650,000 to $1,000,000	$800,000 to $1,150,000
Horizontal	Heating and Cooling	18,720 feet trenching	$500,000	$2,600,000 to $4,200,000	$3,100,000 to $4,700,000
Vertical	Heating	150 boreholes 150-feet deep	$1,000,000	NA	$1,000,000
Vertical	Heating and Cooling	252 boreholes 300-feet deep	$3,500,000	NA	$3,500,000

The estimated costs in Table 1 are based on conservative estimates of thermal conductivity and diffusivity. If PUSD chooses to proceed with either a horizontal or vertical geoloop system a thermal conductivity test would be necessary to design an appropriately sized system and refine the estimated costs.

Enclosures:
Attachment 1 – Ainsworth Associates Ground Loop Feasibility Study
Attachment 2 – NCE Estimate of Probable Costs QJSH Groundloop

Attachment 1

AINSWORTH ASSOCIATES GROUND LOOP FEASIBILITY STUDY

Plumas County School District
Quincy Junior-Senior High School
Ground Loop Feasibility Study
AAME Project #2020-028

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Executive Summary

This study presents the results of the analysis of potential geothermal heat exchange designs considered for the Plumas County School District Quincy Junior-Senior High School. The analysis takes into account horizontal geothermal ground loops and vertical geothermal ground loops (bore fields).

The existing mechanical system at the school is comprised of two diesel fired boilers that serve a heating hot water system. This heating hot water system then routes underground throughout the whole campus to each building and the respective mechanical equipment. Since these boilers are at the end of their useful life, the school district is looking to upgrade this central plant and is looking to geothermal ground loops as a potential replacement.

There was also some interest in looking into what it would take to include a potential cooling load in the new geothermal ground loop design in case the school wanted to add cooling to the buildings on campus in the future. So, four designs were considered: a horizontal ground loop that would serve just the existing heating load, a horizontal ground loop that would serve the existing heating load and a new cooling load, a vertical loop that would serve only the existing heating load, and a vertical loop that would serve the existing heating load and a new cooling load.

After designing the ground loops mentioned above, the results showed that the heating only loops were less expensive when compared to the heating and cooling loops. The overall lowest cost option was the heating only vertical ground loop. The horizontal ground loops were calculated to be slightly more expensive than the respective vertical loop options. An accurate representation of the total cost of these loops would need to include all components that go into furnishing the systems, such as underground piping, central plant equipment, air handling units, terminal units, etc.

MOTIVATION

The motivation behind this study is to provide a rough order of magnitude construction cost for a geothermal ground loop that could serve the existing Quincy Junior-Senior High School (JSHS). The school consists of nine buildings with a total of about 110,000 square feet. Currently, the existing school has only heating equipment. This heating equipment in each building is served by hydronic heating hot water coming from the boiler plant and routed underground where necessary. The boiler plant has two diesel fired boilers: one from 1949 and one from 1973. The boilers are coming to the end of their useful lives. So, it is imperative that the school looks for an upgrade of the central plant.

While the central plant is due for an upgrade, the fields on the north side of the campus have been experiencing drainage issues, which have led to over saturation of the fields. The district asked NCE to look at options to fix these drainage problems. As part of a separate project that is evaluating drainage alternatives for the Athletic Fields at Quincy JSHS, 14 borings were advanced throughout the Athletic Fields and two piezometers were installed. The boring logs from that investigation indicate shallow soils in the Athletic Fields are generally fine-grained, ranging from clay to sandy silt. The soils encountered consist of native material overlain by fill material. The fill material includes a yellowish clay from the surface to 0.5 to 1.5 feet below ground surface (bgs), underlain by either approximately 2 to 4-feet of red to red-gray silt or 2 to 4-feet of brown clay. A gray to black silt and a brown silt underlies these layers and appear to be native material. The lithology encountered is very suggestive of a cut and fill scenario and is consistent with personal accounts of the site being overlain with soil imported to the site. Groundwater at the Athletic Fields is very shallow and ranged from 4.43 to 5.22-feet bgs in June of 2019 and 5.56 and 6.61-feet bgs in June of 2020. Groundwater temperature in the piezometers ranged from 56.1°F to 58.1°F in June of 2020. After looking at the results of this project, the options NCE came up with were to regrade the athletic fields or perform targeted repair with the recommended approach to regrade. If improvements to the athletic fields were to take place, it may make sense to install a geothermal ground loop during the process.

This possibility of a geothermal ground loop yielded itself to specific designs for this loop. With the understanding that the school would potentially add cooling to the campus in the future, designing the geothermal ground loop so that it could incorporate potential cooling loads became part of the study. Additionally, a horizontal geothermal field of slinky pipes instead of vertical geothermal bore holes was considered. The four options considered in the cost analysis include:

- Horizontal slinky loop heating only
- Horizontal slinky loop heating and cooling
- Vertical loop heating only
- Vertical loop heating and cooling

METHOD

In order to adequately compare costs of geothermal ground loop designs, some assumptions had to be made including two critical items that include thermal conductivity and thermal diffusivity. Thermal conductivity measured at past test ranged from 0.76 to 1.34 $\frac{BTU}{hr-ft-°F}$ and thermal diffusivity ranged ranged from 0.54 to 0.91 $\frac{ft^2}{day}$. To estimate thermal conductivity and thermal diffusivity, the past test results from similar locations were combined with other resources, including USGS maps. Below are the assumptions used:

Thermal Conductivity = 0.8 $\frac{BTU}{hr-ft-°F}$

Thermal Diffusivity = 0.55 $\frac{ft^2}{day}$

Average Ground Temperature = 62 °F

The thermal conductivity and thermal diffusivity values used are on the lower end of the range and therefore are considered to be somewhat conservative.

Alongside these values, typical industry standard values for building loads for education type buildings were utilized. This resulted in building loads of 210 tons of cooling and 673 kBtus/hr of heating. These are the loads that were used in the ground loop calculations.

Once the assumptions were made, preliminary design of both horizontal ground loops and vertical ground loops was achieved using ground loop design software. The horizontal ground loop design consisted of 1-inch diameter HDPE piping in 36-inch overlapping loops (slinky loops) that are laid out in a trench. The assumed trench depth for this design was 10-feet. The trench depth of 10-feet was selected based on a number of different factors, including an assumed frost line of 5-feet below ground surface (bgs), as well as ideal placement for horizontal ground loops. The vertical ground loop consisted of a hairpin shaped loop of 1-inch diameter HDPE piping installed in a 5-inch diameter borehole grouted after pipe installation. The designs were then used to come up with associated costs and sizes for each loop design. By comparing the costs and feasibility of a ground loop that serves just heating loads or combined heating and cooling loads, potential overall costs and potential overall sizes for both horizontal loop and vertical loop designs were calculated.

These costs and sizes are preliminary only. If the school district elects to move forward with the design of a ground loop system, a thermal conductivity test for this site is strongly recommended. The results of this thermal conductivity test may differ from the presumed values and therefore affect the sizes and costs presented in this report

RESULTS

It is important to note that the prices associated with each field option are considered rough order of magnitude numbers and should not be considered final. The prices below take into account both materials and installation costs associated with each loop. The horizontal loop installation costs are on the conservative end of a range of values provided by NCE.

Type of Ground Loop	System Served	Field Dimensions	Square Feet of Field	Cost
Horizontal	Heating	200' x 460'	92000	$1,150,000
Horizontal	Heating and Cooling	480' x 585'	280800	$4,700,000
Vertical	Heating	210' x 510'	110000	$1,000,000
Vertical	Heating and Cooling	390' x 510'	200000	$3,500,000

For the horizontal fields, heating only is made up of 10 slinkys with a 36-inch diameter, a length of about 460 feet, and spaced 20 feet apart (center of slinky to center of slinky). The heating and cooling option is made up of 32 slinkys with a 36-inch diameter, a length of about 585 feet, and spaced 15 feet apart. The costs for trenching included in the overall cost shown in Table 1 took into account the minimum dimensions for a slinky loop trench at ten feet deep, three feet wide, and at the listed separation distance. For the vertical fields, the heating only field is made up of around 150 bores spaced 30 on-center (O.C.) at 150 feet deep. The heating and cooling option is made up of around 252 bores spaced 30 ft O.C. at 300 ft deep. The costs included within the pricing calculation take into account the materials, drilling costs, and installation costs. The drilling and installation portion is the bulk of the cost compared to the cost of materials.

The horizontal fields both look to be the more expensive designs. More specifically, the heating and cooling option proved to be the most expensive design. Since the campus would have a dominant cooling load throughout the year, including this load makes the geothermal ground loop larger. Looking at the costs for the vertical fields, you see that these fields are slightly less expensive than the horizontal fields. For the same reasons as the horizontal fields, the vertical field that serves only the heating of the campus is smaller than the geothermal loop that would serve both the cooling and heating loads of the campus.

In order to decide between a horizontal and vertical loop, cost and location both play a part. Based on the fact that shallow soil borings have already been advanced in the Athletic Fields for the recommended horizontal loop trench depth, there is already some understanding to what will go into trenching the athletic fields. Without a thermal conductivity test, there is no way to know what the ground is like for vertical bores (i.e. composition, temperature, thermal conductivity/diffusivity). Drilling could be more complicated than assumed. All this said, since the prices between the loops are so similar, it is hard to say at this point which loop would be most cost effective. One of the obvious conclusions is that heating loops are going to be less expensive than the heating and cooling loops.

It should be understood that the ground loop serves as only one component of the full mechanical system. Other mechanical equipment that would couple the loop includes the following. For the heating only systems, water to water heat pumps would be installed at the current central plant location. The heat pumps would produce heating hot water that would then be distributed to new campus HVAC equipment that would accept 130˚F water through underground piping. The cooling and heating system would look similar, with some differences. The water to water heat pumps would produce chilled water and heating hot water that would be distributed to new campus HVAC equipment through underground piping.

This potential system mentioned above could merit a phased-in approach. Once the ground loop is installed, the existing HVAC equipment will not be able to utilize the water coming from the loop as is. The ground loop can only provide 130˚F water; the existing HVAC equipment that serves the multiple buildings accepts 180˚F water. In order to utilize the ground loop right away without installing new equipment everywhere, there would need to be a supplemental boiler installed to bring the heating hot water from the field up to a temperature that can be used by the existing equipment. The supplemental boiler can then be phased out in the future if the existing HVAC equipment is replaced with new equipment that can accept 130˚F water.

CONCLUSION

For the Plumas County School District Quincy Junior-Senior High School, the heating only geothermal ground loops were calculated to be the less expensive options. This is due to the fact that the school does not currently have cooling equipment. So, if the cooling load is included in the design of the geothermal ground loop, then the field ends up being larger. The prices listed for horizontal loops and vertical loops were pretty similar when comparing heating to heating and heating/cooling to heating/cooling. Having a better understanding of the ground and future plans for the campus would allow for a better understanding of which field would be most cost effective.

Attachment 2

NCE ESTIMATE OF PROBABLE COSTS

General Assumptions:

Inflation Factor	1.089666
Location Factor (Susanville)	1.159
Contingency	1.25
Mobilization	10%

SCENARIO 1: HEATING ONLY

value	**units**	**notes**	
10	trenches		
460	ft/trench		
36	inch	minimum trench width	
48	inch	actual trench width	
4600	ft	total length	
10	ft	depth	
Excavation			
$ 5.55	$/LF	Excavating trench, 10' to 14' deep 1 C.Y. excavator	
$ 4.13	$/LF	Excavating trench,10' to 14' deep 1-1/2 C.Y. excavator	
$ 18,998		Cost of excavation	LOW
$ 22,264		Cost of excavation	MEDIAN
$ 25,530		Cost of excavation	HIGH
Bracing and Shoring			
460	LF	of bracing and shoring	
10	LF	deep	
2		walls	
9200	SF	wall	
$ 1.26	$/SF /day wall	Shoring by S.F./day trench wall protected loose mat., 4' width	
$ 0.55	$/SF /day wall	Hydraulic shoring, S.F. trench wall protected stable mat., 4' width	
$ 12.62	days	Estimate of excavation days (540 BCY/day)	
30	days	with open excavation	
$ 151,800		Cost of bracing and shoring	LOW
$ 249,780		Cost of bracing and shoring	MEDIAN
$ 347,760		Cost of bracing and shoring	HIGH
Dewatering			
	Given:		
	sandy silt soil type		
	5' depth to groundwater		
	10' trench depth		
30	days of dewatering		
4	pumps		
$ 1,250	$/day	Dewatering systems,6" centrifugal pump used for 8 hours	
$ 150,000		Cost of dewatering	LOW
$ 150,000		Cost of dewatering	MEDIAN
$ 150,000		Cost of dewatering	HIGH
Backfill and Compaction			
$ 2.66	$/LCY	Dozer backfilling, trench, up to 300' haul	
$ 4.40	$/ECY	Compacting backfill, 6" to 12" lifts, sheepsfoot roller	
230,000	LCF	Volume excavation loose	
8,519	LCY	Volume excavation loose	
6,815	ECY	Volume excavation compacted (embankment cubic yards)	
$ 52,644.44		Cost of backfill and compaction	

SUMMARY

	LOW	MEDIAN	HIGH
Mobilization/Demobilization	$ 37,344.24	$ 47,468.84	$ 57,593.44
Excavation	$ 18,998	$ 22,264	$ 25,530
Bracing and Shoring	$ 151,800	$ 249,780	$ 347,760
Dewatering	$ 150,000	$ 150,000	$ 150,000
Backfill/Compaction	$ 52,644.44	$ 52,644.44	$ 52,644.44
TOTAL UNADJUSTED	$ 410,787	$ 522,157	$ 633,528
TOTAL ADJUSTED	$ 648,000.00	$ 824,000.00	$ 1,000,000.00

Other Assumptions

1. Actual trench width of 48"
2. Excavation time based on 540 BCY/day per RS Means for 1.5 CY bucket
3. No rock is encountered.
4. Bracing and shoring is only required for one trench at a time.
5. Pressure testing can be accomplished with one trench open at a time.

General Assumptions:

Inflation Factor	1.089666
Location Factor (Susanville)	1.159
Contingency	1.25
Mobilization	10%

SCENARIO 2: HEATING AND COOLING

value		units	notes	
	32	trenches		
	585	ft/trench		
	36	inch	minimum trench width	
	48	inch	actual trench width	
	18720	ft	total length	
	10	ft	depth	
Excavation				
$	5.55	$/LF	Excavating trench, 10' to 14' deep 1 C.Y. excavator	
$	4.13	$/LF	Excavating trench, 10' to 14' deep 1-1/2 C.Y. excavator	
$	77,314		Cost of excavation	LOW
$	90,605		Cost of excavation	MEDIAN
$	103,896		Cost of excavation	HIGH
Bracing and Shoring				
	585	LF	of bracing and shoring	
	10	LF	deep	
	2		walls	
	11700	SF	wall	
$	1.26	$/SF /day wall	Shoring by S.F./day trench wall protected, 4' width	
$	0.55	$/SF /day wall	Hydraulic shoring, S.F. trench wall protected, 4' width	
$	51.36	days	Estimate of excavation days (540 BCY/day)	
	105	days	Excavating	
$	675,675		Cost of bracing and shoring	LOW
$	1,111,793		Cost of bracing and shoring	MEDIAN
$	1,547,910		Cost of bracing and shoring	HIGH
Dewatering				
		Given:		
		sandy silt soil type		
		5' depth to groundwater		
		10' trench depth		
	105	days of dewatering		
	4	pumps		
$	1,250	$/day	Dewatering systems, 6" centrifugal pump used for 8 hours	
$	525,000		Cost of dewatering	LOW
$	525,000		Cost of dewatering	MEDIAN
$	525,000		Cost of dewatering	HIGH
Backfill and Compaction				
$	2.66	$/LCY	Dozer backfilling, trench, up to 300' haul	
$	4.40	$/ECY	Compacting backfill, 6" to 12" lifts, sheepsfoot roller	
	936,000	LCF	Volume excavation loose	
	34,667	LCY	Volume excavation loose	
	27,733	ECY	Volume excavation compacted (embankment cubic yards)	
$	214,240.00		Cost of backfill and compaction	

SUMMARY

	LOW	MEDIAN	HIGH
Mobilization/Demobilization	$ 149,222.86	$ 194,163.73	$ 239,104.60
Excavation	$ 77,314	$ 90,605	$ 103,896
Bracing and Shoring	$ 675,675	$ 1,111,793	$ 1,547,910
Dewatering	$ 525,000	$ 525,000	$ 525,000
Backfill	$ 214,240	$ 214,240	$ 214,240
TOTAL UNADJUSTED	$ 1,641,451	$ 2,135,801	$ 2,630,151
TOTAL ADJUSTED	$ 2,591,000	$ 3,372,000	$ 4,152,000

Other Assumptions

1. Actual trench width of 48"
2. Excavation time based on 540 BCY/day per RS Means for 1.5 CY bucket
3. No rock is encountered.
4. Bracing and shoring is only required for one trench at a time.
5. Pressure testing can be accomplished with one trench open at a time.