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CONSULTANT REPORT

Modoc Joint Unified School District Geothermal Expansion Project

Prepared for: **California Energy Commission**
Prepared by: **Modoc Joint Unified School District**

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PREFACE

The California Energy Commission's Geothermal Grant and Loan Program is funded by the Geothermal Resources Development Account and provides funding to local jurisdictions and private entities for a variety of geothermal projects.

Modoc Joint Unified School District Geothermal Expansion Project is the final report for the Geothermal Grant and Loan Program Agreement Number GEO-16-001, conducted by Modoc Joint Unified School District. The information from this project contributes to the Geothermal Grant and Loan Program's overall goals to:

- Promote the use and development of California's vast geothermal energy resources.
- Mitigate any adverse impacts caused by geothermal development.
- Help local jurisdictions offset the costs of providing public services necessitated by geothermal development.

For more information about the Geothermal Grant and Loan Program, please visit the Energy Commission's website on the Geothermal Grant and Loan Program webpage (http://www.energy.ca.gov/geothermal/grda.html), or contact the Energy Commission's Renewable Energy Division toll-free in California at 844-454-2906 and outside California at 916-653-0237.

ABSTRACT

The City of Alturas, California and the surrounding areas in Modoc County have extensive geothermal resources. This resource provides a sustainable heat source that does not burn fossil fuels or use large amounts of electricity, puts the heating costs under local control, brings revenue into the local area, and provides cost savings for the Modoc Joint Unified School District (MJUSD).

MJUSD has been using geothermal resources to heat portions of their schools since the early 1990s. In 2018, they completed a project to construct the necessary piping and other components to provide a functional geothermal heating system for all the school buildings. Funding was not available at that time to complete all building retrofits, so the system operated at only 60 percent of its potential.

The California Energy Commission funded this project to construct and complete additional building retrofits and control system installations at three school campuses to optimize the heating system performance. Since the geothermal resource still had additional capacity, this project also extended the geothermal piping to the site of the new Modoc Medical Center, allowing that facility to connect to the geothermal resource.

The system, which is now fully operational in all the school buildings, because of this project, is estimated to save MJUSD approximately $85,000 during the 2019-2020 heating season, up from $70,000 saved in the 2018-2019 heating season. An additional savings of $3,000 annually will come from the use the fiber optic cable, installed for the geothermal system and used for their computer network connection between the schools.

Once the Modoc Medical Center system is online, the center will save approximately $16,000 annually by using the geothermal system instead of purchasing heating oil. MJUSD will receive an estimated $20,000 in annual revenue from the Medical Center for providing geothermal heat. MJUSD is expected to save as much as $6.5 million over the estimated 30 year life of the system, considering an initial diesel oil cost of $3.07 per gallon, a heating cost inflation rate of 3.5 percent per year and the completion of the Modoc Medical Center and the planned skilled nursing facility. The additional energy savings, the use of the fiber optic cable, and revenue from the medical facility will allow MJUSD to spend more on education and public programs and to purchase important items such as equipment, supplies, books, and technology instead of heating oil every year for the life of the system, which could be over 30 years

MJUSD successfully completed a project that can serve as a model for other small, rural communities that want to use their local geothermal resources, save money, and reduce greenhouse gas emissions.

Keywords: geothermal, Modoc County, Alturas, direct use geothermal, retrofit

Anderson, Darryl and Brian Brown. (Anderson Engineering & Surveying, Inc. and Brian Brown Engineering on behalf of Modoc Joint Unified School District), 2019. ***Modoc Joint Unified School District Geothermal Expansion Project.*** California Energy Commission. Publication Number: CEC-300-2020-009.

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Introduction

Using direct source geothermal groundwater for heating is not a new concept. It involves transferring heat from hot groundwater to a building system's heating water using a heat exchanger. Geothermal water is circulated from a production well to a heat exchanger to heat a closed-loop building heating water system. After the heat is transferred to the building's heating system, the water is re-injected back into the groundwater source through an injection well. Using an injection well minimizes water loss and avoids contamination of the surface water as the water is re-injected into the same water body from where it came.

Efficiently using natural heat from the earth is a sustainable heat source that does not burn fossil fuels or use large amounts of electricity. This heating concept may be relatively straight forward, but executing geothermal projects, including the associated infrastructure, is not simple.

The city of Alturas, California and the surrounding areas in Modoc County have extensive geothermal resources. The Modoc Joint Unified School District (MJUSD) has been using geothermal water to heat portions of their schools since the early 1990s. Using this sustainable natural resource puts the heating costs under local control, reduces costs and greenhouse gas emissions by avoiding petroleum-based heating oil purchases and use, brings revenue into the local area, and allows the MJUSD to apply the savings toward educational opportunities in Modoc County that will benefit the approximately 800 students in these schools.

In 2018, MJUSD successfully completed a project to use the geothermal resources for heating in all the three schools' buildings with the construction of an injection well and installation of geothermal piping to connect the production well to three schools. The project also installed basic system controls and constructed some retrofits to the heating systems in the schools. However, funding was not available to complete all the retrofits or install all the control systems and the system was operating at approximately 60 percent of its potential. This project completed the rest of the retrofits and installation of remaining control systems and the system is now operating at 100 percent of its potential.

Purpose

The purpose of this project was to expand on the 2018 project by completing the school building retrofits and installing additional control systems to allow the system to operate at its full potential. Since the geothermal resource had additional capacity that was not fully utilized by the school buildings, this project also extended the geothermal piping to the site of the new Modoc Medical Center, allowing that facility to connect to the geothermal resource and provide the district an additional revenue source.

Objectives

The scope of the project was to construct a geothermal piping extension to serve the Modoc Medical Center and to complete the necessary retrofits in the school buildings to optimize the heating system performance.

The project included the following objectives:

- Design and construct retrofits to the heating systems at the High School campus to better utilize the geothermal resource and increase system efficiency.
- Design and construct retrofits to the heating systems at the Middle School campus to better utilize the geothermal resource and increase system efficiency.
- Design and construct retrofits to the heating systems at the Elementary School campus to better utilize the geothermal resource and increase system efficiency.
- Design and construct the extension of geothermal piping to the new Modoc Medical Center Facility.

Conclusions and Recommendations

The tasks for this grant agreement were successfully completed, resulting in an optimized geothermal heating system that provides heat to the three school campuses. The geothermal piping was extended to the Modoc Medical Center site and this facility will be connected to the system as soon as construction of the facility is complete.

MJUSD saw a significant reduction, almost double what was expected, in heating costs after the completion of the first project, saving $70,000 during the 2018-2019 heating season. These savings were calculated by comparing the amount budgeted for heating costs (based on the conventional methods of electricity and fuel oil used prior to the geothermal system) with the actual amount paid for electricity and fuel oil during the heating season.[1] Now that the system is fully operational in all buildings, MJUSD estimates heating cost savings for the 2019-2020 heating season will be $85,000. An additional savings of $3,000 per year will also be possible because MJUSD can use the fiber optic cable installed for the geothermal system for their computer network connection between the schools.

MJUSD will be selling geothermal heat to Last Frontier Healthcare District (LFHD) to heat the Modoc Medical Center, resulting in approximately $20,000 per year additional revenue for the school district. With the additional $15,000 in heating costs savings, the $3,000 in communication savings, and the $20,000 heating sales revenues combined, this project adds an additional $38,000 a year to the school district, on top of the $70,000 a year savings from the first project. In total, the district is now realizing nearly $110,000 a year in benefits because of the two projects.

This project was ultimately a tremendous success, but it did present numerous challenges. Retrofitting the existing building systems as much as possible and using equipment from the 1992 geothermal project did reduce costs, but also extended the project time and required extensive coordination between the designers and the contractors during the installation process. One of the biggest challenges was that old pipes developed leaks that then had to be repaired and some equipment also required repair or replacement. The need to repair and replace old pipes and equipment was not anticipated to the extent that occurred. Retrofitting existing systems, if possible, can be a good cost saving option, but it does result in a more

[1] Heating cost savings were estimates based upon heating season costs which coincide with fiscal years, not calendar years. All annual savings numbers are for fiscal years, not calendar years. Likewise, discussed annual expenditures are for fiscal years, not calendar years.

complicated construction process, and based on lessons learned it is recommended that the likelihood of needing to replace additional piping and equipment that is disturbed as a result of the project be considered.

Even with the cost savings from retrofitting existing equipment, MJUSD would not have been able to complete this project without the grant funding received from the California Energy Commission (CEC). Despite the savings potential, the total cost of nearly $5 million ($4 million from the CEC and $1 million in match funding) for both phases was too high for MJUSD to finance the project on their own.

Another potential opportunity stemming from this project would be to connect the high school campus greenhouse and, in the future, perhaps a planned senior center with the geothermal system.

Benefits to California

Despite the challenges encountered, this was a successful project that showed direct source geothermal heating projects are a viable option for rural communities with available geothermal resources. The project also showed that existing heating systems can be retrofitted to operate with geothermal water.

MJUSD is estimated to save $6.5 million in energy costs over the life of the system, which is likely to last as long as 30 years. Serving approximately 800 students throughout Modoc County, MJUSD plans to use the savings to fund a variety of things including: field trips to colleges, increase student access to technology, provide professional development for staff, hire additional staff to meet the increasingly complex needs of students, and fund field trips to enhance student career options. The revenues received from LFHD will go into the school district general fund and be available to purchase equipment, supplies, books, and technology. MJUSD also plans to use the heating system to help teach students about geothermal resources and their applications. Kindergarten through high school students will be able to learn about geothermal resources in the classroom and then actually see how a functioning system operates.

LFHD would be expected to spend nearly $36,000 a year for heating with conventional fuels but will save approximately $16,000 per year by using the geothermal system for heating. These savings can be used to provide enhanced medical services for Modoc County. Since LFHD will be purchasing the geothermal heat from MJUSD, the partnership will also result in additional revenue for MJUSD, approximately $20,000 per year.

MJUSD successfully completed a project that can serve as a model for other small, rural communities that want to use their local geothermal resources. Often designers are not aware of existing geothermal resources or are unfamiliar with their application. This project can serve as an example to other communities with a similar geothermal resource and needs. Other projects have successfully heated schools with a resource temperature as low as 120°F (49°C).

Although there are large capital expenses associated with production and injection wells, geothermal heating can provide significant cost savings when analyzed over the lifetime of the system and if supported with grants. Despite these cost barriers, small communities can still successfully complete geothermal heating projects with funding assistance from programs like the Geothermal Grant and Loan Program.

Further, as the need to lower greenhouse gas (GHG) emissions increases, projects like this can play an important role by eliminating fuel oil and associated emissions. The geothermal system will reduce MJUSD’s diesel fuel oil usage by 30,000 gallons per year and LFHD’s diesel fuel oil usage by about 12,400 gallons per year. This will reduce greenhouse gas emissions by 305 metric tons per year for MJUSD and 126 metric tons per year for LFHD, based on a reduction rate of 0.01018 metric tons per gallon of diesel.

CHAPTER 1: Project Overview

Introduction

This project builds upon earlier CEC work with the MJUSD using direct source geothermal groundwater for heating.[2] Such projects have been successful in many areas that have geothermal heat resources, including Alturas, California; Klamath Falls, Oregon; Boise, Idaho; and Lakeview, Oregon. The concept involves using the naturally occurring hot groundwater to heat a hydronic heating system in a building via a heat exchanger, which transfers heat to the building system's heating water. The geothermal water is pumped and extracted from the supply or production well to the heat exchanger. Heat is transferred to the building's hydronic system, and then the geothermal water is injected back into the aquifer through an injection well. Re-injection ensures minimal net water loss or aquifer stress. An injection well is also required because geothermal water contains contaminates such as high chloride levels that cannot be discharged into surface water.

Direct source geothermal heating provides a sustainable heat source without burning fossil fuels or using large amounts of electricity in resistance type heating. In this closed-loop system there are no concerns of water contamination when discharging geothermal water into surface water because the geothermal water is moving from one location to another within the same aquifer. Efficiently using natural heat from the earth does not result in any carbon emissions, unlike burning fossil fuels.

The City of Alturas, California and the surrounding areas in Modoc County have extensive geothermal resources, which continue to be underutilized. Sufficient capacity exists to provide heating for the Alturas schools and other public facilities, but funding and cost barriers have historically prevented these resources from being fully developed. The continued increase in the cost of conventional heating methods, such as diesel, propane, and electricity, has intensified the need to develop sustainable, cost effective heating alternatives for area schools and public facilities. Geothermal heating systems also provide significant environmental benefits because they produce fewer harmful emissions than conventional methods. Using this sustainable natural resource puts heating costs under local control, brings revenue into the local area, and allows the Modoc Joint Unified School District (MJUSD) to spend the savings for better educational opportunities in Modoc County.

In 1992, MJUSD constructed a geothermal production well with associated piping and controls in Modoc Middle School (Middle School) and Alturas Elementary School (Elementary School). The 1992 project was never fully completed, and an injection well was not constructed, so the system could not be operated. In 2018 with funding from the CEC, MJUSD successfully completed a project to use the geothermal resources for heating in all the school buildings.

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[2] Much of this introduction sections draws directly from the Geothermal Grant and Loan project GEO-14-002: *Design and Construction of Alturas Schools Geothermal Heating Project*. California Energy Commission. Publication Number: CEC-300-2020-003

The 2018 project constructed an injection well and installed geothermal piping to connect MJUSD's production well to Modoc High School (High School), Modoc Middle School, Alturas Elementary School, and the injection well. The project also installed basic system controls and constructed some retrofits to the heating systems in the schools. Sufficient funding was not available to complete the retrofits or install all control systems and the system was operating at approximately 60 percent of its potential.

Project Purpose

The purpose of this project was to expand on the 2018 project by completing the school building retrofits and installing additional control systems. Since the geothermal resource had additional capacity that was not fully utilized by the school buildings, this project also extended the geothermal piping to the site of the new Modoc Medical Center, allowing that facility to connect to the geothermal resource. The project included the following objectives:

- Design and construct retrofits to the heating system at the High School to better utilize the geothermal resource and increase system efficiency.
- Design and construct retrofits at the Middle School to better utilize the geothermal resource and increase system efficiency.
- Design and construct retrofits at the Elementary School to better utilize the geothermal resource and increase system efficiency.
- Design and construct the extension of geothermal piping to the new Modoc Medical Center Facility.

Partnership with Last Frontier Healthcare District

Last Frontier Healthcare District (LFHD) has shown a strong commitment to developing geothermal resources in the Alturas area and supported MJUSD's 2018 geothermal project, even contributing $35,000 toward the construction of the injection well. LFHD collaborated with MJUSD in developing the grant application for this project and contributed 22 percent of the required match contribution. The geothermal piping extension connects the MJUSD piping network to the medical facility. The Modoc Medical Center will be able to use the geothermal system for heating once the facility construction is complete. The geothermal heating system will also have sufficient capacity to heat future buildings at the medical center site. There are plans to construct a skilled nursing facility in the future which would also be heated by the geothermal system.

The medical facility construction will not be complete until July 2020, but the facility may start using the geothermal system earlier, to provide heating during the construction process. MJUSD developed a use agreement with LFHD. The use agreement includes the cost calculation for determining what LFHD will pay MJUSD for the heat and cover the procedure for metering devices and determining heat usage. Maintenance responsibilities will also be included in the agreement. LFHD would be expected to spend nearly $36,000 a year for heating with conventional fuels but will save approximately $16,000 per year by using the geothermal system for heating. Since LFHD will be purchasing the geothermal heat from MJUSD, the partnership will also result in additional revenue for MJUSD, approximately $20,000 per year.

Project Layout

This project includes buildings located at the High School campus, Middle School campus, and Elementary School campus. The production well, Well AL-2, is located at the Middle School campus. The injection well, Well AL-4, is located near the airport. The Modoc Medical Facility site is located north of the Elementary School campus. Figure 1 shows the location of the various project sites as well as the constructed pipe route.

Figure 1: Project Map

Source: Anderson Engineering & Surveying, Inc.

CHAPTER 2:
Project Design and Construction Bidding

Geothermal Piping Extension Design and Construction Bidding

The geothermal piping extension phase of the project consisted of installing approximately 2,700 lineal feet of insulated ductile iron piping to connect the existing MJUSD geothermal piping to the new Modoc Medical Center facility, expected completion July 2020. The piping connects to MJUSD's existing piping system at 8th Street and Nagle Street and extends along Nagle Street to the new medical facility site. MJUSD worked closely with LFHD during this phase of the project.

Pre-Design

MJUSD's design subcontractor, Anderson Engineering & Surveying, Inc. (AES), worked with representatives of LFHD to determine the best route for the pipe extension. AES also worked with members of the medical facility design team to make sure the medical facility connections and equipment would be compatible with MJUSD's geothermal system.

Final Design

Once the route was finalized AES prepared final design drawings and specifications for the pipe extension portion of the project. The extension tied into the existing geothermal piping at the intersection of 8th Street and Nagle Street. Valves had been installed at this location during the previous project so the extension could be easily connected to the existing system piping. From there the piping could extend straight along Nagle Street to the medical facility site. AES coordinated with the medical facility design team to determine the location of the mechanical room, where the geothermal piping would be housed. AES specified 6" pipe to provide enough capacity for future connections. LFHD may construct a long-term care facility near the Modoc Medical Facility, so the piping extension design included installation of a tee in the piping so a future facility could be connected.

Construction Bidding

The geothermal piping extension was included in the site work contract for the new medical facility. AES provided the design drawings and specifications to LFHD and this information was included in the bidding documents for the medical facility site work. LFHD awarded the contract to White Bear Construction, Inc. The geothermal piping extension portion of the work was listed as a separate bid item so that it could be tracked separately from the other site work.

Building Retrofit Design and Construction Bidding

The building retrofit component of the project included additional improvements to the heating systems in the school buildings. Sufficient funding was not available to complete these improvements during the previous project funded in 2014. An earlier project in 1992 installed piping and related heating equipment but was not completed because reinjection of the geothermal fluid was not available.

Pre-Design

The pre-design phase included detailed inspections of the buildings to determine exactly what was needed to optimize the geothermal heating system performance. These inspections were initially performed by AES and their mechanical subcontractor, Brian Brown Engineering, in October 2016. The inspections focused on the capacity and control of the existing heating equipment. Due to use of some piping and equipment from the incomplete 1992 project, several buildings also required additional bracing for the existing geothermal piping and equipment. Bracing was required because the original project was not completed to the specifications required by the California Division of the State Architect (DSA). The bracing needed to be completed before DSA would issue approval for the retrofits.

Final Design

The inspections performed during the pre-design phase were the basis of the development of the following final design elements under this CEC grant:

- Complete the boiler conversion in the High School
- Install control systems in the Elementary School
- Install control systems in the Kindergarten building
- Install control systems in the Pod building
- Construct a heat exchanger building to serve the Wood Shop
- Complete bracing of existing geothermal piping in Middle School, Elementary School, and Kindergarten (DSA requirements)

AES and Brian Brown Engineering prepared final design drawings for the control system improvements. MJUSD's subcontractor, Semingson Architects (Semingson), prepared the design drawings for the DSA requirements. Semingson also coordinated the DSA approval process.

Construction Bidding

Since the building retrofit portion of the project consisted of numerous small, specialty projects, MJUSD decided to complete the work using three different processes. Semingson prepared a bid package for the completion of the DSA requirements, which included bracing of existing geothermal piping in the Middle School, Elementary School, and Kindergarten. This portion of the retrofits was awarded to Harbert Roofing through a competitive bidding process.

AES and Brian Brown Engineering prepared a bid package for the control systems in the Middle School and coordinated the bidding and award process. MJUSD initially received two bids for the project, both of which were much higher than anticipated. The scope of work was adjusted and the bid package was revised and advertised again. MJUSD received one bid for the revised scope of work. The bid price of $115,200 was acceptable and the project was awarded to Joe Lloyd General Contracting.

The remainder of the retrofit work was completed by specialty contractors working under individual purchase orders. MJUSD can use this method for smaller contract amounts, per the requirements of the Uniform Public Construction Cost Accounting Act in the Cost Accounting Policies and Procedures Manual issued by the California State Controller's Office. Under this method, MJUSD obtains cost quotes from their approved contractors and then issues a purchase order for completion of the work. AES reviewed the quotes received from the specialty contractors before MJUSD issued purchase orders.

Chapter 3: Project Construction

Geothermal Piping Extension Construction

Construction of the geothermal piping extension was included in the site work contract for the Modoc Medical Center facility. The medical center site work contractor, White Bear Construction, Inc., also installed the geothermal piping. Construction began in August 2018 and was completed in September 2018. The contractor installed two lines of 6” ductile iron piping, a supply line that brings the geothermal water to the medical center heating system and a return line that takes the water back to the main return piping system for re-injection. The piping to the schools is also 6”, allowing for future connections at the medical center site.

The piping was connected to the existing valves at 8th Street and Nagle Street that were installed during the previous 2014 CEC funded project. The piping was laid in a trench with 30” minimum burial. Piping was bedded with select granular material and the remainder of the trench filled with ¾”- rock. Figure 2 shows a photograph of the geothermal piping installation.

Figure 2: Geothermal Piping Installation

Photo Credit: Anderson Engineering & Surveying, Inc.

The geothermal piping was terminated at the location of the medical center mechanical room as can be seen in the photograph in Figure 3. A tee connection with one length of pipe was also installed on the site to allow for future connections. Figure 4 shows the heat exchanger installed in the Modoc Medical Center mechanical room.

Fiber optic cable was also installed to connect the medical facility with MJUSD’s control network. This allows MJUSD to monitor the medical facility’s BTU meter readings, geothermal flow amounts, and temperatures. The fiber optic cable installation was performed by MJUSD’s subcontractor, McComb’s Electric. The fiber was pulled after the piping installation was complete.

Figure 3: Piping Termination at Medical Center Mechanical Room

Photo Credit: Anderson Engineering & Surveying, Inc.

Figure 4: Modoc Medical Center Heat Exchanger

Photo Credit: Anderson Engineering & Surveying, Inc.

Building Retrofit Construction

Construction activities were completed in the Middle School buildings, Elementary School buildings, High School buildings, Kindergarten, and Pod building.

Modoc High School

Construction activities in the High School included boiler conversion, control system installation, installation of a heat exchanger to serve the Wood Shop, and construction of a heat exchanger building.

The High School Main building was originally heated with a steam system, with two low-pressure steam boilers supplying heat to cast iron steam radiators and unit ventilators with steam heating coils. To be compatible with the geothermal heat, the building heating system was converted from steam to hydronic (hot water). That conversion included:

- Conversion of boiler controls to hydronic operation
- Installation of heating water circulation pumps and removal of steam condensate pump
- Removal of steam traps from the radiators and unit ventilator coils
- Installation of a heat exchanger to transfer heat from the geothermal source water to the building heating water
- Installation of Direct Digital Controls (DDC) to monitor and control the heat exchanger, pumps, and boilers

These construction activities were completed by specialty subcontractors. CR Combustion completed the boiler conversion, Heard Plumbing installed the heat exchanger and pumps and McComb's Electric installed the controls. Figure 5 shows the converted boilers at the High School.

Figure 5: High School Boilers

Photo Credit: Anderson Engineering & Surveying, Inc.

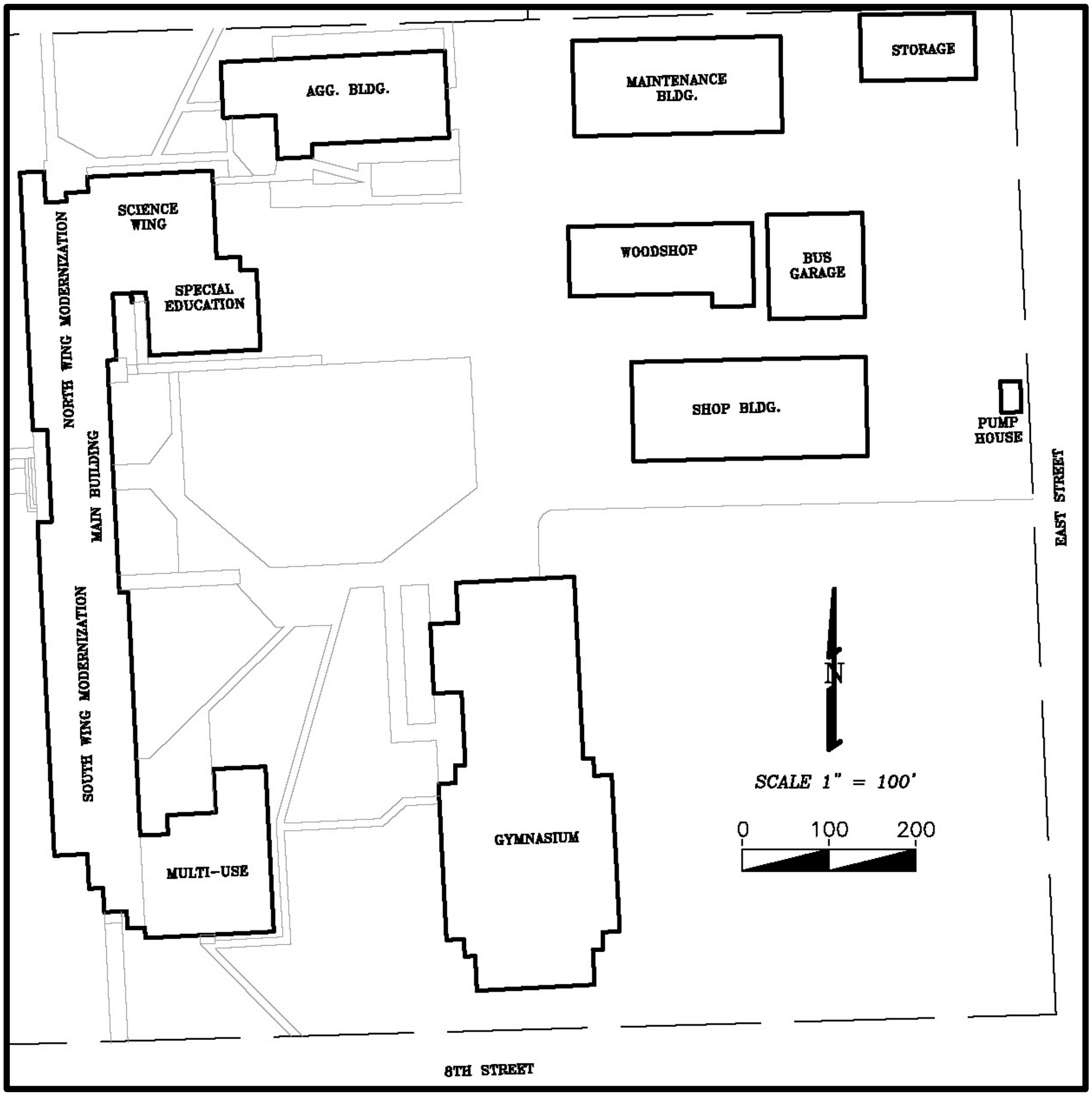
The High School Wood Shop was previously heated with geothermal. This project provided a new heat exchanger, new heat exchanger building, and pumps and controls to allow operation from the central geothermal system. Figure 6 shows the new heat exchanger installed at the

Wood Shop. To maximize the beneficial use, the geothermal water is cascaded from the main school building to the Wood Shop and Gym buildings. This means that the geothermal water leaving the High School main building is reused at a lower temperature to heat the Wood Shop and Gym. Reusing the water from the Wood Shop benefits the entire system by increasing heating capacity throughout the system without increasing the geothermal flow from the production well. Figure 7 shows the building layout at the High School campus.

Figure 6: Wood Shop Heat Exchanger

Photo Credit: Anderson Engineering & Surveying, Inc.

Figure 7: Modoc High School Building Layout



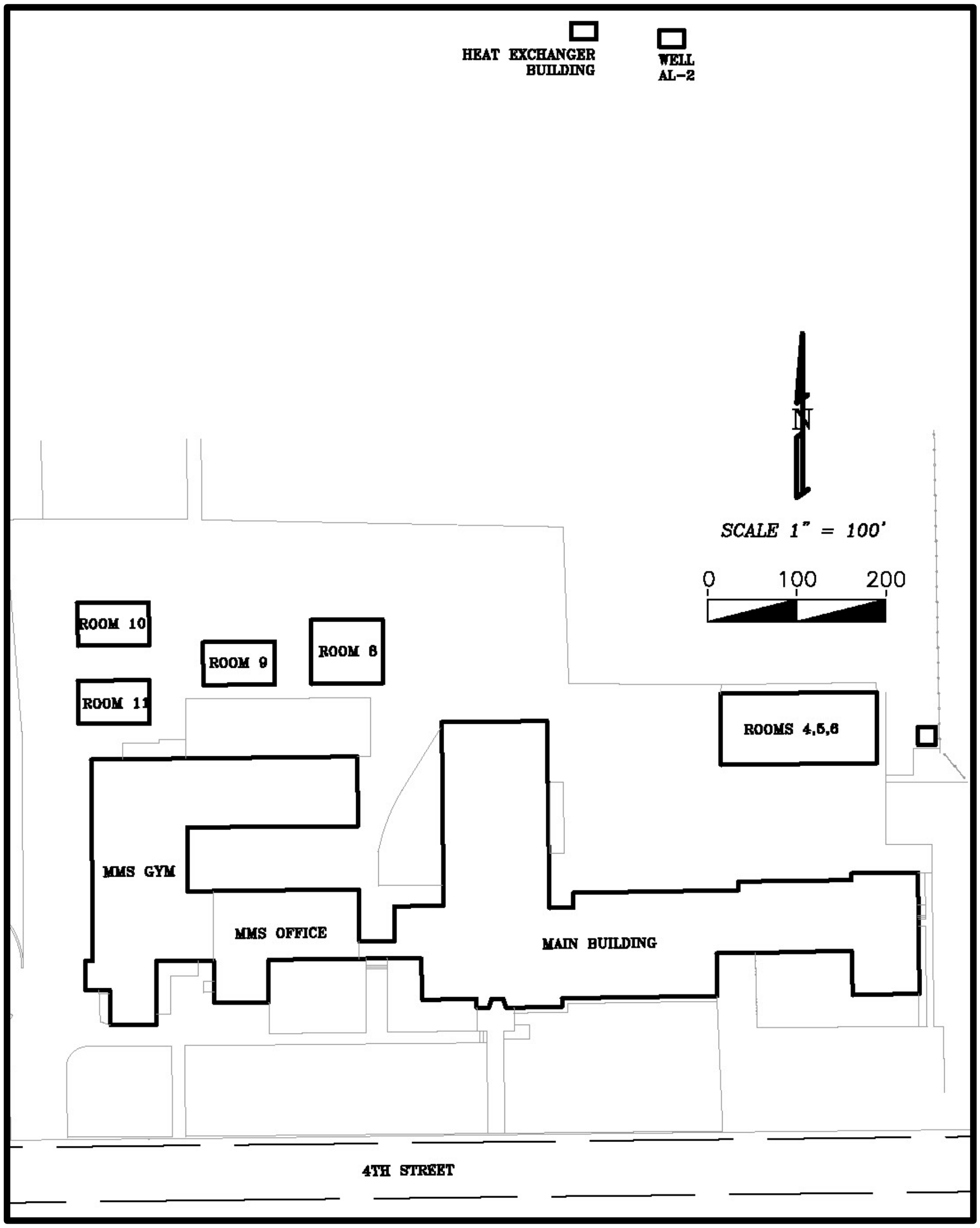
Source: Anderson Engineering & Surveying, Inc.

Modoc Middle School

Construction activities at the Middle School included new circulating pumps, control systems, and completion of the DSA required pipe bracing. Figure 8 shows the building layout at the Middle School campus.

The 1992 geothermal project provided piping, heating coils, and circulation pumps that were not activated. This project activated the 1992 equipment, replaced the over-sized circulation pumps, and added controls to monitor and operate the pumps, boilers, and classroom unit ventilators. Figure 9 shows the Middle School heat exchanger.

Figure 8: Modoc Middle School Building Layout



Source: Anderson Engineering & Surveying, Inc.

Figure 9: Middle School Heat Exchanger

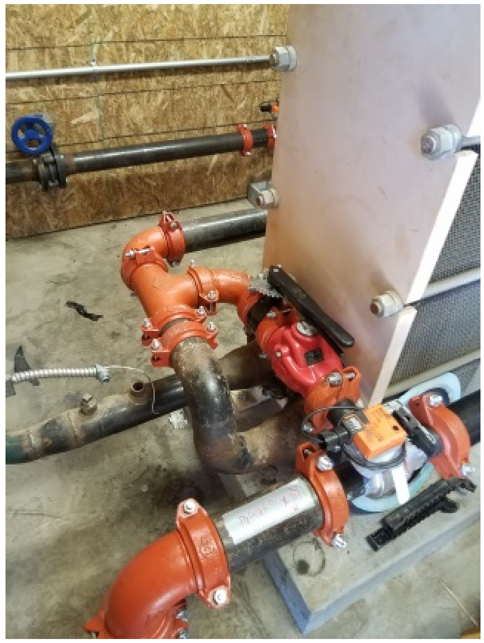


Photo Credit: Anderson Engineering & Surveying, Inc.

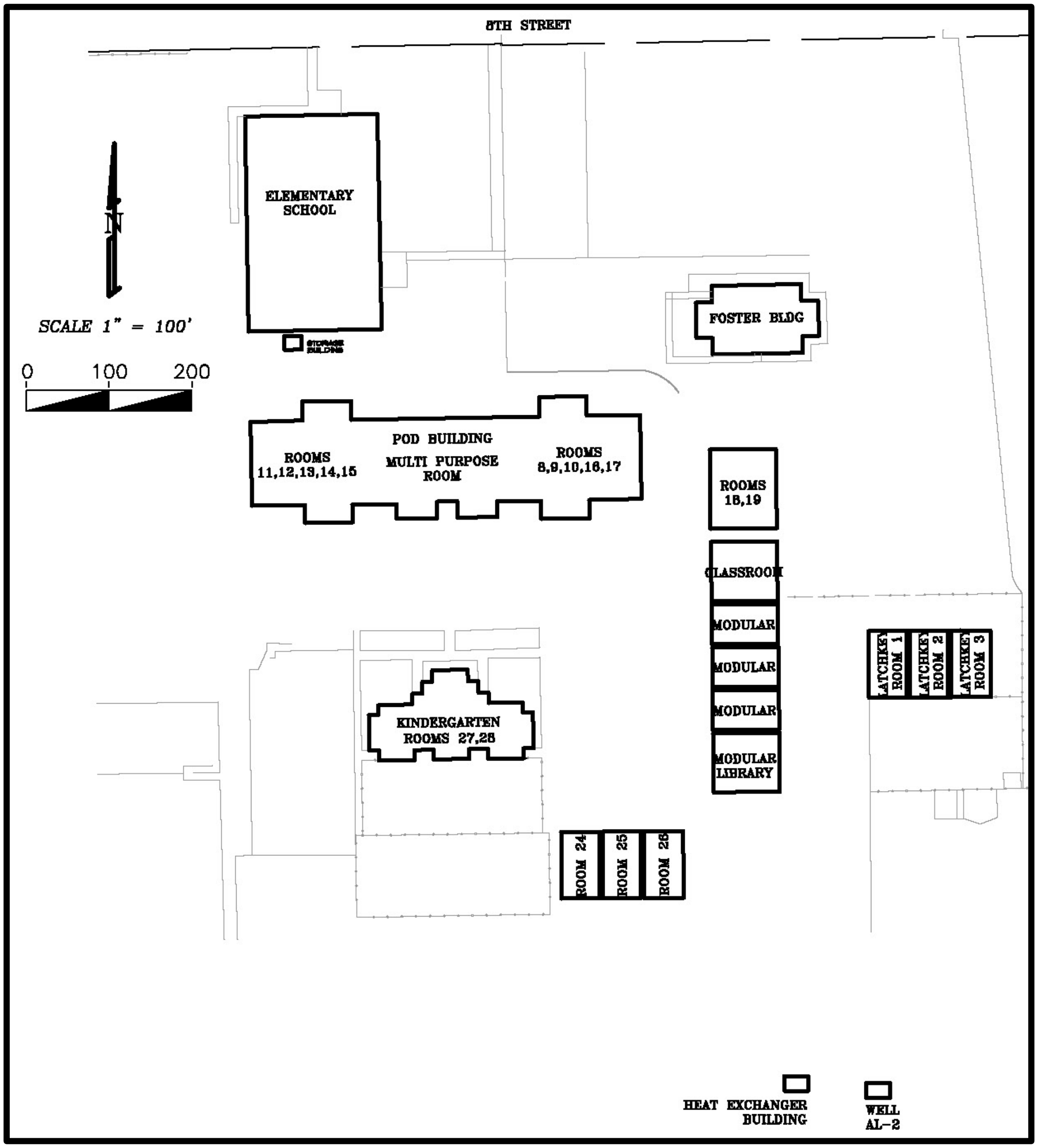
Alturas Elementary School

Construction activities at the Elementary School included control systems as well as completion of the DSA required pipe bracing. Figure 10 shows the building layout at the Elementary School campus.

The 1992 geothermal project provided piping and hydronic fan-coils in the Elementary School Main Building. The fans were later activated and paired with split-system rooftop heat pump condensing units to provide space cooling and air-source heat pump heating.

This project activated the hot water coils in the fan-coils to provide geothermal heat, and added DDC controls to monitor and control the classroom heating, ventilation and air conditioning (HVAC) equipment.

Figure 10: Alturas Elementary School Building Layout



Source: Anderson Engineering & Surveying, Inc.

Kindergarten Building

The Kindergarten Building is located on the Elementary School campus and can be seen on the map in Figure 10. Construction activities at the Kindergarten building included control system installation and completion of the DSA required pipe bracing.

The original HVAC system in the Kindergarten was electric heat-pump units. The 1992 project added hydronic coils to the supply ducts and piping to supply the coils. This project activated the hot water coils in the fan-coils to provide geothermal heat and provided DDC controls to operate the HVAC equipment. Figure 11 shows a typical classroom heating unit.

Figure 11: Typical Classroom Heating Unit

Photo Credit: Anderson Engineering & Surveying, Inc.

Pod Building

The Pod building, which contains additional classroom space, is located on the Elementary School campus and can be seen on the map in Figure 10. Construction activities at the Pod building included control system installation and completion of the DSA required pipe and equipment bracing.

The original HVAC system in the Pod Building was electric fan-coil units. The 1992 project replaced the electric coils in the existing fan-coil units with hydronic coils and added piping to supply the coils. Subsequent work included addition of roof-top heat pump units to supply cooling and air-source heat pump heating in the classrooms.

This project activated the hot water coils and the original fan-coils to provide geothermal heat and provided DDC controls to operate the HVAC equipment. A typical thermostat control unit can be seen in Figure 12. The thermostat unit has a small lever on the right side that can be used to adjust the temperature of the room within a preset range.

Figure 12: Typical Thermostat Control Unit

Photo Credit: Anderson Engineering & Surveying, Inc.

Chapter 4: Project Commissioning and Operation

Geothermal Piping Extension Commissioning and Operation

The geothermal piping extension was commissioned at the completion of construction in September 2018. AES verified during the construction process that all pipe and fittings were installed correctly. The piping was flushed to remove construction debris and pressure tested to verify pipe tightness. AES reviewed the pressure test reports submitted by White Bear Construction, Inc.

The fiber optic communication cable was tested for continuity once installation was complete.

Once the Modoc Medical Facility heating system is operational, the piping extension will supply geothermal water to the medical center heating equipment. A BTU meter will be installed on the geothermal supply side of the heat exchanger to monitor the heat used by the medical center facility. The fiber optic line connects to MJUSD's control system, allowing the BTU meter to be monitored remotely. MJUSD will use the BTU meter data to generate a monthly bill for the medical center heat use.

Building Retrofit Commissioning and Operation

The various building retrofit components were commissioned as they were completed. Operation of each component was verified once installation was complete.

Modoc High School

Commissioning activities included:

- Verifying controller inputs (temperatures and pressures)
- Verifying correct operation of valves, pumps, and boilers through observations of manual operation of controller outputs
- Commissioning of variable frequency drives on pumps for proper motor rotation, current limits, control configuration, and BacNet communication
- Verifying that control loops track the set points with control stability through observation of automatic operations
- Establishing trend logs to track system operation and facilitating diagnosis of problems
- Monitoring over the long-term to observe operation in changing weather conditions
- Training of operation personnel on system operation and technical support for questions

The High School system operates using geothermal water delivered under artesian pressure from the production well AL-2. Geothermal return flow and circulation is established by the injection pumps at AL-4. A control valve in the geothermal return line controls flow through the high school heat exchanger based on the heating water supply temperature on the building side of the heat exchanger. The return geothermal water is re-pumped at a reduced temperature to the heating systems in the High School Gym and Wood Shop.

The heating water pumps are controlled by variable frequency drives (VFD) to maintain a set-point pressure differential across the building heating water system. The pressure differential is calculated from measured heating water supply pressure minus return pressure. When individual heating units require more heat, the local unit controller opens the control valve for more flow. The increased flow demand reduces the supply pressure, and the pump control compensates by speeding up the pump.

In the event of an interruption of geothermal service, the controls can automatically start the boilers to provide back-up heat.

Operation of the high school heating system is monitored by a DDC system that communicates through a dedicated fiber-optic network connection from the High School to the Middle School network server room.

Modoc Middle School

Commissioning activities included:

- Verifying control inputs (temperature and pressures)
- Verifying correct operation of valves, pumps, etc. through observations of manual operation of controller outputs
- Verifying that control loops track the set points without control instability through observations of automatic operations
- Establishing trend logs to track system operation and facilitating diagnosis of problems
- Monitoring over the long-term to observe operation in changing weather conditions
- Training of operation personnel on system operation and technical support for questions

The Middle School system operates using heating water supplied from a geothermal heat exchanger located near the production well AL-2, at the adjacent Elementary School campus. VFD controlled pumps circulate heating water from the Middle School boiler room to the heat exchanger to be heated, through the back-up boilers, and to the building heating equipment to deliver heat to the classrooms and other areas of the building.

Similar to the High School, the pumps are controlled to maintain a set-point pressure differential adequate for the required circulation.

In the event of an interruption of geothermal service, the controls can automatically start the boilers to provide back-up heat. The boiler backup heat can also be supplied to the Elementary School because the Middle School and Elementary School heating water systems are interconnected.

Alturas Elementary School

Commissioning activities included:

- Verifying control inputs (temperature and pressures)
- Verifying correct operation of valves, pumps, etc. through observations of manual operation of controller outputs
- Verifying that control loops track the set points without control instability through observations of automatic operations

- Establishing trend logs to track system operation and facilitating diagnosis of problems
- Monitoring over the long-term to observe operation in changing weather conditions
- Training of operation personnel on system operation and technical support for questions

The Elementary School system operates using heating water returned from the Middle School. That is possible because the newer heating equipment in the Elementary School is generally designed to provide the required heating capacity at a lower water temperature than the older equipment in the Middle School.

VFD controlled pumps circulate return heating water from the Middle School boiler room to the building heating equipment in the Elementary School. The water is then circulated back to the heat exchanger to be heated. If the return water temperature from the Middle School is not as hot as desired, a 3-way control valve allows mixing of hotter heating supply water from the heat exchanger with the Middle School return water for supply to the Elementary School.

DDC controls located at each classroom heating unit monitor the classroom temperature and Carbon Dioxide (CO_2) levels, and operate the fan, hot water valve and/or condensing unit to provide heating and cooling to the classrooms. The CO_2 monitoring is currently used for information and tracking purposes only. The monitor readings can be viewed remotely and if the system indicates levels are high, ventilation can be adjusted manually. The controls have the capability to use the CO_2 reading to adjust ventilation automatically, but additional ventilation ducting and dampers are needed to allow ventilation control. Controls at the office, teachers' room and hallway operate similarly but without monitoring CO_2 levels.

Kindergarten

Commissioning activities included:

- Verifying control inputs (temperature and pressures)
- Verifying correct operation of valves, pumps, etc. through observations of manual operation of controller outputs
- Verifying that control loops track the set points without control instability through observations of automatic operations
- Establishing trend logs to track system operation and facilitating diagnosis of problems
- Monitoring over the long-term to observe operation in changing weather conditions
- Training of operation personnel on system operation and technical support for questions

The Kindergarten system operates using the heating water distributed to the Elementary School.

DDC controls monitor the classroom temperature and CO_2 levels and operate the fan, hot water valve and/or condensing unit to provide heating and cooling to the classrooms. The CO_2 monitoring is currently used for information and tracking purposes only. The monitor readings can be viewed remotely and if the system indicates levels are high, ventilation can be adjusted manually. The controls have the capability to use the CO_2 reading to adjust ventilation automatically, but additional ventilation ducting and dampers are needed to allow ventilation control. The controls are configured to automatically switch to back-up heat from the existing heat pumps or electric resistance heat to protect the building if the geothermal heat were to fail.

Pod Building

Commissioning activities included:

- Verifying control inputs (temperature and pressures)
- Verifying correct operation of valves, pumps, etc. through observations of manual operation of controller outputs
- Verifying that control loops track the set points without control instability through observations of automatic operations
- Establishing trend logs to track system operation and facilitating diagnosis of problems
- Monitoring over the long-term to observe operation in changing weather conditions
- Training of operation personnel on system operation and technical support for questions

The Pod building operates from the heating water distributed to the Elementary School.

DDC controls monitor the classroom temperature and CO_2 levels, and operate both the hot water fan-coil and the rooftop heat pump/AC unit. The hydronic fan-coil provides geothermal heating. The roof-top heat pump/AC unit is operated to provide cooling or back-up heating. Both are operated from a single controller which prevents the system from attempting simultaneous heating and cooling.

System Maintenance

MJUSD has an excellent facility maintenance program. Maintenance activities for the geothermal heating system will not be substantially different from the maintenance activities that were conducted for the previous heating systems. District maintenance personnel have been involved in the installation of the new equipment and are familiar with the operation and maintenance of the various system components, heat exchangers, pumps, boilers, etc. Routine maintenance activities include:

- Excise (fully open and close) all valves in system twice a year.
- Check all temperature and pressure gauges daily.
- Clean all strainers before the beginning of each heating season.
- Visually inspect the system for leaks daily.
- Visually inspect to ensure system is in working order daily.
- Monitor injection pressure daily.

The cost of routine maintenance for the geothermal system will be similar to maintenance costs for the prior systems. MJUSD will not need to hire additional maintenance staff; the current staff of five maintenance personnel will be able to perform the routine maintenance activities. Staff has received training on the operation of the control system from the project's mechanical engineer, Brian Brown, who will continue to provide consulting services for control system operation and monitoring as needed. MJUSD will maintain repair and replacement funds that can be used for major maintenance or repairs to the system.

Chapter 5: Results and Conclusions

This project had the following goals:

- Design and construct retrofits to the heating systems at the High School, Middle School, and Elementary School campuses to better utilize the geothermal resource and increase system efficiency.
- Design and construct the extension of geothermal piping to the new Modoc Medical Center.

This project was able to achieve all goals. The DSA required pipe bracing was successfully installed in the Middle School, Elementary School and Kindergarten buildings. The control systems are operating effectively in all school buildings. The piping extension to the Modoc Medical Center site was completed and is ready for the hospital start-up.

System temperatures have remained steady when the system is in use. Water is leaving Production Well AL-2 at a temperature of 175°F (79.4°C), dropping to 140°F (60°C) as it cycles through the buildings, and entering the Injection Well AL-4 at 120°F (48.9°C). This shows an average net heat use of 55°F (12.8°C). Once the Modoc Medical Center is connected, the system will still have adequate capacity for additional connections. LFHD also plans to construct additional facilities at the Modoc Medical Center site, including a skilled nursing facility. Another potential opportunity stemming from this project would be to connect the high school campus greenhouse with the geothermal system.

MJUSD already saw a significant reduction in heating costs after the completion of the first project. Savings from reductions in heating costs during the 2018-2019 heating season were $70,000. These savings were calculated by comparing the amount budgeted for heating costs (based on the conventional methods of electricity and fuel oil MJUSD used prior to the geothermal system) with the actual amount paid for electricity and fuel oil during the heating season. The heating season generally runs from October through April. Now that the system is fully operational in all buildings, MJUSD estimates heating costs for the 2019-2020 heating season will be reduced by $85,000. The value of these savings will increase over time as the price of heating oil and electricity increases. Prior to the completion of the geothermal system, MJUSD used approximately 30,000 gallons of heating oil per year. Heating oil costs are estimated to be around $3 per gallon. If the cost of heating oil were to increase to $4 per gallon, the energy savings from the project is estimated to be over $100,000 per year. The control system improvements that were installed with this project will increase the system efficiency and reduce the volume of water that needs to be pumped for heating purposes. This reduces pumping costs, resulting in additional savings. Operation and maintenance costs for the geothermal system will remain relatively stable, increasing at a much slower rate than the cost of conventional heating methods like fuel oil or electricity. Because of this, MJUSD is expected to save as much as $6.5 million over the estimated 30 year life of the system.

The savings over the life of the system was calculated using initial heating fuel costs of $3.07 per gallon for diesel fuel, $2.57 per gallon for propane, and $0.195 per kilowatt hour for electricity.[3] These rates were then multiplied by the total amounts of diesel fuel, propane, and electricity MJUSD was using to heat their buildings prior to the geothermal system to calculate the total annual heating cost savings. The costs for diesel, propane, and electricity were given an annual escalation rate of 3.5 percent.

MJUSD was also able to use the geothermal system fiber optic line for their computer network connection between the school buildings. Previously, MJUSD rented the cable that connected the main network hub at the Middle School to the High School from an outside service provider. MJUSD is now able to use the fiber optic cable that was installed for the geothermal heating system, resulting in a savings of $3,000 per year. This annual savings was included in the calculation for total system savings.

MJUSD will also be selling geothermal heat to LFHD to heat the Modoc Medical Center. Once this system is online, MJUSD will receive approximately $20,000 per year in additional revenue, as much as $600,000 over the 30 year life of the system. This money will go into the district general fund and be available to purchase equipment, supplies, books, and technology.

Costs to MJUSD, including match funding provided for the projects and annual maintenance costs, were also included in the savings calculation. Initial maintenance costs were estimated at $5,000 annually and are assumed to have a 2 percent annual escalation rate.

The energy savings will allow MJUSD to spend more on education and public programs instead of fossil fuels. MJUSD plans to use the cost savings to fund college field trips, increase students' access to technology, provide professional development for staff, hire additional staff to meet the increasingly complex needs of students, and fund field trips to enhance student career options. MJUSD also plans to use the heating system to help teach students about geothermal resources and their applications. Kindergarten through high school students will be able to learn about geothermal resources in the classroom and then actually see how a functioning system operates.

LFHD will also benefit from the system. Once the system is operating in the Modoc Medical Center facility, LFHD is estimated to save $16,000 annually, when compared to traditional heating with fuel oil. These savings can be used to provide enhanced medical services to Modoc County.

Renewable energy applications, such as direct source geothermal heating, have long-term economic benefits. Additionally, there are environmental benefits, including reduction of greenhouse gas emissions. The geothermal system will reduce MJUSD's diesel fuel oil usage by 30,000 gallons per year and LFHD's diesel fuel oil usage by 12,400 gallons per year. This will reduce greenhouse gas emissions by 305 metric tons per year for MJUSD and 126 metric tons per year for LFHD, based on a reduction rate of 0.01018 metric tons per gallon of diesel. The value of these projects may increase over time as the need to reduce emissions grow. Despite these benefits geothermal water is often overlooked as a viable heating source due to a lack of awareness of existing geothermal resources or familiarity with their application. Many communities think the resource is not available or that the geothermal water is not "hot"

[3] Prices are average price from local suppliers during Fall 2019

enough. Extremely high temperatures are not essential; the Henley High school project in Klamath Falls, Oregon was successful with water temperatures of 120°F (48.9°C). Water at 80°F (26.7°C) is still a viable resource for smaller applications such as water source heat pumps that can be used to heat smaller spaces like office buildings or homes. Figure 13 provides a summary of the cost savings and reduction in greenhouse gas emissions for both MJUSD and LFHD.

Figure 13: Summary of Cost Savings and Emissions Reduction

			FY 2018-2019	FY 2019-2020	FY 2020-2021	On-going
MJUSD	Savings	Reduction in Heating Oil/Electricity Purchases [1]	$ 70,000	$ 85,000	$ 85,000	$ 85,000
MJUSD	Savings	Reduction in Network Communication Costs from using Geothermal Fiber Optic Cable	$ 3,000	$ 3,000	$ 3,000	$ 3,000
MJUSD	Revenues	Revenue from sale of Geothermal to LFHD			$ 20,000	$ 20,000
MJUSD	Expenses	Geothermal System Maintenance Costs [2]		$ (5,000)	$ (5,000)	$ (5,000)
MJUSD	**Net Savings and Revenues [3]**		**$ 73,000**	**$ 83,000**	**$ 103,000**	**$ 103,000**
LFHD	Expenses	Heating Oil Purchases (if not using geothermal) [4]			$ 36,000	$ 36,000
LFHD	Expenses	Geothermal Heating Costs			$ (20,000)	$ (20,000)
LFHD	**Net Savings [3]**				**$ 16,000**	**$ 16,000**
MJUSD	Estimated Annual Greenhouse Gas (GHG) Emissions (Metric Tons CO_2)	Heating Oil GHG [5]	305	305	305	305
MJUSD		Geothermal GHG	-	-	-	-
MJUSD		**Potential GHG Reduction**	**305**	**305**	**305**	**305**
LFHD		Heating Oil GHG [6]			126	126
LFHD		Geothermal GHG			-	-
LFHD		**Potential GHG Reduction**			**126**	**126**

1. On-going heating oil/electricity reduction amount is +/- depending on inflation rate of fuel prices
2. On-going geothermal maintenance costs are +/- depending on inflation rate of labor and materials
3. On-going net savings amounts are +/- depending on inflation rates
4. This is the amount LFHD would pay for heating if the geothermal system was not available
   On-going heating oil purchases amount is +/- depending on inflation rate of fuel prices
5. MJUSD heating oil GHG calculation: CO_2 Factor for Diesel of 0.01018 x 30,000 Gallons Diesel Fuel
6. LFHD heating oil GHG calculation: CO_2 Factor for Diesel of 0.01018 x 12,400 Gallons of Diesel Fuel

Source: Anderson Engineering & Surveying, Inc

Lessons Learned

This project was ultimately a tremendous success, but it did present numerous challenges. The existing building systems were retrofitted as much as possible and some equipment from the 1992 geothermal project, which was never operated, was integrated into the new system. While these measures reduced costs, they did extend the project time and require extensive coordination between the designers and the contractors during the installation process. Old pipes developed leaks that had to be repaired and some of the old equipment required repair or had to be replaced completely. Retrofitting existing systems, if possible, can be a good cost saving option, but it does result in a more complicated construction process with more design coordination.

Even with the cost savings from retrofitting existing equipment, MJUSD would not have been able to complete this project without the grant funding received from the CEC. Despite the huge savings potential, the capital costs were just too high for MJUSD to finance the project on their own. The cost of this project was approximately $1,020,000. The first phase, completed in 2018, had a total cost of $3,900,000.

That is why programs like the CEC's Geothermal Grant and Loan Program are so important to developing geothermal resources in rural areas. MJUSD had wanted to develop their geothermal resources for some time, but did not have the financial resources to complete such a large project. When MJUSD personnel became aware of the Geothermal Grant and Loan Program grant funding opportunity, they submitted an application and received the funding needed to complete the project.

Benefits to California

Despite the challenges, this was still a successful project that can be used as an example for other small communities with geothermal resources. This project showed that retrofitting an existing heating system to work with geothermal water is possible The low-temperature geothermal resource provides a sustainable heat source that does not burn fossil fuels or use large amounts of electricity, puts the heating costs under local control, brings revenue into the local area, and provides cost savings for the MJUSD. Small communities, with the assistance of grant funding or long-term low interest loans, can complete large scale geothermal projects and save money for important school related costs that benefit the students, teachers, administrators and ultimately the community, while also reducing greenhouse gas emissions.

GLOSSARY

Abbreviation, Acronym, or Term	Definition
aquifer	A body of permeable rock which can contain or transmit groundwater
artesian pressure	The natural pressure of a well, which allows for water flows without pumping.
BACnet	Building, Automation, and Control Network
BTU	British Thermal Unit. The amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit.
°C	degrees Celsius
CEC	California Energy Commission
CO_2	Carbon Dioxide
DDC	Direct Digital Controls
DSA	(California) Division of the State Architect
ductile iron	A graphite-rich cast iron containing magnesium where the graphite is in the form of nodules instead of flakes.
Elementary School	Alturas Elementary School
CEC	California Energy Commission
°F	degrees Fahrenheit
GHG	Greenhouse Gas
Gym	Gymnasium
High School	Modoc High School
HVAC	Heating, Ventilation, and Air Conditioning: The systems used to provide heating and cooling services to buildings
hydronic	A heating (or cooling) system in which heat is transported using circulating water
Infrastructure	The basic physical and organizational structures and facilities needed for the operation of a society or enterprise.

Abbreviation, Acronym, or Term	Definition
Injection well	A well that places fluid deep underground into porous rock formations.
LFHD	Last Frontier Healthcare District
MMS	Modoc Middle School
MJUSD	Modoc Joint Unified School District
VFD	Variable Frequency Drive: A type of adjustable-speed drive used in electro-mechanical drive systems to control motor speed and torque by varying motor input frequency and voltage.
Well AL-2	Existing Production Well AL-2
Well AL-4	New Injection Well AL-4