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# A Report on the Benefits and Disadvantages of Prototypical School Design and Construction in Alaska

Prepared for the

**Alaska State Legislature**

through  
the Alaska Department of Education &  
Early Development

October, 2015



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## EXECUTIVE SUMMARY

In the fall of 2014, the State of Alaska's Department of Education & Early Development, Division of School Finance, Facilities Section (DEED) selected the multi-disciplinary team of Nvision/Dejong-Richter to investigate the benefits and disadvantages of using prototypical designs for school construction throughout the state of Alaska, and to prepare a report detailing the team's findings for submission to the Alaska State Legislature in response to HB278, sec. 52.

The purpose of the study and resulting report is to provide up-to-date insight into how prototypical design for school construction has and has not worked in recent years in a fair sampling of school districts and communities across the state, and to establish a deeper understanding of how prototyping may or may not be of benefit to school design and construction in Alaska in the future.

The project team's methodology for this project involved three primary parts: first, a review of existing national and in-state research on the topic; second, statewide data gathering inclusive of a topical Request for Information (RFI) designed to collect quantitative data from all 53 school districts across Alaska, followed by seven regional conferences to collect qualitative data, followed by statewide teleconferences to gather additional input; and third, data analysis.

The conclusion of the research is that a statewide prototype school program would likely be unsuccessful given the insurmountable diversities influencing design and construction in the state in combination with the long-term projections of student population growth over the next 30 years. Individual school districts have a greater potential for success in the pursuit of prototypical facility development, and they also have the best understanding at the local level to determine when and under what circumstances they should pursue prototyping.

A statewide prototype program for building components would also likely prove to be unsuccessful for similar reasons as noted for a facility prototype program, with diversity of design conditions being the most problematic. As with school facility prototyping, the potential for success at the district or regional level for component prototyping shows some promise on a limited scale. Whether facility or component prototyping, the potential for success of any program is increased when the design or component is carefully scrutinized prior to implementation, and follow-up testing and refinement are made mandatory prior to scaled implementation.

## ACKNOWLEDGEMENTS

Nvision Architecture, Inc. (Nvision) of Anchorage, Alaska, served as the lead firm on this project and DeJong-Richter of Hilliard, Ohio, was in charge of the research. Due to the variety of demands for local knowledge and technical expertise, a team of experts was assembled that included a wide range of specialists from applicable professional disciplines including architecture, construction, educational planning, and engineering (civil, electrical, energy efficiency, mechanical, structural).

Project team members reviewed existing research, assisted in the creation of information gathering tools, participated in regional and statewide conferences, contributed expertise to disciplinary and teamwide analyses, and collaborated on the preparation of this report. Grateful acknowledgement is given to all team members for their professional, technical, and practical expertise, which was more than adequate for the demands of this project.

The project team included the following disciplinary professionals:

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The entire project team sincerely appreciates the opportunity to perform this study and hopes the study's results will be beneficial for the State of Alaska, the Department of Education and Early Development, every school district in the state, and ultimately, Alaska's teachers and students.

# INTRODUCTION

## PROJECT DESCRIPTION AND PURPOSE

In the fall of 2014, the State of Alaska Department of Education & Early Development, Division of School Finance, Facilities Section (DEED), selected the multi-disciplinary team of Nvision/Dejong-Richter to investigate the benefits and disadvantages of using prototypical designs for school construction throughout the state of Alaska, and to prepare a report detailing its findings for submission to the Alaska State Legislature. The purpose of the study and resulting report is to provide up-to-date insight into how prototypical design for school construction has and has not worked in recent years in a fair sampling of school districts and communities across the state, and to establish a deeper understanding of how prototyping may or may not be of benefit to school design and construction in Alaska in the future.

## METHODOLOGY

The project team’s methodology for this project involved three primary parts: first, a review of existing national and in-state research on the topic; second, statewide data gathering inclusive of a topical Request for Information (RFI) designed to collect quantitative data from all 53 school districts across Alaska, followed by seven regional conferences to collect qualitative data, followed by a statewide teleconference to gather additional input; and third, data analysis.

### Review of Existing Research

Critical to the information gathering process, and to ensure thorough and accurate direction in the development of research to be conducted within the state, the research team established a baseline understanding of the topic by exploring existing research at the national and state level. By doing this, the team was better prepared to explore the topic and related topics in depth, and to develop precise questions for the questionnaires to be distributed at conferences during the statewide data gathering process. The national research was a valuable resource that provided relevant information related to why and under what circumstances prototypes were considered and used in other parts of the country. In addition, this research informed the project team as to whether or not the use of a prototype succeeded or failed in other states, and as importantly, the circumstances explaining why. This work equipped the project team with a broader understanding of prototype development, and was invaluable during the execution of the study within Alaska. State-level research provided insight to the level of success anticipated within Alaska and helped direct the team toward new areas of research not previously investigated.

## **Statewide Data Gathering**

The project team collected quantitative data through the formation and distribution of a Request for Information (RFI), which was developed with knowledge gained from existing national and in-state research, the team's professional expertise and experience, and DEED input. The RFI was distributed to all 53 Alaska school districts and it solicited quantitative data directly from districts on the variables they encounter in facility design and construction. The data was useful in establishing the diversity of construction influences and components within the state, and was intended to be used as a tool for identifying common influences that impact the benefits or disadvantages of prototypical design and construction in Alaska.

Following the RFI effort, the project team performed multiple school site visits and hosted regional conferences in seven school districts representing Alaska's diverse geography, culture, climate, educational needs, and population. In preparation for these conferences, questionnaires were developed to allow school districts, the professional design community, and citizens to provide qualitative data on their recent experiences with school planning, design, construction, and maintenance, as well as their thoughts on how prototypical design and construction may or may not benefit their school, district, or community.

Lastly, a statewide conference was held to provide a second opportunity primarily for school district superintendents and staff who were unable to attend a regional conference. Recognizing the logistical difficulties inherent in attending a conference not hosted in one's immediate district, the project team determined it was important to host a statewide conference in Anchorage to minimize logistical obstacles and to encourage district leaders to participate in the research. In addition, statewide teleconferences were conducted based on the same questionnaires and in the same format as the regional conferences.

## **Data Analysis**

Analysis of all gathered input began between team members early on in the research process, and collective discussions continued throughout the course of the project. National research findings, for example, were referenced often and used to inform the Alaska-specific research and information gathering efforts. The RFI generated responses from 62% of all Alaska school districts, which fueled discussions and improved the effectiveness of the questionnaires developed for the regional conferences. Throughout the project, and at important intervals between activities, the project team met in person and via teleconference to discuss and evaluate findings, develop conclusions, and prepare this report.

## DEFINITION OF KEY TERMS

The nature of this project was such that some technical language was unavoidable in presentations, questionnaires, and reporting. Accordingly, the project team developed operational definitions for key terms used extensively throughout the process. The following are definitions developed to provide clarity for all participants. These definitions were shared in presentations at the regional conferences and at the beginning of the questionnaires used for soliciting stakeholder input.

**Component Prototype** – A component prototype is an operating system, equipment, or component of a system or equipment that becomes the standard for integration into a school design, regardless of whether or not the school design is a facility prototype. Modifications of standard components are largely confined to matters of differing site needs. A component prototype is applicable to new or existing buildings and infrastructure.

**Design Standard** – Design standards are made up of design documents and/or technical specifications developed by the school district or borough responsible for school development specifically for use by architects, engineers, and contractors in the design and construction of new and remodeled buildings and infrastructure.

**Educational Adequacy** – This term describes the ability of a school facility to support the local educators' current and desired educational programming and instructional models. The term is not intended to imply correlating inadequacies, since facilities can support current and desired programs to matters of degree depending on changing educational strategies.

**Educational Specifications** – Educational specifications or “Ed Specs” are protocols written from the owner (or educator) to design professionals (i.e., architects, engineers, etc.) that describe the current and future educational activities that a school facility should accommodate. They clearly illustrate goals and outcomes, activities to be conducted, the persons to be served, spatial relationships of the program areas, equipment and technology needs, and any special considerations.

**Facility Prototype** – A prototype school design is any school plan that is repeated more than once using the original blueprint as the basis, with modifications largely confined to matters of differing site needs.

**Road System** – This term is used to describe the areas of the state reachable by road or marine highway. It was favored over “railbelt,” which refers only to areas reachable by rail. “Road system” infers a more urban context since many connected communities, such as those on the Kenai Peninsula, have more conventional access to the delivery of products and supplies, yet it also includes communities such as Glennallen, Valdez, and Tok (accessible by road), and Juneau, Ketchikan, and Sitka (accessible by water). All of these communities could be considered quasi-urban in the context of this study.



## CHAPTER 1 – REVIEW OF EXISTING RESEARCH

### SUMMARY OF EXISTING NATIONAL RESEARCH

The first step undertaken was the review of existing national prototypical design studies for schools. This enabled the project team to establish an informed perspective from which to develop Alaska-specific research strategies. This approach allowed the team to establish a baseline of comparison for evaluating local findings. Research included a comprehensive search and review of existing literature on the topic.<sup>1</sup>

The team determined that there is not an especially significant body of research available on the topic of the benefits and challenges of facility prototype design and construction for schools at the statewide level. Articles were found that described individual state and district-level experiences with prototyping, with the probable causal factors behind their benefits and disadvantages. Articles that lacked supporting evidence are not cited in this report.

Most pertinent and comprehensive among the materials reviewed was “Prototype School Designs: Can Prototypes Be Used Successfully?” a national research study sponsored by the Council of Educational Facility Planners International (CEFPI).<sup>2</sup> In it, lead authors Laura A. Wernick and John F. Miller performed a widespread study and analysis of materials related to the use of prototype school designs in the United States. They evaluated studies by Departments of Education in Arkansas, California, Georgia, North Carolina, Virginia, and Washington, position papers by the American Institute of Architects (AIA), as well as articles, newsletters, and other sources. They also communicated directly with school districts across the country, and through the AIA sought out architects nationwide who had designed prototype school designs. Their study included source materials from multiple states and covered a time period spanning 41 years (1964-2005).<sup>3</sup>

Wernick and Miller reviewed and summarized several prior studies of the topic performed by other State Departments of Education. The summarized conclusions of these studies are helpful in establishing context and understanding national trends:

**1. “Stock Plans Program, Experience of Two School Districts,” Washington, 1960**

*The use of stock plans may have contributed to the higher costs in school construction.*

*The school building program can best be served by the continued encouragement of original design and use of new and varied materials.*

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<sup>1</sup> See attached Bibliography.

<sup>2</sup> Wernick, Laura A. and John F. Miller et al. “Prototype School Designs: Can Prototypes Be Used Successfully?” A CEFPI Research Publication. 2007.

<sup>3</sup> Ibid, 4.

**2. “Stock Plans for Schools: Chimera or Panacea,” California, 1970**

*History indicates that achieving modern school facilities at less cost through the use of stock plans is an unrealized dream...the idea of stock plans has been extensively explored and the preponderance of available facts and opinions has prompted us to reject stock plan proposals as neither sound nor economical.*

**3. “Standard Architectural Drawings for School Buildings,” California, 1972**

*Use of prototype school designs...was impractical due to variations in soil conditions, weather conditions, site access, orientation, accessibility of utilities, educational program policies and class size.*

**4. “Recommendations Regarding the Development and Use of Stock Plans,” Georgia, 1991**

*The feasibility of using this approach as a means of reducing costs or shortening the time required for design and construction of new schools does not appear to be practical or economical.*

**5. “School Design,” Oregon, 2000**

*Prototype designs make sense within a local system when building multiple buildings of the same type in a short time frame.*

**6. “School Design,” Virginia, 2002**

*The economy of multiple uses of architectural plans is doubtful at best, and the most [sic] would be a fraction of the total cost of a school building. The perceived savings with model school design plans are actually nothing more than shifting costs from the local school division to the Commonwealth.*

**7. “Prototypical Building Designs: Recommendations,” Arkansas, 2004**

*The feasibility of using this approach does not appear economical and/or practical to meet the educational facilities needs of the State of Arkansas.<sup>4</sup>*

Wernick and Miller’s national study concluded the following:

- State-run prototype school design programs are not practical and will not result in cost savings.

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<sup>4</sup> Ibid, 5.

- Prototype school design programs in large school districts where there are ample resources can ultimately result in significant savings in time and cost when a large number of school buildings are being built within a short time frame.
- There is a lack of documentation on actual cost savings achieved when a school district reuses a prototype design that requires modification for site adaptation, educational program changes, or code changes.
- Web-based clearinghouses of prototype school designs are a valuable resource. However, there is a lack of research that documents cost savings from the reuse of these plans.
- A “Kit of Parts” approach to prototype school design has been used successfully when a large number of school buildings are being built within a short time frame. This variation of a prototype design addresses a number of the disadvantages of the one-size-fits-all approach.<sup>5</sup>

The CEFPI study and findings were important points of comparison as the team prepared to gather statewide input on the benefits and disadvantages of prototype design and construction in Alaska.

Additional findings in the existing research are also worthy of mention. For example, the State of Wyoming reported prototypical designs have not consistently saved time and money due to different site utilities, infrastructure, and location.<sup>6</sup> Wyoming’s school districts did not always have the manpower to utilize the prototypical design in a timely manner, and the State cited design complications due to differences in site selection.<sup>7</sup> The State also noted that designs need updating periodically to keep pace with changing leadership, educational programs, guidelines and standards.<sup>8</sup>

In Washington State, a 2014 State report recommends that, “a ‘stock plan’ catalogue or repository not be established for Washington State school districts to borrow plans already produced and implemented by other districts,” but rather the facilities commission, “believes the use of prototypical designs (not ‘stock plans’) can be beneficial to individual school districts that have a particular need to build the same or similar facility multiple times over a short duration.”<sup>9</sup> Though without written deliberation on the best use of prototypical plans, Washington’s 2014 report aligns with other findings in the research by suggesting prototypical school design and construction is best confined to individual districts experiencing acute growth.

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<sup>5</sup> Ibid, 7.

<sup>6</sup> State of Wyoming, School Facilities Department. “The Use of Prototype Designs.” Department White Paper. 2014.

<sup>7</sup> Ibid.

<sup>8</sup> Ibid.

<sup>9</sup> State of Washington, School Facilities Technical Advisory Committee. Update of the 1994 Report to the Legislature on the Use of Prototypical Plans by Local School Districts: Prototypical Plans/Stock Plans. 2014.

The AIA also notes in a brief entitled “Stock Plans: Bad for Schools” that 25 states have attempted state prototype plans for school designs and all “abandoned the idea...when the school districts realized they were losing money and receiving an inferior product.”<sup>10</sup> The AIA brief is consistent with all other reviewed reports in one important aspect: while viable for districts in defined circumstances, no states have found success with a statewide prototypical design program for their public schools.

In 2002, the Hillsboro School District in Oregon was the fourth largest district in the state, serving nearly 19,000 students. The district was also experiencing significant growth, with more than 2,200 new students enrolling between 1996-2002.<sup>11</sup> Within districtwide facilities, “elements such as cafeteria, gymnasium, kitchen and office areas are essentially the same.”<sup>12</sup> It is likely because of this homogeneity that Hillsboro was able to consider modular design, saving time and money on design and construction.

## SUMMARY OF EXISTING ALASKA RESEARCH

The State of Alaska has previously inquired into the benefits and challenges of facility prototyping. Several of these studies were reviewed by the project team, and the following is a brief overview of the key findings within these reports.

In August of 1997 a paper titled “The Prototypical/Standard Plan Dilemma” was presented by the Alaska Department of Education to the Bond Reimbursement & Grant Review Committee (BRGR).<sup>13</sup> Much of the information contained in the report is based on a research paper commissioned by the State of Georgia Department of Education, Facilities Services Section. The paper concludes from the onset that standard plans were far from favorable and that some 36 states abandoned the prototypical school approach since it was impractical and uneconomical. Key issues cited as being problematic were diversity in design influences such as site, climate, and structural considerations. Other factors included the perpetuation of a plan’s shortcomings, the restriction of creativity, and concerns about liability.

In an undated BRGR brief titled “Alaska Educational Facilities Prototypical Brief,” prepared in response to the 20<sup>th</sup> Legislature’s resolution<sup>14</sup> to encourage the use of prototypical schools where feasible, the committee concludes that prototypical school design and construction should be encouraged under certain circumstances, citing that there had been successful examples of prototypical use in several

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<sup>10</sup> The American Institute of Architects. “Stock Plans: Bad for Schools.” Issue Brief. February 2012.

<sup>11</sup> Riegel, Rich. “Hillsboro uses Mahlum Architects’ ‘kit of parts’ for school design.” DJC Oregon. December 10, 2002.

<sup>12</sup> Ibid.

<sup>13</sup> State of Alaska, Department of Education, Bond Reimbursement and Grant Review Committee. “The Prototypical/Standard Plan Dilemma.” August 18, 1997.

<sup>14</sup> Legislative Resolve 55, SLA 1998 (SCR 19).

districts around the state.<sup>15</sup> The brief advises that a single prototype is unlikely and suggests that as many as five to seven different prototypes might be necessary based on grade models alone (i.e., K-12, elementary, etc.). Caution related to diversities such as climate, educational programs, and soil conditions that would influence design was presented with the recognition that these variables would require further modifications to each of the prototype models. The report also relates the importance of user group input prior to plan development and the need for post occupancy refinement.

In a 1998 report from the Alaska Department of Education titled “A Report to the Legislature, Legislative Resolve No. 55., Use of Prototype Designs in Public School Construction Projects,” the strengths and weaknesses of concepts related to the development of prototypical school facilities, prototypical components, and creative incentives for districts to consider these concepts were explored.<sup>16</sup> The report took the idea of prototyping to a level that implies acceptance and the value of the prototype to the point where actual incentives were conceptualized to encourage districts to move in that direction. The report included a list of benefits, requirements for effective use, and limitations of using a prototype. The BRGR did claim that most advantages of prototype development would go to the school district and that the State would only expect to see modest savings related to design fees.

In “State of Alaska Rural Prototype Analysis,” an in-depth 1978 investigation by Construction Systems Management, Inc. (CSM) into the multitude of parameters surrounding the development of rural schools in Alaska, the authors examine the various external design influences that challenge the design process.<sup>17</sup> Influences included variations in environment, availability of utilities, student enrollment, project site placement, and structural considerations, as well as more subjective influences such as educational delivery models and contextual relevance within the community. This exhaustive report goes on to explore variables to consider in the process of design itself as well as the vast number of challenges facing a facility operations manager. The report concludes by emphasizing the importance of proper operations and maintenance and cites the many challenges related to facility care in rural Alaska in general, but does not necessarily bring these considerations into the context of their relationship to prototypical schools specifically.

Much of the Alaska resources are quite dated, and in the case of the report by CSM regarding rural schools specifically, seemed to focus more on the variables encountered in rural school design, construction, and maintenance than the applicability of prototypical school development. Furthermore,

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<sup>15</sup> State of Alaska, Department of Education. Bond Reimbursement & Grant Review Committee. Alaska Educational Facilities Prototypical Brief. Undated.

<sup>16</sup> State of Alaska, Department of Education. A Report to the Legislature, Legislative Resolve No. 55. Use of Prototype Designs in Public School Construction Projects. April 1, 1998.

<sup>17</sup> State of Alaska. Rural Prototype Analysis: I. Design Determinants and Options. Construction Systems Management, Inc., Livingston Sloan. August 1, 1978.

while life in rural Alaska is still less developed than life in urban Alaska, the approach to school design and construction is not as radically dissimilar between rural and urban Alaska as it once was.

Overall, the Alaska-specific literature on the topic was similar to the findings identified in the national research. Large scale efforts to develop prototype programs seem to be too problematic to merit pursuit at the State level while reasonable success could be anticipated under the right set of circumstances on a more focused scale. The information documented over three different reports by the BRGR seemed to progress from relative negativity toward prototyping to relative optimism, at least on a limited scale.

## EXISTING RESEARCH TAKEAWAYS

The background research provided a simple and concise framework for understanding the benefits and challenges of prototypical design strategies. While numerous states in the Lower 48 have attempted statewide prototypical school programs, there was no record of any prototypical school design and construction programs that, when applied statewide, were found to be viable by any state's department of education. In Alaska, the topic of prototypical school design and construction has been of interest to the State for many decades with varying degrees of study.

Diversity of important design influences contributed significantly to the viability of universally applied State-level prototyping programs. Throughout the project team's review of the existing research, four common variables that predict the viability of prototypical programs became apparent. They are growth, size, homogeneity, and time.

- **Growth** is imperative because prototypes by definition are designed to be repeated. Without population growth, a designed facility or component will not need to be repeated. This growth has to be significant enough to demand multiple reproductions of a design as the initial investment in a prototype is greater than a non-prototypical design since design professionals must anticipate future design challenges when developing a prototype.
- **Enrollment Size** is important because low enrollment attendance areas are unlikely to need multiple reproductions of a design even in periods of significant population growth. For example, an attendance area of 400 students experiencing 20% growth in 5 years will only add 80 students. Distributed over 13 grades, 80 students can be accommodated through scheduling and classroom additions, and would not constitute sufficient demand to build a new school or multiple schools.
- **Homogeneity** matters as design professionals cannot create a standard design for a group of users with diverse needs. Diverse facility sizes, climates, educational program needs, and site requirements preclude standardization and thus prototypical strategies.
- **Time** is a challenge to prototyping for two reasons. First, user needs often change thus requiring modifications to previous prototypical design. Second, updated technologies

and educational program delivery models require rethinking of previous design assumptions in order to take advantage of innovation.

All of these variables apply to predicting the viability of prototypical programs in Alaska as much as they do in other states. Diversity in geology, culture, climate, population and educational needs was found to impact the viability of prototypical strategies across the country. Since Alaska's environment, population, and educational needs are equally or potentially more diverse than other parts of the country, it can be anticipated that similar challenges to implementing prototypical design and construction will be experienced.

The project team's review of the available literature suggests that the development of a prototypical school design for statewide use in Alaska has little chance of being successful given the diversity of variables influencing design across the state. An individual district has a better chance of prototype viability when faced with population growth sufficient enough to warrant the construction of multiple schools in a short timeframe. Such a situation would present a reasonable opportunity for prototype success as long as there are homogeneous conditions within the district like school size, educational programs, and climate.

## CHAPTER 2 – STATEWIDE DATA GATHERING

### REQUEST FOR INFORMATION

Concurrent to the review of existing research, the project team developed a Request for Information (RFI) to collect quantitative data from all 53 school districts around the state. The purpose of the RFI was to gain a more comprehensive understanding of the districts' perceptions of the variables that the team considered influential in design development and construction of Alaskan schools. With a snapshot of the numerous design variables across the state in hand, the project team would be able to compare data gathered to qualitative questionnaires to be used during the regional and statewide conferences.

The RFI was developed by the project team utilizing their combined disciplinary expertise. Each team member was asked to create questions specific to their expertise that they determined would be useful in considering a statewide prototypical school design. Questions generated were to identify whether or not a district had utilized prototypical development strategies in the past, what kind of design infrastructure variables were available or currently implemented, and generally to gauge the overall interest in the subject of prototyping.

Along with the RFI data, the team populated existing data for school district size in terms of gross square feet of buildings managed and district enrollment growth in the last 15 years.

The RFI was organized into two parts, first it asked questions regarding individual schools within each district:

- Is the school a prototype?
- If the school is a prototype, is it considered successful?
- Does the facility use prototype components?

Secondly, the RFI asked questions on a districtwide basis regarding:

- Prototyping (Facility)
- Prototyping (Component)
- Fuel Source
- Electrical
- Water/Plumbing
- Foundation Systems
- Construction
- Alternative Energy



The RFI was sent to all 53 school districts along with an introduction to the overall research project. The introduction included preliminary announcements for future regional and statewide conferences along with a request to complete the document as soon as was reasonably practical.

**RFI Results**

A total of 33 out of 53 districts responded to the RFI. Through the RFI and additional follow up, eight districts reported that they had previously used prototype schools. It is worth noting that, as the team conducted additional research, several instances were discovered where an understanding of a district’s historical use of prototypes was lost due to the age of the district and changing personnel. The following is a list of school districts that responded to the RFI:

Responding School Districts		
Alaska Gateway	Aleutian Region	Anchorage
Bering Strait	Bristol Bay	Chatham
Chugach	Copper River	Craig
Delta Greely	Denali Borough	Fairbanks North Star Borough
Galena City	Hoonah City	Juneau
Kake	Ketchikan Gateway Borough	Klawock
Kuspuk	Lower Kuskokwim	Lower Yukon
Mat-Su Borough	Nenana City	North Slope Borough
Northwest Arctic Borough	Petersburg	Pribilof
Sitka	Southwest Region	St. Mary’s
Valdez	Yakutat	Yukon Koyukuk

***Prototyping as a Function of Size and Growth***

In order to establish current district attitude towards prototyping, the RFI asked each district to identify whether it was interested in prototype designs. Nineteen districts affirmed interest in exploring facility prototyping, and 14 responded in the negative. The correlation between expressed interest in prototyping and district size is strong, as the districts expressing interest in facility prototyping had significantly larger enrollment (246%) than those that did not.

Alaskan school districts’ expressed interest in prototyping mostly correlated with background research findings regarding successful use of prototypes. The RFI assisted the team in identifying districts that would have working knowledge of prototypical school use and that may be most receptive to utilizing prototype design in the future.

Districts with significant student population growth also expressed interest in prototyping, while districts with low-to-moderate growth did not. For this research, significant growth was defined as any district growing by 400 or more students since the year 2000, as growth of 400 students would thus suggest the need for new construction in most districts.

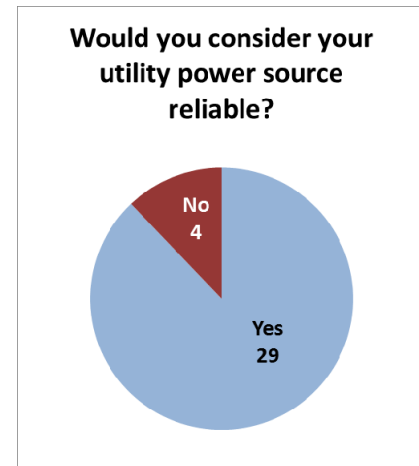
### ***Districtwide Response to Variable Design Influences<sup>18</sup>***

**Energy Source:** Of the districts responding to the RFI, 90% indicated fuel oil as their source of energy, while 27% also indicated natural gas and electricity. Approximately 9% reported using biomass (wood) sources. One district reported using hydroelectric as an energy source. Two districts indicated use of propane gas.

Use of different energy sources around the state plays an important role in the design of school mechanical systems. When restricted to fuel oil as a source, mechanical design choice is limited to the use of boiler systems as a heat source. Natural gas and electric fuel sources allow significantly more freedom in the design and selection of multiple mechanical systems on the market. Freedom to choose among a variety of systems allows the designer to select systems particularly suited for the environment, which increases the potential for efficiency and cost savings.

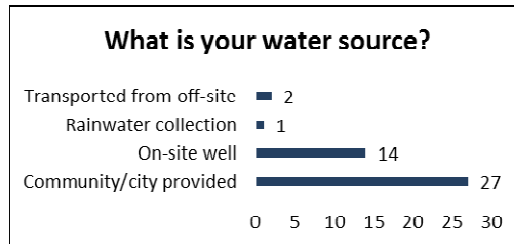
Diversity in regionally available fuel sources presents serious challenges in the development of a statewide prototype; however, regionally based prototype mechanical systems and/or components may have some potential opportunity for success.

**Electrical:** Of the reporting districts, 88% reported having reliable power and 75% reported that power is distributed underground from the utility. Reliable electrical power plays a role in whether or not a school would need to have an electrical generator. If a generator is required, it is typically provided in a standalone outdoor module that would have limited impact on a prototypical building footprint; however, if there is not adequate room on the site to accommodate an outdoor generator module, it would have a large impact on the configuration needs of a mechanical/electrical utility space inside the school. Overhead and underground electrical service changes the approach of how that service enters the building and would require updating on a school by school basis. Modifications may be required on most sites even if several predetermined “prototypical” scenarios could be pre-designed, and individual overview would be necessary for final approval.



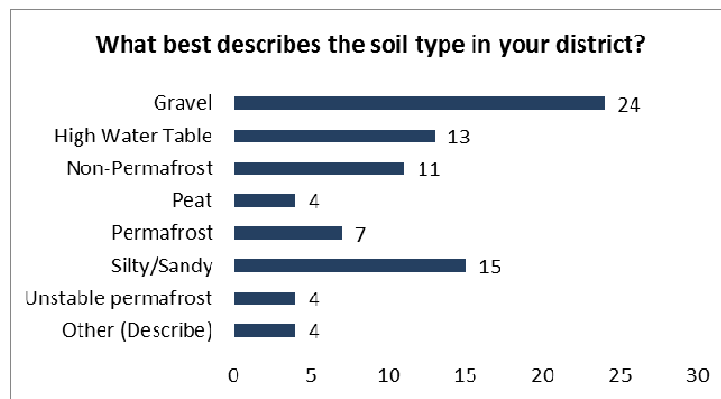
<sup>18</sup> Percentages are rounded to the nearest 1%.

**Water/Plumbing:** When asked to provide information regarding the water source, 82% said water and septic were community-provided systems and 42% indicated that they utilized on-site well systems. Only about 1% utilized rainwater collection systems or transported water from off site. Different water sources and required septic systems impact civil design and individual site design. Design of a prototypical facility would still need to consider each site on a case by case basis.

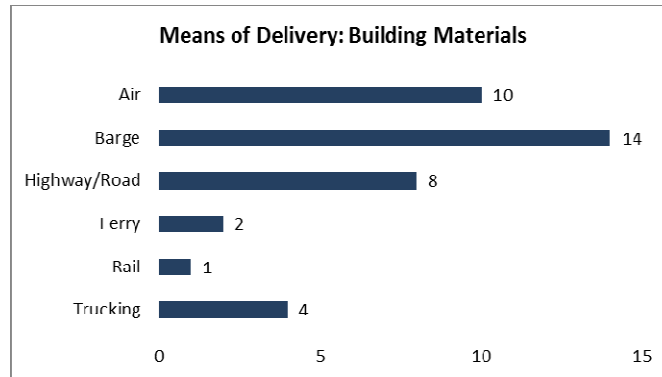


A community (public provided) system would have the least consequence to a proposed prototypically designed facility. Well and septic systems require individual design, and prototype design methodology would be problematic to apply. Practically speaking, developing prototype components such as a septic system could only be approached in relatively generic terms with individual oversight and potential modification needed by an engineer prior to final design.

**Foundation Systems:** When districts were asked to describe soil types in their district, multiple districts reported a variety of soil types due to geographically separated school sites. Among the responses, 73% of the districts reported having gravel, 33% reported having permafrost, 45% said they had silty/sandy soils, and 12% said they had peat. The variability in soil types around the state requires substantially different approaches in how a school’s foundation would be designed. Given the variability, foundation design is a significant challenge for prototype design of foundation systems.



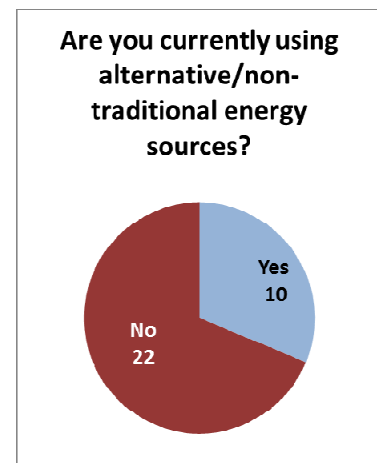
**Construction:** In review of the results to the question about how building materials are delivered to the site, virtually every mode of practical transportation is used. Combining trucking and highway road as a single response, 36% of the districts reporting said they receive goods via the road system. Combining ferry and barge delivery, 48% of the districts said they depend on delivery by way of water travel, and 30% said they utilize air travel as a means to receive materials. In overview, 82% of the districts claimed that they depended on transportation of materials by means other than the road system.



While these statistics do not necessarily discourage or promote prototype design, they suggest limitations on materials and products utilized. In general, the most limiting factors of air and water travel are weight and size of materials to be transported. Designs then must be limited to what can be effectively and efficiently transported by air and barge.

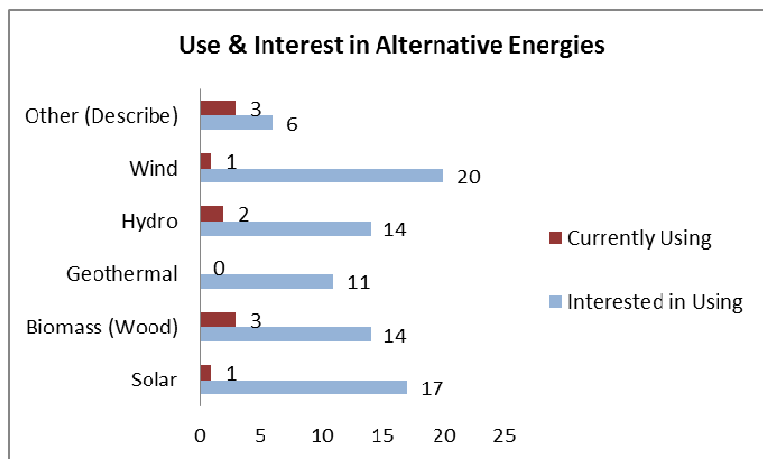
A prototype design would need to consider the availability of essential construction equipment like pile drivers, excavation equipment, drilling rigs, and booms or cranes. Should a school be designed that requires a piece of equipment that is not available, that equipment would have to be delivered to the site. Assuming transportation is feasible, cost will always be a factor. In many instances, the equipment itself is considered in the cost of the school construction contract as it is not uncommon for contractors to leave equipment behind after construction is complete.

**Alternative Energy:** The project team wanted to know whether or not districts were interested in using alternative sources of energy. A total of 31% of the districts reporting indicated they were currently using alternative energy sources. Of those, about one-third were using biomass (wood) heat systems, 20% were using hydroelectric, and 40% were using solar or other sources. There was an overwhelming response at 100% of responding districts expressing interest in the use of alternative energy sources with wind and solar receiving the most interest followed closely by hydroelectric and biomass (wood). Implications of this data as to how it may influence prototypical design in the near future is uncertain and



would require additional research into the success of such systems should they be considered for component prototyping.

The diversity of such systems presents the biggest challenge with respect to prototypical design application. The various alternative energy sources noted are often highly dependent on the natural resources of the region. Use of biomass (wood) or hydroelectric alternative energy is reasonable in a region such as Southeast where those resources (wood and water) are readily available and have greater economic potential of success. The same fuel sources in the Arctic would be impractical given the lack of trees and flowing water for much of the year. A reasonable prototype school would need to consider the most practically available fuel source within all regions if a single prototype were considered. Regional prototyping for alternative fuel source component design would have a greater potential for success.



### RFI Takeaways

The RFI confirmed key background research findings: district enrollment size and growth are necessary for prototypical programs to be economically viable. Alaskan school districts' expressed interest in prototyping does align with those factors that enable prototypes to be economical. Before beginning the facility tours and regional conferences, the hypothesis was that the viability of facility prototyping in Alaska would have to consider the same factors of homogeneity, size, and growth as background research identified. Whereas facility prototyping research resoundingly shows individual districts are the only predictable benefactors from facility prototyping, the hypothesis was that multiple districts could theoretically benefit from a prototypical component program. Results suggested there were enough similarities in the conditions affecting utilities and construction to explore the viability of regionalized component programs in Alaska.

Any prototyping program will need to limit diverse design challenges while generating a product that can be built several times over in a defined period of time with little to no modification. Benefits to a

regionalized component prototyping program could be possible under two circumstances: 1) when multiple districts share the same set of environmental and construction-related conditions; and 2) when the prototypically designed component would be used multiple times within a narrow window of time by the users for which it was designed. This would ensure the extra time and money spent in the design would pay off through multiple uses and that the product would be used quickly enough so that new product innovation would not undercut cost savings from the earlier design.

**REGIONAL CONFERENCES**

The project team hosted seven regional conferences across Alaska over a period of two weeks. During the first week (March 9 – 13, 2015) the team held conferences at the North Slope Borough School District (NSBSD), Fairbanks North Star Borough School District (FNSBSD), Lower Kuskokwim School District (LKSD), and Kodiak Island Borough School District (KIBSD). During the second week (March 30 – April 3) the team held conferences at the Juneau School District (JSD), Matanuska-Susitna Borough School District (MSBSD), and Anchorage School District (ASD), and also hosted the statewide stakeholder conference.

Regional conferences consisted of two events. First, the team performed facility site visits at pre-selected schools (both prototypical and non-prototypical), where interviews were conducted with principals and facility operations managers. Second, the project team hosted a public presentation featuring an explanation of the study, review of the existing research, questionnaire completion, and discussion about relevant statewide and local topics. The presentations were designed to engage school district personnel, design professionals, and citizens in order to facilitate discussion with a cross section of Alaskans and gather as much stakeholder input as possible.

Regional conferences were organized to visit regions that represented as much diversity as possible, and that represented multiple facets of the state such as geographic location, climate, culture, and population density (i.e., rural, urban, or both). The table below shows the characteristics of the districts included in this study:

Location	Region	Culture	Rural or Urban
Anchorage	Southcentral	Athabascan	Urban
Barrow	Arctic	Inupiaq	Rural
Bethel	Southwest	Yup'ik	Rural
Fairbanks	Interior	Athabascan	Urban
Juneau	Southeast	Tlingit/Haida	Urban
Kodiak	Aleutians	Alutiiq	Rural/Urban
Mat-Su	Southcentral	Athabascan	Urban

Within these regions or districts, the team toured representative educational facilities to strengthen overall understanding of how design diversity influences planning, design, and construction. It was important to see how design manifests itself through construction in relation to dramatically different influences. This allowed the team to analyze the individual importance of identified design variables in relation to prototype design use. Individual schools visited within the districts noted above included prototypes, non-prototypes, and those constructed in between these strict definitions.

The selected cities were chosen in part due to their status as regional transportation hubs and the potential for hosting large groups of people. The strategy behind the regional conferences was to host events in locations where the maximum number of people could be conveniently serviced. By hosting conferences in regional hubs, the team believed it improved the potential and opportunity for people residing in outlying communities to attend the conference.

The project team utilized all communication platforms, including electronic distribution, printed direct mailings, print and radio advertising, and telephonic communications to reach as many people as possible, and invite and encourage them to attend and participate in the regional conferences. Target audiences for all forms of solicitation included school superintendents, educators, architectural/engineering design professionals (including general contractors and building safety departments), and local Alaska citizens. Among these, educators and design professionals were encouraged to attend, participate, and invite others in their respective circles of influence. A website was developed during the early phases of project strategy development to provide a means by which information could be disseminated.

Conferences were planned as one day events that included two distinct sections. Mornings focused on the school site visits and interviews with principals, educators, and facility operations staff. Evenings were dedicated to hosting the public presentation where all noted target groups could gather, complete questionnaires, participate in a conversation related to the questions on the questionnaires, and voice opinions and practical experiences. Evening sessions were held between 4:00 p.m. and 7:00 p.m to maximize attendance from targeted groups.

Regional conference attendance was low in most locations. To some extent, low attendance from people beyond the travel distance of an automobile was anticipated. Conversely, low attendance from school district personnel was not anticipated in locations where events were held within school district headquarter cities. In such instances, questionnaires were left for distribution to district staff at a later date.

With low conference attendance and low questionnaire completion, analysis of data results must take into consideration the lack of broad base representation. Consequently, interpretations and conclusions have been tempered with trends indicated by research findings.

### **Presentation Questionnaires**

The project team spent approximately six weeks developing unique questionnaires for three primary target groups: school district personnel (i.e., educators, staff, and facility operators), the professional design community (i.e., architects and engineers), and citizens of Alaska. Each of the three questionnaires was intended to illuminate relevant factors that would influence design and construction of school facilities in Alaska, and solicit input as to whether or not prototypical design had been or was perceived to be successful. In every case, questions were designed to probe respondents with respect to viability implications, acceptance, and the potential benefits and disadvantages to using prototypical facilities or prototypical components in school design and construction in Alaska. Many of the questions were appropriately repeated for all target groups; however, the design professional questionnaire included specific questions of a more technical nature, particularly with regard to design component topics.

The questionnaires were a crucial element in the project and the primary tool by which the project team reached out to and gathered input from the target groups. These questionnaires consisted of 12-15 questions related to prototype and school program needs and five demographic related questions. Demographic questions were identical in all three questionnaires and were noted as optional on the questionnaire. Where questions were specific to prototype schools, the respondent was asked to reply “No opinion” if they did not have experience with prototypical schools.

### ***District Questionnaire***

Questions were directed toward school district personnel across the gamut of expertise within the district. The questionnaire was written around gaining an overall understanding of the value school districts placed on prototypical design relative to non-prototypical and the perceived benefits or lack thereof on a series of related subjects. The questionnaire also attempted to gain perspective on what components were considered viable for prototyping within their district or region.

Questions 1-6 asked the respondents to make comparative choices in terms of advantages and disadvantages, more or less beneficial, and level of importance to a series of questions related to the following areas:

- Community Identity
- Community Use (Non-Educational)



- Educational Adequacy
- Energy Efficiency
- Expandability (Growth Potential)
- Initial Capital Cost
- Long-term Maintenance and Operational Costs

Within this group of questions one question of the six asked respondents to rank the importance of specific program spaces typically found in school facilities and one asked the respondent to describe their experience with construction and renovation projects as it related to cost savings and support of the educational needs of the school.

Questions 7-12 were focused on project development time, cost, component standardization, and several qualitative questions relative to overall school appropriateness. These questions covered topics such as:

- Prototype impact design time and cost.
- Benefits, if any, to component prototyping from a list of suggested components related to new or renovated projects.
- Whether or not schools in the district are appropriately sized.
- Whether or not certain mechanical/electrical components were worth paying a premium for.
- Appropriateness of school sites in the district to receive pre-constructed modules.

### ***Professional Design Community Questionnaire***

Questions directed toward design professionals were intended to gain insight into big picture priorities in the design of a facility and a detailed picture of what may be appropriate in facility components.

Questions 1–6 were similar to the district questionnaire and asked the respondent to make comparative choices in terms of advantages/disadvantages, more beneficial/less beneficial, and the level of importance to a series of questions related to the following:

- Community Identity
- Community Use (Non-Educational)
- Educational Adequacy
- Energy Efficiency
- Expandability (Growth Potential)

- Initial Capital Cost
- Long-term Maintenance and Operational Costs

In most instances, the respondent was asked to explain their choices to provide insight to the response. Questions 1–6 were facility prototype focused. Questions 7–15 asked for a more technical response and were pointed to experienced design professionals that have worked with educational facilities. The questions were also more focused towards component prototype use. These questions covered such topics as:

- How often prototypical plans would require updating.
- Usefulness of Ed Specs vs. plans and specifications.
- The future of hardwire vs. wireless in classrooms.
- Advantages/disadvantages of standardized mechanical equipment.
- Whether or not the use of highly sophisticated control systems is appropriate in all locations.
- What kinds of mechanical systems are used in program spaces common to all schools like gymnasiums and classrooms.
- Who drives the requirements for energy related design.
- Types of prototype infrastructure (components) may be economically appropriate for various regions.

### ***Citizen Questionnaire***

Citizen questionnaire questions focused on how important the school was to the community above and beyond traditional student education.

The questionnaire asked seven questions related to prototype schools and what was important to the responder. The questions covered topics such as:

- Would a prototype reproduction school be acceptable in their community.
- Level of concern over rising construction costs.
- Ranking of importance of features related for community schools like art and music spaces, educational opportunities, vocational training, and meal programs.
- Use of the school for activities other than school/educational training.
- Importance of energy cost and construction cost.
- Appropriateness of current school size in the community.

## Questionnaire Findings

In total, 63 district staff, 38 design professionals, and 22 citizens responded to the questionnaires. With smaller sample sizes, it is important to not generate broad generalizations from this data alone, but rather consider the results in light of the existing research and the regional conference meeting discussions.

Questionnaire results revealed that the needs of the local education program and long-term costs to operate and maintain a facility are paramount concerns for all stakeholders. Community-related considerations were seen as not as crucial a design consideration in comparison to educational and economic matters. Facility prototypes were seen as impractical across districts in Alaska due to diverse programmatic, size, and environmental factors. Component prototypes were seen as potentially viable cost saving solutions depending upon individual site requirements and the ability to operate and maintain the components.

### District Questionnaire Results

Along with citizens and those in the professional design community, district respondents prioritized current educational needs and long-term maintenance in school design as the most important issues. When asked to rank design considerations in order of importance when “deciding between a prototype plan vs. a non-prototype plan,” educational adequacy was clearly the most important factor (see Table 1). The next most important concern noted was long-term maintenance, followed by initial capital costs, and energy efficiency. Growth potential and community use considerations were ranked relatively low, and community identity was ranked as the least important consideration from the list provided.

**Table 1: Ranking of Criteria Related to Prototypical vs. Non-Prototypical Plans**

District Questionnaire	Priority Ranking						
	1*	2	3	4	5	6	7
Community Identity	4%	4%	11%	7%	13%	19%	43%
Community Use (Non-Educational)	2%	2%	5%	16%	22%	38%	15%
Educational Adequacy	63%	11%	11%	7%	7%	0%	2%
Energy Efficiency	6%	9%	27%	30%	11%	13%	0%
Expandability (Growth Potential)	2%	11%	13%	16%	20%	17%	19%
Initial Capital Costs	9%	25%	20%	9%	15%	13%	15%
Long Term O&M Costs	15%	38%	14%	14%	11%	2%	6%

\*#1 Most Important

Long-term maintenance and initial capital costs were the biggest advantages district staff noted from previous prototypical projects. One comment provides a good summary of district stakeholder responses to their priority concerns: “Education for today is most important. Being asked to afford the building for its design life is necessary. The building is successful if accepted and used by community.” Sixty-one percent (61%) of district staff noted that educational adequacy was an “advantage” stemming

from prototypical design, an interesting contrast when compared to the professional design community with nearly 50% saying it was a disadvantage. Similarly, while district respondents thought the majority of building systems “would benefit [their] region/school district if developed as component prototypes,” their comments reflected that actual experiences were mixed:

- “All details have to be verified by the design team of record and their subs. No savings.”
- “Had to redesign 3 times to fit needs.”
- “Did not save money in design. Did not really decrease design time.”
- “Design cost was not reduced as much as expected; however, it was reduced.”
- “Helped fast track the Valley Pathway project.”
- “Needed to build multiple elementary schools at one time. Helpful with time and budget.”
- “Design time was reduced as there was a major component done with the prototype.”

### **Professional Design Community Questionnaire Results**

Architectural and engineering design professionals focused on controlling long-term costs. Comments highlighted the fact that the costs potentially saved in upfront design using prototypical strategies are a fraction of the lifetime operations and maintenance (O&M) costs of a facility:

- “Life Cycle Cost Analysis shows O&M dwarfs all other costs associated with design and construction. To successfully deliver and fulfill the mission, design to minimize O&M.”
- “Long-term O&M is the most costly part of life cycle school ownership.”
- “Let’s cut to the chase, a prototype can save on some design time and fees, but only if the plans fit the site and current code requirements. These fee savings are negligible compared to 40 year operating costs of a facility.”

**Table 2: Perceived Advantage/Disadvantage of Prototype School Design**

Professional Design Community Questionnaire	Advantage	Disadvantage	No Impact
Community Identity	4%	63%	33%
Community Use (Non-educational)	27%	23%	50%
Educational Adequacy	25%	46%	29%
Energy Efficiency	21%	46%	33%
Expandability (Growth Potential)	33%	42%	25%
Initial Capital Costs	54%	13%	33%
Long-term O&M Costs	46%	29%	25%

Among surveyed architects and engineers expressing previous experience with prototypes, roughly half believed the use of prototypes has a positive impact on initial and long-term costs, slightly more than

half believed prototypes were either an advantage or made no difference on educational adequacy, and between a quarter and a third did not believe the use of prototypes has any impact on most of the identified design considerations. Similarly, when asked to “rate the level of importance you would assign to each of the following when considering whether to pursue a prototype plan or a non-prototype plan,” architects and engineers ranked “Delivery of Educational Program” and “Long-term O&M Costs” as most important from the list provided. “Community Identity” was seen as least important of the given considerations when deciding whether or not to pursue prototypical design. Responding architects and engineers also believed that facility and component prototyping is a strategy best employed at the district level. In line with background research, architects and engineers thought prototyping at the state level was not practical due to complications from diverse client and environmental factors. Representative comments include:

- “Beyond basic classroom instruction, most schools I’ve worked with had vastly different needs from each other.”
- “The state is too diverse to make [prototypical] component or building design viable.”
- “Prototypical components could be useful with large diversities in geographic locations and local community values overall, prototypical design cannot respond properly.”
- “I believe that prototype schools can be an effective tool for individual districts but not statewide. There are too many variations in community demographics, climate, terrain, technology access, construction techniques, etc., in Alaska to make a statewide prototype useful, however when individual districts devote a significant effort to identifying their needs and creating a design that reflects those needs it can be a useful tool to guide the design process.”
- “1-4 year shelf life of the prototype regarding user and system technology integration. Why would you continue to use building systems that are out of date?”
- “Component design should be by district – standardization of lighting or boiler types. Square footage limitations miss the mark for storage, circulation and entry requirements of rural districts.”

**Table 3: Length of Relevancy for Electrical Plan Prototypes**

Professional Design Community	Less than 6 months	7-12 months	1-2 years	3-5 years	Greater than 5 years
Total Responses	8%	15%	49%	28%	0%

Relative to components, most architects and engineers noted that electrical plans need updating every 1-2 years (see Table 3). The pace of such innovation provides a challenge to regional or statewide component prototyping of these systems, since by the time a standard can be determined for multiple users, component innovation has already occurred. Direct Digital Controls (DDC) was a strategy for controlling energy and O&M costs advocated for by the professional design community in conference

discussions; however, it was acknowledged that facilities personnel need training to properly use and maintain DDC controls before it could be effectively standardized.

**Citizen Questionnaire Results**

Eighty percent (80%) of citizen respondents were accepting of prototypes for their community. All but two respondents expressed concern over “increasing construction costs for new schools,” and 90% said that their school’s energy use was a priority to them. Of seven different considerations, the top three design concerns of citizen respondents were Educational Offerings, Vocational Education, and Art-Music-Theater Programs/Spaces (see Table 4). School Meals, Special Education Programs, and Venue for Community Events/Meetings were next in importance with Cultural Identity ranked as the least important design consideration. Citizen comments provided insights into their consensus on the importance of educational considerations and operational costs:

- “As a tax payer, of course I am concerned about increasing construction costs. But my small community does not build a lot of schools. When it is our turn, we want to do it right, and the solution needs to last for many decades.”
- “Schools last 30-50 years. Think long term.”

**Table 4: Ranking of School Features by Community Respondent**

Citizen Questionnaire	Priority Ranking							
	1*	2	3	4	5	6	7	8
Educational Offerings	71%	33%	0%	0%	0%	5%	0%	0%
Vocational Education	12%	22%	25%	21%	11%	11%	0%	0%
Art-Music-Theater Programs/Spaces	6%	11%	25%	11%	16%	16%	18%	0%
School Meals	0%	0%	19%	26%	21%	16%	6%	29%
Special Education Programs	0%	11%	13%	21%	26%	21%	12%	0%
Venue for Community Events/Meetings	0%	6%	0%	16%	16%	16%	29%	57%
Cultural Identity	6%	11%	19%	5%	5%	11%	35%	14%
Other	6%	6%	0%	0%	5%	5%	0%	0%

\*#1 Most Important

**Questionnaire Results Summary**

Questionnaire results showed that the experiences school districts and the professional design community surveyed have had are mixed. All respondents clearly prioritized educational adequacy as a primary design focus, with long-term maintenance and operational costs a secondary but important consideration. The standardization of building components within districts was favorable insofar as component standardization led to long-term savings from streamlined operations and maintenance. The selection of such components depends on site needs and district capacity to successfully operate and maintain them.

Facility prototyping was not favorable when considered at the state level, but received positive comment when mentioned in the context of individual district growth. Community respondents expressed openness to prototypical schools in their community as a cost saving measure provided the local school's educational mission was satisfactorily addressed in design. The questionnaire results are consistent with findings from the initial background research and reflected during regional conference discussions.

## STATEWIDE CONFERENCE

An additional statewide conference hosted in Anchorage was designed to be identical to the evening sessions of the regional conferences, but intended for stakeholders statewide. This conference did not include project team interviews with district personnel or school site visits. The format was designed to be essentially the same as the regional conferences with a brief introduction of the national research findings, questionnaires, and subsequent discussion related to the questionnaires. Unfortunately, attendance was extremely minimal. To follow up, two teleconferences were conducted through the Alaska Council of School Administrators and the Alaska Association of School Board Officials. The team provided a presentation summarizing the existing national research, similar to that presented during the regional conferences to familiarize the group with the subject. The group engaged in a discussion related to the benefits and challenges of prototypical design and construction with particular emphasis on several topics of interest that had arisen in conversations with groups around the state.

### *Findings*

The results of the relatively brief discussions were direct and to the point with respect to the research subject. Participants expressed interest in the following:

- Component prototyping;
- Building standards;
- Statewide database for components, specifications, and training;
- Pool of experts for use in maintenance and training; and
- Regional maintenance agreements.

Participants in the statewide teleconference expressed their belief that multi-district facility prototypes would tend to be “overdesigned” in an attempt to accommodate diverse user needs and thus not be productive. As with the regional conferences, participants in these conferences believed that long-term O&M savings were possible through well-thought-out component standardization programs. Such programs, it was generally expressed, could save a little money in upfront capital/construction costs but most savings would be realized over time through efficiency gains in maintenance and maintenance training efforts.

## CHAPTER 3 – DISTRICT PROFILES AND SITE VISITS

The project team visited 15 schools within the seven districts where regional conferences took place. The purpose of these visits was to familiarize the team with local educational programs and delivery philosophies, capture first-hand the history and potential for future use of prototype facilities and components within the state, learn how construction technologies differ from region to region, and grasp the essence of Alaskans' opinions related to the viability of using prototype facilities and components in the future. The following districts and schools (listed in order of visits) were visited:

- **North Slope Borough School District (Barrow)**
  - Ipalook Elementary School – *Non-prototypical*
  - Barrow High School – *Non-prototypical*
- **Fairbanks North Star Borough School District**
  - Nordale Elementary – *Prototypical*
  - Ladd Elementary – *Prototypical*
- **Matanuska-Susitna Borough School District**
  - Su Valley Jr. /Sr. High School – *Non-prototypical*
  - Valley Pathways – *Non-prototypical*
- **Anchorage School District**
  - Dimond High School – *Basis for Prototypical (Eagle River High School)*
  - Kincaid Elementary – *Prototypical*
- **Lower Kuskokwim School District (Bethel)**
  - Napaskiak K-12 School – *Partial Prototypical*
  - Kwethluk K-12 School – *Partial Prototypical*
  - Gladys Jung Elementary School – *Non-prototypical*
- **Kodiak Island Borough School District**
  - Kodiak Middle School – *Non-prototypical*
  - Kodiak High School – *Non-prototypical*
- **Juneau School District**
  - Mendenhall River Community School – *Prototypical*
  - Thunder Mountain High School – *Non-prototypical*

Since regional conferences were held back-to-back over two one-week time periods, similarities and differences between schools were immediately apparent and offered excellent insight. All schools visited provided unique insight into the individual processes that each district utilized in their development. The information and knowledge gathered was cumulative. The experience gained through interviews informed and enabled the project team to ask more in-depth questions during subsequent site visits. As a result, follow-up interviews with several districts were conducted via telephone to



further explore prototype history and future use potential. The district profiles on the following pages are reflective of information gathered during site visits, initial interviews, follow-up interviews, and additional research on related topics.

## **NORTH SLOPE BOROUGH SCHOOL DISTRICT**

### ***Background***

Located in the northernmost part of the Arctic, the North Slope Borough School District (NSBSD) is responsible for 12 schools (as reported in the District's RFI response). Overall the student population is considered stable with no real growth or decline in the population in the foreseeable future. The need for new school construction is relatively low with only one major renovation project expected on the horizon. The District allows each community to have a reasonable say in the design of their school and encourages community involvement in the development of individualized Ed Specs when opportunities for substantial change arise. Lack of newly developing schools and subsequent construction has led to infrequent updates to building standards. The District faces difficulty in obtaining accurate estimates for construction projects, which has been problematic in developing project budgets for construction; however, the Borough has assisted with construction budget shortfalls in the past. The cost of material procurement in rural districts drives up capital cost and as a result takes funds from educational related improvements.

### ***Past Prototype Use***

The North Slope Borough School District has never developed or utilized a prototypical school. With a relatively flat student enrollment and only renovation of schools determined necessary anytime soon, the District does not anticipate the construction of a new school in the foreseeable future.

### ***Site Observations***

The project team visited Ipalook Elementary and Barrow High School (both non-prototype schools). During the walk-throughs, there were few apparent differences in the approach to design and construction when compared to other schools across the state, with the exception of the elevated pile foundation, indoor playgrounds, swimming pool, and intentionally placed corridors to separate primary building components. These features can be directly attributed to the unique geographic and climatic influences found in the Arctic region as well as the complete isolation that limits services such as fire department response. A pool in the high school serves a critical fire protection service by doubling as a water source for the code required automatic fire protection system. Corridors are placed on a separate foundation system, creating separation between school programs, which enables the corridor to be bulldozed in the event of fire to prevent further damage both from fire and the demolition of the connecting corridor.

While on site, the team looked for design concepts that would be an expression of the unique culture of the region to determine how this design influence may be affected by a potentially more generic prototypical school. Generally speaking, the Inupiaq culture in these schools was expressed only by art work, artifacts, and displays of crafts, tools, and clothing. Similar to schools subsequently observed, it appeared that cultural differences in the region did not necessarily play a significant role in the design of the school itself.

### ***Future Prototype Use***

The District was interested in the concept of prototypical system/components, but has no need to develop prototypes due to no foreseeable new school construction. Given the difficulty of training staff to properly maintain the various systems and components across the district, the idea of standardized parts and systems seemed to resonate with the facility operations staff. They believed that the more similarities in the equipment of each school, the better the chances of training staff to maintain that equipment.

## **FAIRBANKS NORTH STAR SCHOOL DISTRICT**

### ***Background***

Located near the geographic center of the state, the Fairbanks North Star Borough School District (FNSBSD) is responsible for 30 schools (as reported in the District's RFI response). Student population is relatively flat and trending to a slight decline, though population does occasionally shift within various communities throughout the district. With a flat and declining student population, there are no new projected construction needs; however, renovations required to maintain schools and comply with life safety codes will be ongoing. FNSBSD allows each community to develop its own Ed Spec for a new school so, when a school design is fundamentally a prototype, modest internal changes are facilitated. As with primary internal functions, the exterior of the school apparently changes little, thus facilitating minimal infrastructure changes to structural, mechanical, and electrical systems. FNSBSD says the community embraces the concept of prototypical school design, believing it to be a cost effective model from which to approach educational facility delivery.

### ***Past Prototype Use***

FNSBSD reported in their RFI response that seven of their schools are prototypical. In a follow-up interview, the District said the earliest prototype schools were developed in the 1970s with two schools being constructed during that time period. In the mid-1980s to mid-1990s, a second prototypical plan was developed and utilized for three schools. A third prototype plan was designed in the early 2000s and two additional schools were constructed from this model.

The project team visited two of the District's prototypical schools: Ladd Elementary School (1992) and Nordale Elementary School (2005). Ladd Elementary was initially constructed and refined for three subsequently constructed schools. The design remained relatively unchanged except for code required changes and modest internal modifications. Nordale Elementary was constructed two times simultaneously (the second being Denali Elementary, also in 2005).

FNSBSD indicated that the community gravitated toward the use of prototypical school plans believing there was economy in the repetitious use of plans and the standardization of components. With a strong commitment to staff training and operational efficiency, District personnel contend that a prototype design philosophy contributes to training efficiencies and the ability to operate installed systems as originally designed. Through operational efficiency, FNSBSD boasts some of the most efficient operational and energy usage in the state, reportedly cutting previously recorded operational costs by up to 50%.

Research indicates that prototypes are often adapted to meet changing community needs or to make refinements in operational systems. This was the case with the prototypes developed by FNSBSD in the 1980s and 1990s. Initial conversations at the regional conference indicated that FNSBSD generated "adapted prototypical design," but upon further investigation, however, adaptation occurred approximately 50% of the time. Adaptations observed during site visits to FNSBSD's prototypical schools appeared to be relatively minimal and generally limited to minor functional modifications, mainly minor circulation changes. The exterior shell and mechanical/electrical systems of the school had no appreciable modifications.

It was learned that FNSBSD designed and constructed the initial prototype school of the 1980s and 1990s, and then spent time analyzing, evaluating, and refining the design prior to reproducing the school. Through construction evaluation and refinement, the District recognized the need to make substantial changes to the location of the mechanical rooms and to take a different approach to the heating design. With major refinements in place, the District worked with individual communities regarding additional programmatic changes that made sense prior to finalizing design and continuing with replication of additional schools under the prototype model. Subsequent school design and construction of Nordale Elementary and Denali Elementary were fundamentally the same.

By definition of this research, FNSBSD has constructed relatively conventional prototypical schools. For all practical purposes, the minor adaptations made do not negate the usefulness or the definition of a prototype. Specifically, Nordale Elementary was mentioned as a likely candidate for further reproduction, citing its two story solution as efficient and functionally viable. It is important to note that this school's design is over 10 years old and is believed to adequately serve today's educational delivery model.

When asked if the District believed or the public perceived any substantial differences in how a prototypical design enabled education to be delivered as compared to a non-prototypical design, the answer was no real difference. They said there was modest economic advantage, particularly in respect to design. They also indicated that contractors that built one prototype were more likely to build additional prototypes. This tends to suggest that construction of prototypes may reduce contractor risk and consequently the cost of construction

### ***Site Observations***

The project team visited Nordale Elementary and Ladd Elementary (both prototypical schools). Observations revealed no obvious differences in the approach to design and construction when compared to many of the schools visited across the state. While this may suggest prototypical design could be practically applied, acceptance by the stakeholders without the ability to adapt the design for individual community nuances seems unlikely. The team also observed the schools in Fairbanks from the perspective of cultural identity influence. Not unlike most of the schools visited, cultural identity is demonstrated by decoration rather than by integration into the design of the school itself.

At Nordale Elementary, the principal claimed that siting of the school with respect to the plan was not optimal and that potentially more attention could have been given to this design challenge.

### ***Future Prototype Use***

FNSBSD indicated that the use of prototypes had been successful, and they would continue to utilize prototype models in the future should the opportunity arise; however student enrollment is currently in decline. In the foreseeable future, new prototypical facilities appear to be unlikely. Renovation and asset protection are the most likely up and coming construction projects. While prototype facilities are embraced by the District, the need to have “adaptable” prototypes was emphasized.

FNSBSD does utilize building and material procurement standards, and they strongly believe that standardization of parts and systems leads to overall improved efficiency, particularly in the ability of the facility and operation’s staff to operate systems as designed, a key to building efficiency. Standardization enables the District to effectively train staff and to operate systems producing substantial return on training investment. Like all public projects, they are bound to competitive pricing, so sole sourcing is prohibited without a substantiated reason. That said, generally system types can be standardized with only vendor specific deviations.

The District embraced the idea of system component standardization believing that the more the systems are similar, the more potential there is to have appropriately trained staff for the system. The District also believes training costs would decline if systems were similar or identical. There was some

expressed concern over State regulated component use for fear of losing flexibility, but overall the concept or notion that it could work was positive. There is at least one example of component standardization use in the district through the use of skid-mounted generator buildings.

## **MATANUSKA-SUSITNA BOROUGH SCHOOL DISTRICT**

### ***Background***

Located in the southcentral region of Alaska and only 30 miles from Anchorage, the Matanuska-Susitna Borough School District (MSBSD) is responsible for 37 schools (as reported in the District's RFI response). Unique to all other districts in the state, MSBSD student population is increasing, with multiple design and construction projects in progress. (For comparison, in the Bethel-based Lower Kuskokwim School District, new construction projects are essentially for replacement schools, while in MSBSD there is insufficient classroom space to support the increasing number of students.) The District does not have a districtwide Ed Spec but rather opts for a more site-specific community developed specification. Strong community engagement and the Ed Spec process are believed to be the most important components to the design process by the District. A significant part of the District's design and construction philosophy is to regularly maintain a building design standard. This standard is constantly evolving.

MSBSD schools are owned and operated by the Borough. A strong and integral working relationship clearly exists between the two entities, both are commonly and singularly focused on bringing educational and facility needs together in mutually beneficial ways.

### ***Past Prototype Use***

MSBSD has been experiencing steady growth since the 1980s, resulting in a need to bring multiple schools online in a short period of time. Reproduction of prototypical schools during this period was limited to elementary schools, because elementary school programmatic needs are such that prototype schools are viable. Under such circumstances, the trend seems to rely more on past experience and steady production than the development of schools in response to voiced community needs.

MSBSD identified 16 schools as prototypical in the RFI response. Three schools, Iditarod Elementary (opens fall 2016), Susitna Valley High (2010) and Valley Pathways (2000) were noted in the RFI information as being prototypical schools; however, these schools, as well as Mchetanz Elementary (2009) and Dena'ina Elementary (opens fall 2016), were developed under a "basis of design" model rather than a prototypical model. By the definition of a prototypical school in this report, none of these schools would be considered a prototype. A basis for design allows for reconfiguration or room size variations in response to an individual user. With prototypical schools, room sizes, spatial adjacencies, and plan configurations typically remain relatively unchanged. Dena'ina and Iditarod were developed

based primarily on the Machetanz floor plan, but the changes made were such that they should be considered a basis of design.

The district originally intended to develop Machetanz Elementary as a prototypical school; however, after reconsideration the district determined a basis of design model was a more fitting approach. According to MSBSD, rapidly changing technology, educational delivery models, and individual community needs were such that reproduction of the same plan did not serve District or community needs as well as allowing greater freedom in the design. The basis of design model allows subsequent designs to be refined as necessary to reflect lessons learned from previous schools. Lessons learned may be in response to construction and component system improvements to functionality differences or preferences by the community served. While schools developed under a basis of design model have a familiarity to them, there are sufficient fundamental differences in each subsequent design such that a complete new set of construction documents are needed to construct the building. When the District was asked to compare prototype design and basis of design, the single biggest difference seemed to be the personalization that comes with basis of design, which allows for a more individualized design response.

Construction approach and efficiencies that may be afforded in exact duplication in a prototype as defined would not necessarily be realized in the basis of design model. There seems to be an expectation that the benefits of basis of design versus prototypical design would be realized in the refinement process, both in construction and functional product. There is a substantial emphasis on refinement of plans developed for a school project in an effort to keep up with changing technology and educational models. As a result, there is little to no complete duplication of previous school plans. Adaptation is always a part of the district's process.

District staff noted changes toward a more "hands on" learning approach in the district and more group and individual work with less overall reliance on lecture-based instruction, impact classroom and school design, space requirements, and adjacencies. They describe the design philosophy as "I like this design, but...." Through the basis of design model, the District provides a conceptual design containing the fundamental components of a previously resolved design to a community and allows the design to evolve into a product more specific to stated community needs. The research team saw a similar model in FNSBSD where the district allowed a prototypical design to be modified to be more specific to the community. In both cases, neither example meets the definition of a prototype school as defined in this report, though the FNSBSD facility was closer to a prototype than the MSBSD designs.

MSBSD's elementary schools of the 1980s and 1990s were developed as a prototype by the definition of this research. Though modest changes were allowed and refinement on each school was encouraged, for all intents and purposes the overall plan changed little. MSBSD claimed that design fees to develop

prototypical elementary schools in the 1980s and 1990s were more economically beneficial than the cost of design fees to develop a school on a basis of design model.

MSBSD believes the basis of design model serves the community better than a prototype in the delivery of educational models because the schools are designed more specifically to the desired educational model. When this philosophy was questioned, it was acknowledged that certain educational models were not sufficiently different to merit significant plan changes. For example, elementary schools have quite similar programmatic needs, so as long as a school's technology infrastructure is appropriately designed and classroom space is sufficiently flexible, a prototype plan with modest adaptations would more than likely be successful.

### ***Site Observations***

The project team visited Susitna Valley High School and Valley Pathways School (Grades 7-12), which were both developed under the basis of design model but serve fundamentally different programs (one is more vocational/technical in nature than the other). Reproduction of Susitna Valley High's plan for Valley Pathways under a more traditional prototype model would have resulted in the construction of a school that would have effectively been inadequate for the students served. At Susitna Valley High, the program is heavily influenced by the need for vocational training, whereas Valley Pathways is an alternative education school and has no need for the vocational program; therefore, reproduction of Susitna Valley High as a prototype for the community served by Valley Pathways would have been inappropriate.

For consistency in reporting, both of the MSBSD schools were viewed for cultural integration and relevance. In the case of these schools, Su-Valley could be considered an almost rural environment vs. the Valley Pathways School, a somewhat isolated school deeply embedded within a neighborhood. There was no evidence that cultural identity or even context within the environment in which it was constructed played any relevance to the design approach. Representatives from MSBSD did say, however, that community needs were not always fully explored prior to construction. That said, they also noted that some changes were made to the plans over the years in response to program needs and required site constraints. Modest changes are generally tolerable in prototype development, though not nearly to the level seen in the development of Susitna Valley High and Valley Pathways under a basis of design approach.

### ***Future Prototype Use***

MSBSD anticipates future use of the basis of design model for the development of their schools. The District has been one of the most active in the state as far as the design and construction of schools, and with the student population currently growing, additional schools are anticipated. Community support

of bond money to construct schools has been tied to the State's participation in funding. There is concern in this district, as well as others, that a withdrawal of State assistance in school construction will cause greater long-term problems since districts that continue to experience growth in enrollment may stop building schools due to lack of funds. The fear is that growth without additional classrooms will lead to overcrowding and diminished educational quality.

MSBSD reported a desire to standardize as many systems and components as practical. Similar to much of the conversation around the state, practicalities of training and operation, interchange of parts, and economies in purchasing were all considered excellent reasons for standardization. In some instances, they believe sole sourcing is appropriate for what they think are the best practical solutions; however, standard practice in the use of public funds makes it difficult to lock into a single source or manufacturer. As a result, cost often becomes the deciding factor in making purchases.

## **ANCHORAGE SCHOOL DISTRICT**

### ***Background***

Located in the southcentral region of the state, Anchorage is the primary urban hub of Alaska. The Anchorage School District (ASD) is responsible for more than 87 schools (as reported in the District's RFI response), which makes it by far the largest of the state's 53 districts. The student population in Anchorage is in decline with no projections for that to change in the foreseeable future. The need for construction of new schools is considered low, with only renovations related to building life extension and modest intermediate renewal projects likely for several years to come. ASD has and regularly maintains Ed Specs and building standards.

### ***Past Prototype Use***

ASD projects developed as far back as the 1950s demonstrate the District's propensity to utilize designs or portions of a design to replicate subsequent schools. In the late 1960s, 1970s, and early 1980s, the District used prototypical school designs to keep up with the rapidly growing population. Research indicates the use of a minimum of three distinct floor plans repeated multiple times over a short period of time in this era. Plans were repeated with little to no substantial change in design, and to the best of the District's knowledge, without significant community input beyond the initial design of each prototypical plan.

ASD identified at least 18 prototypical schools that were developed from three different floor plan configurations. Follow-up investigations revealed that there were at least two other prototype plans used by ASD prior to the open plan models constructed in the late 1970s. Additionally, there is some belief that the District may have also utilized prototype components like gymnasiums and multi-purpose rooms. These program spaces may have been added to schools to bring them more in alignment with



the District's Ed Specs. Exact time periods for these earlier prototypes are unknown but most likely reach back to the 1960s.

The post pipeline construction era population boom in the 1980s caused the District to realize a major classroom shortage by the end of the decade, consequently resulting in the development of a new elementary school prototype. After initial construction and refinement of the original prototype – Willard Bowman Elementary (1991) – nine additional schools were constructed over a period of approximately 8 years. The first phase included the construction of four prototype schools (104 classrooms) simultaneously in under two years, with the remaining five being constructed over a period of the next six years. ASD made only modest building plan changes throughout the construction of the follow-on prototype schools; however, site plan adaptation was necessary to accommodate the school plan. In every instance, the site was configured to suit the prototype plan, sometimes resulting in less than optimal efficiencies. One of these prototypical schools was built in response to the destruction of an older elementary school by fire. In this instance, the readily available plans enabled the District to expedite a new school with a known product at a known price in a short period of time.

ASD claims to have saved enough funds in the design services for the first four schools to design a fifth school with the savings. Construction of prototypes was implemented under two different project delivery methods. The first four prototypes were approached as Design/Bid/Build, the most traditional model in design and construction. The remaining six schools were approached through a Design/Build model in which the contractor includes the design team in the cost of constructing the project. The remaining six schools were constructed by two competing firms. This fact seems to suggest that prototypical design and construction enables contractors to minimize risk and consequently cost when constructing a known product. It may also be that the Design/Build relationship between designer and contractor facilitates less risk.

Interestingly, prior to the design of Willard Bowman, ASD released an RFP soliciting previously developed prototype elementary schools from within the state. That RFP procured several prototype plans from districts around the state, two of which were believed to be the Kenai Peninsula Borough School District and Fairbanks North Star Borough School District. Neither were considered appropriate by educators within ASD. The FNSBSD design in particular was considered inappropriate for application in Anchorage largely due to different responses to climatic conditions such as limiting the number of windows. In this case a successful prototype model in one district was considered unsuccessful in another. This scenario suggests the potential difficulty in having a single prototype plan that meets the needs and expectations of an entire state.

While ASD prototyping is historically evident at the elementary school level, it was not until recently that the ASD used adapted prototypes at the high school level. In the case of Eagle River High School (2005),

ASD utilized a modified version of the Dimond High School (2003) design. The frequency in which new high schools are needed is much less than at the elementary school level and consequently less likely candidates for prototyping due to the typical time span that occurs between the design and construction of a high school. In the case of Eagle River High School, the need for this school came on the heels of Dimond High School, making the relevancy of the program model appropriate for at least partial reproduction.

Since ASD develops a districtwide Ed Spec, prototypical schools are constructed within a neighborhood with measured community input. The District says it does not build schools for specific individuals or personalities, but rather in response to what the districtwide Ed Specs indicate is best for the greater community. In this way, schools – and in particular prototype schools – serve each neighborhood or community in as equitable a fashion as practical. The idea is that school principals, staff, and community members change, and with that comes changes in personal preferences; therefore, the District builds schools for the greater community's needs rather than the community that happens to utilize the school at the time of school design and construction.

Overall, prototypes have worked well within ASD to solve the problem of historic rapid growth over a short window of time. This aligns with existing national research findings based on other parts of the country.

### ***Site Observations***

For the purposes of this study, the team visited Dimond High School (the prototype school for Eagle River High School) and Kincaid Elementary (a prototype). Dimond High School was not developed with the mindset that it would be utilized as a prototypical school in the future. Classroom pods were developed around the common core elements like the main circulation commons, library and gymnasium. Planning focused on self-contained learning centers where classrooms fed into a smaller commons or multi-use environment. Constructed on a relatively grand scale with materials that would be considered very bulky and heavy (concrete block external shell), prototyping a school like Dimond High on a state level would be completely inappropriate from a practical shipping basis alone not to mention the size and scale being much too large for the average Alaskan community outside Anchorage.

Kincaid Elementary was the first school among three others constructed at the same time (Lake Hood Elementary, William Tyson Elementary and Kasuun Elementary), all of which were the product and adaptation from the original prototype, Willard Bowman Elementary. The primary difference between Bowman and Kincaid (and all subsequent prototypes of the era) was the change from a 32 classroom school to a 26 classroom school, which became ASD's education specification standard size. Kincaid's plan is essentially three classroom wings stemming from the school's core program elements, the library, multi-purpose room, and gymnasium. The plan is a basic and straightforward single level plan.

One of the more unique features of the school is the utility spine that includes a walkway in the ceiling plenum of the classroom wings feeding into the second level fan room. ASD maintenance staff is particularly partial to the efficiencies and practicalities of this operations and maintenance feature. The school is fairly sprawling when compared to other prototypical schools observed in other districts, which would not make it an appropriate choice for reproduction around the state if for no other reason than energy efficiency. Both the FNSBSD and MSBSD's prototypical elementary school plans were designed and constructed with more energy-efficient compact plans.

ASD is one of the most culturally diverse school districts in the country.<sup>19,20</sup> That said, the impact of any one culture is somewhat muted since each minority group is relatively well-dispersed among several other groups. Moreover, the relatively homogeneous characteristics of the ASD student population, as well as the relatively homogeneous geographical and climatic characteristics within the district, are also consistent with the criteria for successful prototype design. Based on the national research, homogeneous conditions support successful reproduction of a similar or prototypical design.

### ***Future Prototype Use***

ASD indicated they would strongly consider utilizing prototype plans in the future, given the successes from past use. They believe the efficiency in consultant design and the demands in overhead at the district level make prototype planning worthwhile. Not only does the District believe design costs are lowered, they believe that construction costs are minimized as well. Additionally, to bring schools online in an expeditious manner effectively serves the overall community in both reduced cost and relief in overcrowded school classrooms. Currently, however, ASD does not see new schools in their future. With potentially decreasing student populations, renovations and asset preservation appear to be their primary focus.

ASD believes prototype design and construction make economic sense. They believe prototypes have a demonstrable economic advantage and that so long as the school is technologically up to date, there seems to be no real educational quality difference between a prototype and a non-prototype. From a community-wide perspective, ASD believes utilization of prototype plans may be a more equitable method of delivering education.

ASD is also an advocate of component prototyping. The District has design standards to encourage the use of components and systems that, at a minimum, functionally operate with sufficient familiarity that facility operations staff can more efficiently train for maintenance. This benefit is facilitated by the fact that ASD has a large number of schools of similar size making this more practical. Of the districts

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<sup>19</sup> Anchorage School District English Language Learners Program. October 2014.

<sup>20</sup> Tunseth, Matt. "Anchorage public schools lead nation in diversity." Alaska Dispatch News. May 23, 2015:

interviewed, ASD is the only district that mentioned it had tried to use prototypical program elements such as a gymnasiums or multi-purpose room.

## **LOWER KUSKOKWIM SCHOOL DISTRICT**

### ***Background***

Located on the west coast of Alaska in the southwest region, the Lower Kuskokwim School District (LKSD) is responsible for 28 schools (as reported in the District's RFI response). Overall the student population seems to be experiencing a modest increase. This, along with the District's aging facilities, makes LKSD one of the more active school districts in the state with respect to design and construction. The District needs both future school renovations and replacement schools. Two schools, Kwigillingok K-12 and Kipnuk K-12, will be completed in the summer/fall of 2015 and two schools, Napaskiak K-12 and Kwethluk K-12, are currently under construction. The District provides individual Ed Specs for each new school; however, it did not appear that there was significant community contribution to the development of the Ed Spec. The District does not have a set of building standards.

### ***Past Prototype Use***

LKSD identified eight schools as prototypical in their RFI response. The District did not know how many different plans from which the eight schools evolved. The perceived success of the various prototype schools is mixed. Interestingly, all of the prototype plans identified as "not successful" by the District during the research were developed as open plan concept models. Implementation of these schools was believed to be in direct response to the Molly Hootch lawsuit and the requirement to provide all students with reasonable and accessible education. All prototype schools in the district were believed to have been developed between 1979 and 1981 with multiple schools being constructed simultaneously.

The project team learned that several schools had to be modified to satisfy the constraints of the available sites. Specific site-related modifications to the plan, other than a need to "mirror" the plan, were unknown. Other than the alterations required to adjust the plan for the site, it is not believed or known whether or not the District evaluated specific educational or community needs prior to the installation of each school. Given that multiple schools were constructed simultaneously, the District seemed to believe there was no testing or evaluation of an initial prototype plan prior to replication.

Discussion about prototypical design of facilities and components highlighted a general mindset that overall facility prototypes are impractical due to dramatic differences in school populations found in the district; however, there may be programmatic elements such as gymnasiums and kitchens that could be reasonably prototyped. As with other rural school districts, gymnasiums, kitchens, and food storage are all key design elements that are considered essential in the success of many rural schools. There may be some merit in prototypical system components and program elements as noted. Like other rural

districts, maintenance and operation are key concerns along with the training required to facilitate those activities.

LKSD utilizes a single entity to provide Ed Specs for each of its schools. The original Ed Spec provided for each school has given the district a more comprehensive perspective of that school's deficiencies and potential future needs. When the District selects schools for improvement and subsequent design and construction, Ed Specs are refined by the consulting team to more exact requirements expressed by the staff and community. This process further negates the potential for prototypical planning to be effective. Research indicates that the stronger the voice of staff and community, the more likely a single prototypical plan will not meet specific needs. That, in combination with the highly variable soil conditions found throughout LKSD, the substantial variations in community/village size, and the potential for flooding along the Kuskokwim River, make prototypical facility design a challenge.

### ***Site Observations***

The project team visited the Napaskiak K-12 School (a partial prototype), Kwethluk K-12 School (a partial prototype), and Gladys Jung Elementary School (a non-prototype). Napaskiak and Kwethluk share similar prototypical roots, and both had significant additions over time since the original prototype was not much more than an open plan concept school with an administrative area, kitchen, and gym.

Two older village schools located in Napaskiak and Kwethluk are currently being replaced with new facilities. The original designs sited the schools in response to construction convenience rather than environmental orientation or in response to the community around the school. Given the age of the schools being replaced, the level of community input prior to construction is unknown.

Gladys Jung Elementary School is a non-prototypical school constructed in Bethel. The plan was traditionally organized with classroom wings, a gymnasium, kitchen, and an administrative area adjacent to the school's entrance. Being an elementary school, it is unique to most schools in the district that are typically developed as K-12 schools.

As in all the schools, the team measured cultural relevance in design as a factor toward prototypical relevance. With a strong Yup'ik cultural presence, the team looked closely for clues as to how architectural design embraced the culture. The reality in the region is that cultural influences are relegated to display in lieu of incorporation into the school design itself.

### ***Future Prototype Use***

Site differences will be a chief concern in determining the viability in using prototype designs when future needs arise. Currently, budgeting for targeted schools has revolved around renovation and not replacement. While it was clearly expressed that replacement schools are needed, successful funding requests seemed improbable. There is an expectation for future renovation projects due to the current condition of several schools that are in critical need of repair.

LKSD expressed a very strong desire for component prototyping. The District currently utilizes component prototype or standardization in more than 50% of the materials and systems utilized in construction including windows, siding, roof system, floor finishes, boilers, pumps, and generators. Standardizing seems to serve LKSD extraordinarily well. Consistency in component parts and the subsequent efficiency in maintenance were cited as being of high value to the District.

## **KODIAK ISLAND SCHOOL DISTRICT**

### ***Background***

Located in the maritime environment of the southwest region of Alaska, the Kodiak Island Borough School District (KIBSD) is responsible for 14 schools (as listed on the District's website). Overall, the student population is stable. A major influence on this stability is the presence of the U.S. Coast Guard (USCG) on the island. The District provides education for USCG students, so depending on the rise and fall in USCG population, so goes district enrollment. While the transient nature of the base population presents potential classroom overcrowding and subsequently poor student/teacher ratios when the base population is on the upswing, the need for new school construction is minimal with only renovation projects anticipated in the near future. School staff and communities are allowed to create their own Ed Spec, but they are required to meet the State's Career and Technical Education (CTE) Plan. The District has developed standard building guidelines developed by the District; however, the buildings are owned and constructed by the Borough. The community is said to be very outspoken and has a strong commitment to public involvement especially when it comes to matters related to schools.

### ***Past Prototype Use***

There are three small prototype schools: Akhiok, Chiniak, and Karluk (1969-1978). It is believed that all three schools were constructed from the same prototypical plan without any significant changes to the design other than modifications necessary for site adaptations. Plans were unavailable and a site visit was not possible within the available time frame.

### ***Site Observations***

The project team visited Kodiak Middle School and Kodiak High School (both non-prototypical schools). While the two schools are physically connected, they are radically different in educational model and strategy. Of all the schools observed during the project, Kodiak High stands out as a truly unique school with respect to program requirements when compared to the others observed for this study. The team believes this can be attributed to the uniquely generated Ed Spec in combination with the unusual site constraints. Practically speaking, each feature influenced the other. In review of the schools visited, the team could identify the disadvantages to prototypical facility design and construction in this district. It is an opinion that, due to the high degree of variable terrain conditions observed, prototypical design would be effectively rendered useless. This was further reinforced by the unique programmatic differences found in educational delivery.

Schools in Kodiak did not express the Alutiiq cultural heritage through building design. Overall there was little expression of this cultural identity in the Kodiak High School and Middle School. This fact further supports the team's finding that cultural expression is not an essential design influence related to prototypical school design.

### ***Future Prototype Use***

Facility operations managers interviewed in Kodiak expressed the desire to standardize components primarily from the perspective that O&M, along with personnel training, are greatly improved when the "parts" are essentially the same. In their estimation, as existing components wear out, standardization of replacement parts could become the most practical and efficient way to move forward in the future. Discussion input resulted in comments that prototypical facilities would not be practical or well-received by the community. District personnel thought that because of significant variations in geological subsoil conditions on the island, all foundations would require an individualized design approach. As noted by the project team, this is generally true for almost every school foundation in the state, though on the surface they may appear similar or even identical.

## **JUNEAU SCHOOL DISTRICT**

### ***Background***

Located in a maritime environment in the southeast panhandle region of Alaska, the Juneau School District (JSD) is responsible for 11 schools (as reported in the District's RFI response). The overall student population is level and is anticipated to remain so into the foreseeable future. While student enrollment can be influenced by the local economy, given all the government-related jobs in the capitol, the District does not believe these fluctuations are typically significant enough to warrant a response through the construction of new classroom space. Schools may have more space than is actually needed should student enrollment drop. With the construction of Thunder Mountain High School (2008), future

construction appears to be limited to renovation projects. Ed Specs are developed on a per school basis only and not districtwide. Community involvement varies depending on the community and specific project. For example, there was strong involvement in the plans for Thunder Mountain, but only modest community input for the Mendenhall River Community School (1983), which was likely due to the expedited nature in which the school was developed.

### ***Past Prototype Use***

Juneau has only one prototypical school, Mendenhall River Community School, which was a reuse of a school developed in a Southcentral Alaska school district. Unfortunately, the source of that plan could not be identified. The community was in urgent need of a school to accommodate rapid growth in the area. While the school fit the site reasonably well, the plan itself suffered from lack of attention to preferred educational delivery models and updated technological development. Construction details of the school were not developed in response to the environment in which it was constructed. A case in point is the design of the roof and the lack of attention given to appropriate snow shedding. A school designed for Juneau would hopefully have recognized and addressed issues specific to its unique environment, but it was unclear whether this occurred for this school. Renovations to modify the roof were required to rectify the problem.

### ***Site Observations***

The project team visited Mendenhall River Community School and Thunder Mountain High School (a non-prototype). The team learned that a prototypical school arbitrarily placed on a site without addressing site-specific needs (e.g., how snow will shed off the roof), as with Mendenhall River, has an increased likelihood of needing corrective renovation in the future. This example points to the fact that adequate prototype design should consider refinement of a design prior to reproduction and construction and that design must take into consideration all the anticipated variables.

Also learned was that site-specific designed schools like Thunder Mountain would have a better than average chance that the design solution would be inappropriate in the context of another site assuming the design had responded to the unique qualities of the site. In the case of Thunder Mountain High, the school site was such that the Mendenhall Glacier could be seen directly behind the school. Architects very specifically designed the building's exterior forms and finishes to emulate and reinforce the images seen in the glacier. The exterior design of Thunder Mountain was directly and specifically influenced by the views and features of the site that would be unique to that site alone. While a reproduction of the school's plan may offer sufficient program viability for another location, the forms and aesthetics of the school's exterior would not have the same impact in another location.



Given the unique location of the Juneau School District and the surrounding area, the team looked closely for cultural identity as an influence in school design particularly in reference to whether or not it would be affected by generic prototyping. Like other sites visited across the state, indigenous cultural identity did not seem to play a strong role in the development of schools in Juneau. Thunder Mountain did have more fully integrated art features that took into consideration regional cultural heritage to a greater extent than the other school sites visited. In this example, art was featured through building materials in the floor and associated art objects like totem poles.

### ***Future Prototype Use***

At Thunder Mountain, substantial attention during design was given to ensuring that the school blended with and complimented the site and surrounding environment. Assuming this school's programmatic needs were well-suited to work in another community as a prototype, it would be extraordinarily out of context with the environmental surroundings of another location. The reverse would undoubtedly be the case. A prototypical school, designed generically to fit an unknown location, would have little chance of being a well-suited solution for this Juneau site.

In terms of the potential for component prototyping, JSD's operations personnel confirmed the potential usefulness for component standardization as it relates to O&M training and efficiencies. While not specific to JSD, the team's discussions with the Juneau community revealed the trials of small school districts in Southeast. Some districts are so small they cannot afford facility operators, and when they can, qualified personnel are difficult to come by. These smaller districts believe prototyping of schools for small one and two school districts is not relevant, but that operation of what they had was a more critical issue. The concept of information sharing and shared or State-funded training was driven home as a solid idea during the team's visit to Juneau.

## **DISTRICT PROFILES SUMMARY**

The research targeted select school districts in Alaska with a demonstrated history of utilizing prototype design and schools the team could investigate during the regional conferences. Additional research was conducted following the conferences and site visits based on the information gathered, and follow-up teleconferences were conducted to ask questions for clarification and expand what was learned. Through this effort, the project team gained a better understanding of districts' philosophies and the reasoning behind their use of prototypes. It was essential to hear what districts had to say about lessons learned and the benefits and challenges of prototypical design and construction. The following points about prototype school development resulted:

- Districts have unique and individual approaches to prototype development and implementation. Each believes its approach works best for them.

- District philosophies toward educational program delivery models affect perception of how useful a prototype will be.
- The more community input a district allows in the development of a school, the more likely a prototype design will evolve and require modification.
- Prototypical designs can be modified within reason and still be considered a useful and effective tool in school development.
- Prototypical school designs that are constructed, evaluated, refined, and modified in response to evaluation and refinement of earlier designs have a greater success rate and generally provide greater return on investment.
- There can be modest to reasonable savings on design fees. The more a design is repeated, the greater the savings can be.
- Construction of repeated prototypical designs tends to reduce risk which may reduce project construction cost.
- High diversity in site configuration, geological characteristics, and climate discourage the usefulness of repeating a prototypical design. The more diversity a district has in project sites, the less likely a prototype will be an advantage.
- Poorly planned and untested design solutions, if repeated, have the potential to lead to costly renovation projects in the future. Conversely, well-planned and tested solutions, if repeated, can pay dividends in the future.
- District growth in student population and high demand for immediate relief in additional classroom space supports the use of prototypical design solutions.
- Prototypical schools are perceived by the public as being a good use of public funds.
- Districts reported no difference between a prototypical design and a non-prototypical design when it comes to the effectiveness of education delivery.
- Similar program requirements support use of a prototypical school whereas diversity in program requirements discourages effective prototypical use.
- Elementary school program requirements generally support use of prototypical design.
- Middle and high schools have more diverse program requirements, which tends to discourage prototype use.

## **KEY TAKEAWAYS FROM FACILITY SITE VISITS**

The project team reviewed the notes taken from the facility site visits and interviews and examined them for commonalities and differences in their approach to design and development of schools. Also considered and extracted from the conversations were quantitative and qualitative factors found in each district and region that would likewise influence prototypical design development. All factors and influences were evaluated in light of how they may benefit or challenge the utilization of prototypical design and construction across the state. The following key factors should be considered:

### ***Design Adaptation***

Notably, issues and anticipated problems associated with site adaptation for prototype designs have been a common concern in the research. Prototypical schools are by nature not site specific, so to preserve the efficiencies in planning and design, optimal site layout can and is sometimes sacrificed. Unfortunately, there is no available data on the premiums paid to develop a site to conform to a pre-developed prototypical plan. The reverse is also true: there is no data on premiums paid for school design and construction to have the plan conform to the site. In the specific instance of Nordale Elementary, the consequences of site planning deficiencies seemed in general to be more of an observation and minor nuisance rather than a significant functional deficiency.

A prototypical school arbitrarily placed on a site, without addressing site specific needs (e.g., how snow will shed off a roof), has an increased likelihood of needing corrective renovation in the future. A site-specific designed school would have a better than average chance that the design solution would be inappropriate in the context of another site. A prototypical school, designed generically to fit an unknown location, would have little chance of being a well-suited solution for a specific site.

In the project team's search to discover impacts diverse cultures have on the development of schools in Alaska, there seems to be no evidence that it ultimately changes school design approach or would have an impact, positively or negatively, on the development of a prototype school so long as there are reasonable locations within the school for cultures to be featured through displays rather than integration. Cultural displays were typically limited to incorporation of artwork and artifacts after construction.

### ***District Growth***

With the exception of MSBSD and to a modest extent LKSD, districts interviewed either had stable or declining student populations. Again, with the exception of MSBSD, all districts interviewed said they did not anticipate the construction of a new school in the foreseeable future. Since student population growth is a key consideration in determining the need to construct additional schools, an understanding of anticipated future population growth in Alaska is a fundamental consideration.

In “Alaska Population Projections 2012 to 2042,” a report prepared by the Alaska Department of Labor and Workforce Development, Research and Analysis Section, population growth in school age children ages 5 to 13 years old is anticipated to increase 27% in the next 30 years. For high school age children, growth is anticipated to be approximately 26%. In real numbers, the elementary age group is anticipated to increase by around 25,000 students and high school age by around 11,000 students. Assuming a uniform growth rate of approximately 9% per decade, the projected increase for elementary age students is between 8,000 and 8,500 students, and around 3,500 students for high school students, over 10 years. The report projects growth among the native population to be only modestly greater than non-native; however, the total population of school age children noted above includes both.<sup>21</sup>

Considering the hundreds of schools currently in place to absorb the projected population increase, new school construction to support population growth on a statewide basis over the next three decades does not appear to be a high priority. These statistics do not preclude construction of new schools altogether, since over the next 30 years existing schools may require replacement. For example, LKSD expressed a need for replacement schools; however, modest growth and replacement schools do not fit the model for successful duplication of prototype schools when reviewing the national research.

### ***Education Specification Development***

In every district interviewed, Ed Spec development on a per school basis took place. Community participation and input was encouraged in varying degrees, with ASD tending to have the more moderate approach to community-wide participation, and MSBSD and KIBSD tending to have the most aggressive position with respect to facilitating community involvement. Larger districts such as ASD and MSBSD have developed districtwide Ed Specs; however, one larger district, FNSBSD, and all the smaller districts developed Ed Specs for individual schools. In the case of MSBSD, substantial community involvement seems to result in significant Ed Spec refinement.

An important consideration in Ed Spec development is the population and age group served. Larger districts lean toward division of school age groups utilizing three classifications of schools: elementary, middle (junior high), and high. In all of the districts visited, there were schools divided into these groups; however, in all districts visited there were also K-12 (kindergarten through twelfth grade) models within the district. Many communities throughout rural Alaska in particular have sufficiently small populations and K-12 schools are the norm. The Ed Specs for these varying school models are measurably and radically different.

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<sup>21</sup> State of Alaska, Department of Labor and Workforce Development, Research and Analysis Section. “Alaska Population Projections: 2012 to 2042.” April 2014.

Development of a single prototypical school would involve the development of a prototypical school Ed Spec, which would be complicated by the fact that currently schools in Alaska are for all practical purposes developed as unique program spaces. Even where districts utilize prototype schools, prototype designs generally serve only a fraction of the total population. Out of 15 schools visited by the research team, every school had an individually developed Ed Spec.

With the exception of the K-12 prototype schools in the LKSD and Dimond High School in the ASD, all the prototype schools visited were elementary schools. Dimond High was not developed as a prototype but was subsequently used out of convenience in response to immediate needs for the Eagle River community. While MSBSD is currently utilizing a basis of design development model for their elementary schools, they do believe that elementary school program requirements have more consistent and uniform educational needs, making them more viable candidates for successful reproduction as a prototypical school.

There has been some expressed concern about rapidly changing educational models that render prototypes impractical and potentially obsolete if used over time. At least some of the districts interviewed have utilized a single prototype plan for ten years or more without feeling the need for radical change. The notion of obsolescence may be driven by district personality.

### ***Facility Prototype Use***

Of the seven districts visited, six (all but NSBSD) had used prototypical schools in the past and as a means to satisfy demands of student population growth. Of those six, four (FNSBSD, LKSD, MSBSD, and ASD) demonstrated use of more than one prototypical design in multiple instances. JSD and KIBSD had utilized a single prototypical design in the past. JSD used a prototype plan for a single school and KIBSD used one plan for three schools. ASD, MSBSD, and NSBSD indicated that they would consider the use of prototype facilities in the future. LKSD, JSD, and KIBSD all cited the extraordinary differences in site topography and soil conditions in their region as being one of the biggest deterrents to making good use of a single prototype design. It was also apparent that historical use in JSD and KIBSD was minimal, and in the case of KIBSD, a strong commitment to community input into school program development tended to minimize a prototypical design approach in the eyes of the Kodiak city community.

Among the districts indicating a propensity to utilize a prototype design approach in the future, only ASD had demonstrated attempts to use prototypical concepts above the elementary age group. While MSBSD is gravitating toward a basis of design approach in lieu of a prototype model for upper level age students, the prototype model is still being effectively used at the elementary school level.

It is also worth noting that two of the four school districts highlighted in this chapter, Anchorage School District and Fairbanks North Star Borough School District, have constructed two-story elementary school

solutions. In both cases, energy and functional efficiency were common themes. Additionally, these districts speculate that there may be construction cost efficiencies as well.

Of the 33 districts responding to the RFI, nine have used prototype schools. School districts that responded to the RFI indicating that they have utilized prototype schools in the past, but were not visited include: Northwest Arctic Borough School District (NWABSD), Southwest Region School District (SWRSD), and Lower Yukon School District (LYSD). NWABSD has 12 schools of which three were reported as prototypes. One was reported as successful and there was no response on the other two. LYSD has 11 schools, of which two were reported to be prototypical, with one reported as successful and one as unsuccessful. SWRSD has three schools, and one is a prototype, which was reported as unsuccessful.

Based on interview data, and in combination with RFI responses and follow-up research, the majority of the school districts investigated have not used prototype designs.

### ***Long-Term Operations and Maintenance Costs***

It was the unanimous opinion of the facilities staff and design and engineering professionals encountered at the regional conferences that long-term O&M savings would exceed upfront design cost savings from any facility or component prototyping venture. According to ASD facilities staff, the long-term challenge for their district is improving the efficiency of their buildings since enrollment is likely to flatten out for the foreseeable future and the average ASD school is nearly 40 years old. It is likely that most Alaskan schools' needs will center on renovations and reconstruction more than new construction. Since it is commonly accepted by designers and districts alike that the vast majority of a facility's expense over its lifetime is caused by its operation rather than its initial construction, there is a strong argument to consider the practice of component standardization at the district level as a method to positively influence O&M expenditures.

In Fairbanks, FNSBSD echoes a similar strong commitment to operational efficiencies. Operating equipment as it was designed is essential to operational efficiency. The more similarity there is in equipment and building components the easier it is to train staff and operate the equipment. In both cases, the District saves money that can be put back into education. FNSBSD's philosophy is that operational savings directly fund educational opportunities. The project team's research found this to be a common theme among districts.

The lifetime expense of a building begins with component selection and, in renovation terms, with the replacement of said components. Operational challenges exist particularly in communities within small school districts. Finding qualified people to operate the equipment designed is a challenge. Non-maintenance personnel may be called on to operate mechanical systems. It is very important to balance component technology with the skill sets of the talent and expertise of those who will keep it running.

Long-term cost savings projected by the designer of any given piece of equipment will be of little use if the equipment is not operated as designed.

District facilities staff emphasized that the challenge of using even the most prevalent energy efficiency technology like Direct Digital Controls (DDC) is not the technology itself, but the training needed to operate it. Attendees at many of the regional conferences lamented the fact that DDC units retrofitted in remote locations were of little benefit unless staff could receive the training needed to properly use the improved technology.

### ***Use of Program Components***

Schools are centers of activity for communities across the country, and nowhere is this more true than in Alaska, where, in rural locations like Barrow, Napaskiak, and Kwethluk, few other large public buildings for community use exist. Even in remote communities like Kodiak or those in Southeast, the school is often a center of community life for far more than just educational activities. During the team's site visits, the use of school gymnasiums in particular was highlighted, as these spaces often represent the only place where a community may gather for not only athletics, fitness, and recreation, but for social gatherings of all sorts. School kitchens and cafeterias also serve a vital role in many parts of Alaska since they are often the only place in the community where food preparation for large gatherings may be accommodated. Both of these scenarios were expressly stated in Barrow and Bethel, two of the most geographically remote districts visited.

In discussing the potential for commonly used program components as potentially viable for prototype design, rural districts like LKSD and NSBSD indicated such use could be potentially viable. Likewise, most rural schools have full cook kitchens and generally service off the gymnasium. The practicality of such prototypical program elements requires study but suggest some receptivity to prototyping even in districts that don't foresee a need for facility prototypes overall.

## CHAPTER 4 – URBAN VS. RURAL SCHOOL DEVELOPMENT

During the early phases of research on prototypical school development, it was learned that diversity increased the potential that a prototype school would be unsuccessful. Through investigation, conversations, site visits, interviews, and questionnaires by the project team, many diversities and commonalities shared by the communities of Alaska have been revealed. This section investigates one of the unique and potentially greatest design and construction variables within the state: the urban vs. rural factor.

Urban is generally defined as accessible by the road system and rural is not. Urban living is convenient, rural is less so in varying levels of extreme. Are there commonalities that facilitate the opportunity for prototype design either in an entire facility or within components of a facility? How do these differences ultimately influence how design and construction are carried out? This section explores the different and common variables influencing design and construction in Alaska and its application toward prototype development.

The project team visited seven districts in six distinct geographical and climatic regions. Of those, two would be considered rural environments (Barrow and Bethel), four would be considered urban environments (Anchorage, Fairbanks, Matanuska-Susitna Valley, and Juneau) and one the team considered quasi-rural/urban (Kodiak), as it shares both the conveniences of an urban environment and isolation of a rural area. Arguably, Juneau could be placed into this category, though through sheer size and well established alternative access routes, it was labeled urban.

### **Design Approach**

In the districts visited, Ed Specs and community involvement were reasonably important to the process of design and construction of school facilities and appeared to be fundamentally the same between districts. Building standards were more a preference of the district than they were a result of a specific location. Since schools within rural school districts tend to be in more remote locations, community involvement in the design process appeared to be somewhat less than in urban locations. To some extent, size of community served and the diversity that may come with increased population size may lend itself to more discussion within a community to facilitate consensus. Based on conversations with those interviewed, small rural communities tend to have less involvement in school design and development, whereas the opposite is true in urban locations and larger rural communities.

### **Student Populations**

The size of a school is closely related to the number of students served. While there are certain components that may only vary slightly with student population such as administrative offices, gymnasiums, and kitchens, student population significantly influences the quantity and potential size of



classrooms. In rural areas, districts are providing schools for multiple villages spread over vast geographic regions, with each village community being served by an individual school. Since village population may vary significantly with schools ranging from 10-20 students served to 200-300 students, such variation will significantly influence the size of the school especially in the number of classrooms. With the size differences noted above, size will also influence administrative areas as well as the gym and kitchen sizes. Variations of this nature make a prototype school approach a formidable challenge.

In urban areas, schools tend to be relatively the same size. Urban districts control student population by manipulating school boundaries. As demographic shifts occur within the boundaries of the district, individual schools may experience periods of growth or decline but typically within tolerable limits. Districts also have the ability to reconfigure boundaries to balance student populations. While often controversial, redefining boundaries is a useful enrollment management tool within urban districts, though typically it is impractical or unneeded in rural districts. Controlled student enrollment results in predictable school sizes and programmatic needs. As a result, prototyping a school within an urban setting has a greater potential for success. Based on RFI responses, every urban district utilizing more than one prototypical school reported prototype solutions as being successful, whereas rural districts reporting use of prototype solutions more than once had mixed success with prototype methodology.

### **Program/Functionality**

Virtually all of the schools visited had similar school functionality and traditional program spaces. While rural communities placed a greater emphasis on gymnasiums, kitchens, and possibly vocational program space, urban schools all had similar program spaces. School size more than placement within a region played a more important role in program space. School enrollment impacts quantity of classrooms and size of the gymnasium in some instances. The North Slope Borough School District was an exception in that each school was reported to have a full high school regulation size basketball court regardless of school population. Previous experience of team consultants indicates that gym sizes vary with school population in other locations.

One significant difference between rural and urban school functionality is that rural schools tend to be K-12 (Kindergarten through grade 12), whereas urban schools tend to have more school age segregation such as K-6, middle school, and high school. The most common prototypical school type in the state is the elementary school. Higher grade level schools, particularly high school, can have more diverse program requirements depending on the community. These diversities become a challenge in the successful development of a prototype.

There were some noticeable differences in program requirements that could be attributed to rural circumstances. The requirement for automatic fire sprinkler systems by the State of Alaska, State amended building code demands ready access to a water source. In rural environments, this access

typically means water storage on site in large tanks, or as was seen in Barrow, water storage in a swimming pool. Though not always the case, public water systems are not available in sufficient quantity in rural environments to be viable for the fire sprinkler demands. Urban environments typically have readily available water; consequently, space for water storage is not needed.

Another difference discovered between rural and urban program space is in the kitchen and food storage requirements. In most rural schools visited or known through the project team's working experiences across Alaska, rural K-12 schools have full service cooking kitchens. Additionally, since many rural schools are isolated from convenient, easily accessible road systems, food is purchased in greater quantities which creates greater storage needs. Such storage needs require considerably more area than urban schools. Rural schools on the road system would be more similar to urban schools in this example since there would be ready access to food resupply.

### **Building Construction/Material Procurement**

In discussions related to building materials and construction, the urban/rural gap differences widen. Urban schools are relatively unrestricted in which materials can be successfully used and the potential for these materials to be easily assembled on site by the contractor. Material access is generally reasonable within urban environments; however, based on discussions the team had with remote non-road accessible districts, it was quickly apparent that there were substantial limitations to construction and material procurement.

The predominant limitations in rural construction are those posed by the transport vehicle utilized. The only real choices for material acquisition in rural locations are barge and air transportation. The ability to transport material from the barge or plane to the site becomes another potential limitation. Material weight and size become important factors in design, delivery, and construction. While the schools observed did not appear to have any significant differences in the way they were approached in design, the team learned that the extraordinary cost to procure materials sometimes prevented them from acquiring standard school features such as playground equipment, since the budget for this equipment was used for transportation of materials. While this is not true for every district, the burden of material procurement and transportation is certainly greater in rural areas than in urban areas.

### **Construction Labor and Equipment**

This is another important consideration when comparing urban and rural school development. Construction labor and skilled professionals are readily accessible in urban environments with generally large pools of resources from which to choose. Furthermore, construction equipment is also easy to come by. In rural environments, virtually none of these conveniences are available. Construction workers in remote locations are typically provided room and board, all at a premium cost to the

contractor and ultimately reflected in final bid cost. Like material procurement, construction equipment often has to be transported to and from the site. In some instances, it is less expensive to leave equipment on site (often donated to local communities) than to transport it back. Strategies like these are reflected in the cost of construction.

### **Operations and Maintenance**

All of the facility O&M personnel interviewed spoke to the need for easily maintainable schools both in terms of materials and system components. Similar to the discussion on construction and procurement, ready access to materials and replacement parts is of particular interest to facility operations personnel in rural Alaska. Unlike urban locations that can access local suppliers of virtually anything, parts and material replacement in rural areas comes at both high cost and time premiums. Material and parts replacement in rural areas can take up to eight weeks. Emergency replacement almost always depends on air transport. Design of critical systems such as boilers for heat in rural schools is often designed on the principle of redundancy or duplication of systems (full or in part) to ensure backup in case of system failure.

### **Prototypical Context**

In light of the site visits and discussions with district and facility operations and maintenance personnel, the team learned the following:

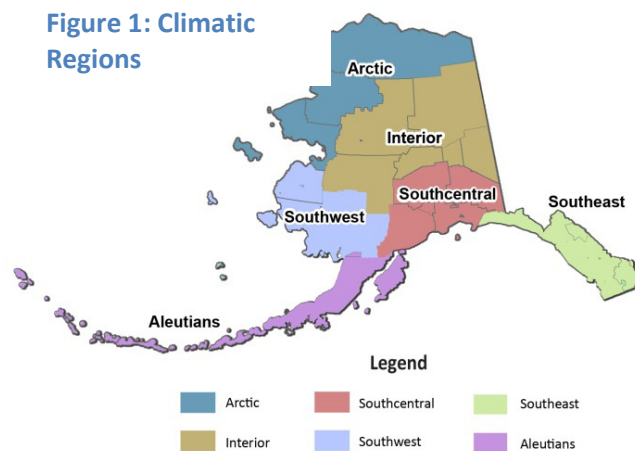
- Communities/districts utilizing prototype designs were typically larger districts that have greater population bases with steady growth. Since rural communities are typically smaller populations, prototypes tend to be impractical.
- Communities/districts that utilized prototype design typically did so in response to rapid population growth and its impact on classrooms needed to maintain desired student-teacher ratios.
- Communities with significant geographical diversity did not utilize prototypes or had minimal prototype use.
- The team observed that extreme differences in climatic regions significantly altered the way in which structural systems (particularly foundations) and mechanical (heating) systems were designed. Both urban and rural communities share in extreme climatic differences from location to location.
- Communities/districts that had significant differences in school size requirements as a result of isolated student populations were reluctant to utilize a prototype plan. Individual rural community schools tend to vary in size more than in urban districts that control individual school population based on district boundary lines.

## CHAPTER 5 – COMPONENT PROTOTYPING

This chapter explores the use of system components and their potential application in a prototypical format. Throughout the project, the team explored the potential usefulness of prototypical or standard components within a school, regardless of whether or not the school was a prototypical facility. In every instance where input was gathered, people enthusiastically embraced the philosophy of component prototyping, and to some extent were already conceptually implementing standard component ideology. This indicates an encouraging openness to component prototyping.

The research also suggests that the use of components in schools is not limited to just new school construction, but may have important potential for renovation projects as well. Successful implementation would depend on the component, application, and how efficiently and cost effectively the component could be installed, especially in light of the anticipated life cycle cost.

It is important to note that early in the review of the existing research, resources from the national and state levels were searched to see if there was any prior documentation related to the use of prototypical components. Since the information discovered pertained to facilities only and not components, the team utilized its own depth of professional experience to create a resource document related to the benefits and disadvantages of prototype components specific for Alaska.



The intent of this chapter is to familiarize the reader with the ways in which Alaska’s diverse climate, geography, geology, and other factors can influence design, selection, and implementation of component systems during construction. By recognizing the vast array of circumstances involved in selecting and designing appropriate component systems, the viability of creating *regionally specific* component prototypes can be further explored.

The following analyses are defined by engineering type (i.e., Civil, Structural, Mechanical, and Electrical). Each one takes an analytical approach to the variables influencing the use of prototype components in the state’s climatic regions as defined in Figure 1 above. In the case of Electrical Engineering, a system by system approach is employed since these components are far less region-specific. Moreover, some influences such as climate or soil appear in more than one analysis, since the appropriateness of components for various systems are uniquely and directly affected by these influences.

## **CIVIL ENGINEERING**

### **Civil Systems Overview**

Civil systems in Alaska are greatly influenced by climate and soil conditions, site conditions, and the difficulty and costs of bringing services such as water and sewer to remote locations.

While there is a wide range of climate and soil conditions throughout Alaska, there can also be a wide range of climate and soil conditions within a region or even an individual school district. This makes geotechnical engineering for foundations, roads, boardwalks, and buried or above ground utilities quite challenging. It is not uncommon, for instance, to encounter silt, clay, sand and gravel, topsoil, organics, peat, permafrost, ice lenses, and fractured or solid bedrock soil conditions in any given area within the state. This makes these variables critical when approaching civil design in any region.

Civil site work is also influenced by varying snow conditions like heavy snowfall, wind drifting, or avalanche danger. Rain events can trigger flooding, damage, or failure of foundations and erosion damage to a site. Wind-blown rain can cause damage to site structures, landscaping, and soils. Changing climate also influences civil systems. Areas of permafrost, once considered stable, are slowly warming with some areas approaching 32F. These conditions require the civil engineer to anticipate their designs for changing conditions. All these factors influence designs for years to come and must be considered in the conceptual planning stage of a project.

Access logistics is a major factor in the construction and maintenance of school facilities. Road infrastructure is well-developed in some regions of the state, but very limited in the majority of the state. Some areas are served regularly by barges, yet some are served only seasonally depending on water levels. Communities along the Arctic Ocean have very limited barge service in late summer when the shore ice melts. Other locations have limited barge service because of the lack of adequate barge landings. Areas without adequate water or road systems must depend upon air service for bringing in materials and supplies, and even then the runway has to be long enough to accommodate large air freight service.

Rural communities located off the road system have unique construction challenges since they have limited access to construction equipment. For example, driving piles depends on pile driving equipment, and concrete used on a job must have a way to mix the concrete in sufficient quantities to be efficient. Without a batch plant nearby to deliver concrete, a mixer must be imported, and if sand and gravel is not locally available, these materials must all be imported. Design engineers must consider all of the variables to be encountered, not just in the finished product, but in the construction of the product. Each variable can have significant impact on a design making a one-size-fits-all solution a considerable, if not impossible task.

## **Regional Analysis of Design Variables Affecting Civil Design**

### ***Climatic Region: Southeast***

#### *Climate and Soil Conditions*

The Southeast Alaska climate is characterized by moderate snow, wind, and seismic conditions. Temperatures are relatively warm. Soil conditions vary greatly from stable soils to peat or other poor soil. Many coastal areas have thin layers of topsoil over bedrock or exposed bedrock. Seasonal frost is less than 30 inches.

#### *Water Supply*

Potable water sources vary from surface water from streams, lakes, and reservoirs to wells. Water quality varies from almost crystal clear water to streams carrying color from decaying plant matter. Rain events can change the water quality hourly, causing disruption to water treatment systems that are not equipped to respond to rapidly changing conditions. For schools connected to municipal water systems, this is not a problem. Schools not on public systems must provide their own on-site water treatment plant. These systems are typically independent to the school and reside remotely to the school structure, and they are excellent candidates for a prototypical component used regionally. In Southeast, there is a city water treatment plant in Coffman Cove that could serve as a model from which a prototype could be developed for the region. A plant of this type could be scaled up or down as required for the specific application. It must be realized that component prototypes of water treatment systems may not carry over into other climatic zones in the state.

For schools maintaining their own potable water systems, there are a number of standard water pressurization systems that are constructed on skids in a wide variety of sizes for almost every application. These systems could be adapted to component prototyping or component standards. The same can also be said for water storage tanks, be they bolted up tanks from 5000 gallons on up. These tanks also apply to fire protection. Caution has to be used for prototyping in this case, as different site conditions will govern different foundations and tank sizing. That said, internal piping configurations and tank design could be prototyped.

Given the shallow freeze depth in Southeast, utility water and sewer piping does not have to be buried as deep as in many other parts of the state. Three to four feet burial will suffice with bare pipe; however, getting that burial depth will be problematic if there is shallow bedrock or deep layers of organics and peat. Areas with bedrock have to be blasted and areas with peat may have to be over-excavated to install geotextiles and engineered fill material to hold the pipe to the desired grade. While sewer piping in Southeast can be buried relatively shallow compared to other regions, the huge range of subsoil conditions would require site-specific design in most instances, making it unlikely that a prototypical component approach would be useful.

### *Wastewater Treatment*

Wastewater treatment types and the extent of treatment for schools requiring on-site treatment will vary depending upon the location. Schools in relatively flat areas could possibly use on-site septic systems with drainfields. Septic tanks could be prototyped, especially with plastic models that will outlive steel tanks. Schools on the coast may require more sophisticated on-site treatment systems and outfalls, which can be highly regulated and monitored. Standard packaged wastewater treatment plants have been around for many years, and could become component prototypes. These designs do not change radically over time, but parts of them, such as instrumentation, are occasionally upgraded and could be adapted later to the component prototype.

### *Site Conditions*

Access roads, parking areas, and site grading can vary from easy and inexpensive to difficult and expensive. Soil conditions and bedrock will govern what can and cannot be built economically. Access for some schools in coastal boardwalk communities may have to be constructed on boardwalks or pilings because the land is too steep to support most improvements. Storm drainage has to be carefully designed because of intense rain events in Southeast. These items are site specific and do not lend themselves to prototyping.

## ***Climatic Region: Southcentral***

### *Climate and Soil Conditions*

The climate in Southcentral Alaska is characterized by highly variable snow, wind, and seismic conditions. Wind speeds vary from 90 mph to 130 mph. Seismic design loadings can vary from moderate to severe. Temperatures in winter can vary from 0F to -40F. Soil conditions are highly variable, varying from stable soils to peat and other poor soils, such as silts, clays, and ice lenses in some areas. Seasonal frost penetrations can be from three to 15 feet, depending upon soil types and ground cover.

### *Water Supply*

Potable water sources are often municipal treatment plants or community water distribution systems. Most on-site water systems for schools are wells with decent water quality. If on-site water treatment is required, commercial packaged systems are often used to eliminate hardness, iron, and manganese, and provide basic filtration of water. Most water services to homes, schools, and commercial users is buried 10 feet deep at a minimum regardless of a municipal source or a well. Wells are governed by Alaska Department of Environmental Conservation (ADEC) standards, as well as standards in municipalities. Well pumps, piping, and connections to the wells and buildings are a category of system that could use best practices and standardization within a relatively homogeneous climatic area or school district. Such usage could cut O&M costs over the lifetime of the water system. Standard details or system component

prototypes could be established for piping connecting to utilities for water and wastewater, which could take the occasional freeze and resist soil corrosion by using High Density Polyethylene (HDPE) pipe.

#### *Wastewater Treatment*

Many schools utilize municipal sewage collection by connecting to established sewer mains. Most on-site treatment consists of septic tanks and drainfields. Component prototypes or standard details for septic tanks utilizing plastics could give longer service lives than standard steel tanks.

#### *Site Conditions*

Site grading, roads, and parking areas use normal design techniques; however, in areas of problem soils, geotextiles and geogrids may be required to run roads, paths, and parking areas over problem soils. Other items, such as light poles, bollards, fences, and playground equipment may need special considerations because of the chance of seasonal frost heave due to frost-susceptible soils, such as silts. There is enough diversity in this region that prototyping for these items is not feasible or economically favorable, but defined best practices may help to increase reliability and decrease life cycle costs.

### ***Climatic Region: Southwest***

#### *Climate and Soil Conditions*

The climate in Southwest Alaska is characterized by moderate snows, very high winds, and moderate seismic conditions. Wind conditions can be from 110 mph to 130 mph, causing extreme blowing snow and blizzard conditions. Winter temperatures can vary from 0F to -40F depending upon the area in question. Soil conditions are highly variable, varying from stable soils to peat and other poor soils, such as silts, clays, and ice lenses in some areas. Seasonal frost penetrations can be from three feet to areas of permafrost, depending upon soil types and ground cover.

#### *Water Supply*

Potable water sources vary from surface water from streams, lakes, and reservoirs to wells. Water quality varies from almost crystal clear water to streams carrying color from decaying plant matter. Rain events can change the water quality hourly, causing disruption to water treatment systems that are not equipped to respond to rapidly changing conditions. For schools connected to municipal water systems, this is not a problem. Schools not on public systems must provide their own on-site water treatment plant. These systems are typically independent to the school and reside remotely to the school structure, and they are excellent candidates for a prototypical component used regionally. There are packaged treatment skid plants that will treat the water and be tailored to areas in Southwest Alaska. Some sites may require wells and could benefit from standard details or best practices.



### *Wastewater Treatment*

Many schools utilize municipal sewage collection by connecting to established municipal sewer mains. A number of sites have above-ground water and sewerage collection systems (i.e., vacuum sewers) because of poor soils for gravity sewers, or because of seasonal flooding issues. On-site wastewater treatment systems may be septic tank/drainfield systems, but in areas of flooding and poor soils, this may be a mechanical system or force main feeding into an engineered sewage lagoon built on the tundra. In these areas, site-specific designs are required to fulfill the needs of the school. Some component prototyping may be appropriate, but limited in applicability. Standard details or best practices for the region or individual district may be more appropriate.

### *Site Conditions*

Site grading, roads, and parking areas in some parts of the region may use normal design techniques; however, in areas of problem soils, geotextiles and geogrids may be required to run roads, paths, and parking areas over problem soils. Often an engineered road may be built right on top of the tundra, utilizing it for its insulation value, over two to three feet of gravel fill. Other items, such as light poles, bollards, fences, and playground equipment may need special considerations because of the chance of seasonal frost heave due to frost-susceptible soils, such as silts. These civil designs are site specific and do not lend themselves to prototyping.

## ***Climatic Region: Aleutians***

### *Climate and Soil Conditions*

The climate in the Aleutians is characterized by low snow loads (except in the high mountains), heavy, wind-driven rain, and winds in excess of 130 mph in exposed locations. Rain can be heavy and is often wind driven. Soil conditions vary greatly from stable soils to peat or other poor soil. Many areas have thin layers of topsoil over bedrock or exposed bedrock. Seasonal frost is about 24 to 30 inches.

### *Water Supply*

Potable water sources vary from surface water from streams, lakes, and reservoirs to wells. Water quality varies from almost crystal clear water to streams carrying color from decaying plant matter. Rain events can change the water quality hourly, causing disruption to water treatment systems that are not equipped to respond to rapidly changing conditions. For schools connected to municipal water systems, this is not a problem. Schools not on public systems must provide their own on-site water treatment plant. These systems are typically independent to the school and reside remotely to the school structure, and they are excellent candidates for a prototypical component used regionally. Most schools are connected to municipal systems, so there will not be a need for water treatment and component prototypes.

Given the shallow freeze depth in the Aleutians, utility water and sewer piping does not have to be buried as deep as in other parts of the state. Three to four feet burial will suffice with bare pipe, although getting that burial depth can be problematic if there is shallow bedrock or deep layers of organics and peat. Areas with bedrock have to be blasted and areas with peat may have to be over-excavated to install geotextiles and engineered fill material to hold the pipe to the desired grade. While sewer piping in the Aleutians can be buried relatively shallow compared to other regions, the huge range of subsoil conditions would require site-specific design in most instances, making it unlikely that a prototypical component approach would be useful.

### *Wastewater Treatment*

Wastewater treatment types and the extent of treatment for schools requiring on-site treatment will vary depending upon location. Schools in relatively flat areas could possibly use on-site septic systems with drainfields. Schools on the coast may require more sophisticated on-site treatment systems and outfalls, which can be highly regulated and monitored. Rather than prototypes, standard details and best practices for wastewater can be established. That said, most schools are connected to municipal sewers.

### *Site Conditions*

Access roads, parking areas, and site grading can vary from easy and inexpensive to difficult and expensive. Soil conditions and bedrock govern what can and cannot be built economically. These are one-off systems that do not lend themselves to prototyping.

## ***Climatic Region: Interior***

### *Climate and Soil Conditions*

The climate in the Interior is characterized by moderate snow, wind, and seismic conditions, though severe earthquakes occur sporadically. Winter temperatures can be extremely cold, and often get down to -65F in some areas. The lowest recorded temperature in Alaska was -80F at Prospect Creek Camp in the Brooks Range. Soils conditions in the Interior are highly variable, varying from stable soils to peat and other poor soils, such as silts. Seasonal frost penetrations can be up to 15 feet to areas of permafrost, depending upon soil types and ground cover.

### *Water Supply*

Potable water sources are often municipal treatment plants or community water distribution systems. Most on-site water systems for schools are wells with decent water quality. If on-site water treatment is required, commercial packaged systems are often used to eliminate hardness, iron, and manganese, and to facilitate basic filtration of water. Most water services to homes, schools, and commercial users is buried 10 feet minimum, regardless of there being a municipal source or a well. Wells are governed by

Alaska Department of Environmental Conservation (ADEC) standards, as well as standards in municipalities. Some areas of permafrost preclude the use of wells, as all of the ground is frozen with no water bearing stratum. In most areas of the Interior, water pipes are insulated arctic HDPE pipe, with circulating water to keep the lines from freezing. If possible the pipes are buried in the ground to avoid the extreme cold air. Component prototyping in this region is of limited applicability, and standard details and best practices may be more appropriate.

#### *Wastewater Treatment*

On-site sewage treatment and disposal of wastewater can be accomplished using standard septic tank/drainfield systems, but these are usually equipped with extra rigid plastic foam insulation to trap heat in the system and keep it above freezing. Sometimes soil conditions, especially permafrost, preclude the use of anything except engineered two-cell sewage lagoons for a school. Keeping water and wastewater systems operating in Interior winters is very involved and expensive in terms of electricity and heat tracing costs. Standard details and best practices would be more appropriate than component prototyping.

#### *Site Conditions*

Site grading, roads, and parking areas in some parts of the region may use normal design techniques; however, in areas of problem soils, geotextiles and geo-grids, as well as rigid plastic foam insulation, may be required to run roads, paths, and parking areas over problem soils. Often an engineered road may be built right on top of the tundra, utilizing it for its insulation value, with more foam insulation over two to three feet of gravel fill. Other items, such as light poles, bollards, fences, and playground equipment may require special considerations because of the chance of seasonal frost heave due to frost-susceptible soils, such as silts. In general, site civil work requires special designs and construction techniques that do not lend themselves to prototyping.

### ***Climatic Region: Arctic***

#### *Climate and Soil Conditions*

The Arctic climate is extreme, with highly variable snow and wind conditions. Design wind speeds vary from 100 mph to over 120 mph. Winters are unforgiving, with fog, ice fog, whiteouts, blowing snow, and blizzards. Summers are short with temperatures ranging from 45F to 60F. Soil conditions are highly variable, but permafrost is most prevalent. There has been a gradual rise of average temperature of permafrost at 66 foot depth since the 1970s. The average temperature is about 24F.

#### *Water Supply*

Potable water sources are often municipal treatment plants or community water distribution systems. Schools in the Arctic obtain their water and sewer services from their communities. Some areas of

permafrost preclude the use of wells, as all of the ground is frozen with no water bearing stratum. In some community water supplies the water is supplied by wells. Water pipes are insulated arctic HDPE pipe with circulating water to keep the lines from freezing. If possible the pipes are buried in the ground to avoid extreme cold air. Sometimes pipes are run above ground in problem soils. In all schools in the Arctic, the municipalities provide water and sewer services, so they already have standards for water and sewer lines, as well as connections to the municipal system. Prototyping in this regard is therefore not applicable in this region.

#### *Site Conditions*

Site grading, roads, and parking areas in a few parts of the region may use normal design techniques; however, in areas of permafrost soils, geotextiles, as well as rigid plastic foam insulation, may be required to run roads, paths, and parking areas over problem soils. Often an engineered road may be built right on top of the tundra, utilizing it for its insulation value, with more foam insulation over two to three feet of gravel fill. Other items, such as light poles, bollards, fences, and playground equipment may require special considerations because of the chance of seasonal frost heave due to frost-susceptible soils, such as silts. These are one-off designs that do not lend themselves to prototyping.

### **Viability of Component Prototyping - Civil Design**

#### *Southeast*

Civil component prototyping is limited in the Southeast region because of the variability of soils; however, there are some areas of civil works that could benefit from component prototypes and standards, namely the piping and component details for water and sewer services to municipal systems. There are enough years of experience with HDPE pipe to establish its success in flow performance, ability to take a freeze, and resistance to corrosive soils. Culverts could also be prototyped to serve where galvanized culverts and appurtenances prematurely fail in corrosive soils. Septic tanks could be prototyped. Plastic septic tanks have improved such that they may be used for many years without corroding the way steel septic tanks have when the inner coating fails. Pressure and booster pump skids have also developed into very reliable and efficient units, with variable speed drives that protect the pumps and deliver highly energy efficient performance.

#### *Southcentral*

Civil component prototyping in the Southcentral region has a limited number of possibilities. The main reason is that most municipalities with schools already have ordinances that establish standard details for civil work and these must be followed. That said, there are some areas of civil works that could benefit from component prototypes and standards. Septic tanks could be prototyped. Plastic septic tanks have improved and may be used for many years without corroding the way steel septic tanks have when the inner coating fails. Pressure and booster pump skids have also developed into very reliable

and efficient units, with variable speed drives that protect the pumps and deliver highly energy efficient performance. These are likely the only areas where civil component prototyping would be viable.

### *Southwest*

Civil component prototyping is limited in the Southwest region because of the variability of soils, which range from permafrost and swampy soils to well-drained and graded soils. That said, there are some areas of civil works that could benefit from component prototypes and standards. These include piping and component details for water and sewer services to municipal systems. There are enough years of experience with HDPE pipe to establish its success in flow performance, ability to take a freeze, and resistance to corrosive soils. Culverts could also be prototyped to serve where galvanized culverts and appurtenances prematurely fail in corrosive soils or marine environments. Septic tanks could also be prototyped. Plastic septic tanks have improved and may be used for many years without corroding the way steel septic tanks have when the inner coating fails. Drainfields could be built using infiltrators where sewer rock cannot be used. Pressure and booster pump skids have also developed into very reliable and efficient units, with variable speed drives that protect the pumps and deliver highly energy efficient performance.

### *Aleutians*

Civil component prototyping can have moderate applicability in the Aleutian region simply because there are a limited number of communities. Areas of civil works that could benefit from component prototypes and standards include piping and component details for water and sewer services to municipal systems. There are enough years of experience with HDPE pipe to establish its success in flow performance, ability to take a freeze, and resistance to corrosive soils. Culverts could also be prototyped to serve where galvanized culverts and appurtenances prematurely fail in corrosive soils or marine environments.

Septic tanks could also be prototyped. Plastic septic tanks have improved and may be used for many years without corroding the way steel septic tanks have when the inner coating fails. Drainfields could be built using infiltrators where sewer rock cannot be used. Pressure and booster pump skids have also developed into very reliable and efficient units, with variable speed drives that protect the pumps and deliver highly energy efficient performance.

### *Interior*

Civil component prototyping has some applicability in the Interior region. Soils vary from tundra and permafrost to limited permafrost and soils with good drainage characteristics. Because of the cold winters, seasonal frost levels could be as much as 14 feet below the surface. That considered, there are some areas of civil works that could benefit from component prototypes and standards. Insulated piping and appurtenances have been used for more than 30 years for acceptable component prototypes.

Pressure and booster pump skids have also developed into very reliable and efficient units, with variable speed drives that protect the pumps and deliver highly energy efficient performance. Sewage treatment skid plants could also be prototyped. Septic systems consisting of septic tanks and drain fields could be used as component prototypes, with the proper insulation to conserve heat and prevent frost penetration.

#### *Arctic*

Civil component prototyping is limited in the Arctic region because of the permafrost nature of the soils. They vary from tundra and permafrost to limited permafrost and soils with good drainage characteristics. Because of the cold winters, frost heave is always a consideration, so most areas are not conducive to designs using civil component prototypes. That considered, there are some areas of civil works that could benefit from component prototypes and standards. Insulated piping and appurtenances have been used for more than 30 years for acceptable component prototypes. Pressure and booster pump skids have also developed into very reliable and efficient units, with variable speed drives that protect the pumps and deliver highly energy efficient performance. Sewage treatment skids could also be prototyped.

#### **Civil Components Prototyping Summary**

Climate, soil conditions, water supply, and wastewater treatment (i.e., sewage collection systems) are highly variable across Alaska. Many civil improvements for schools have similarities, but there is always a site that is an exception to the rule within regions and even within school districts. Pre-designed civil components will always have to be modified or “tuned” to the site. This negates the concept of a prototype on any level, particularly if cost savings are the goal. In some instances, such as on-site water and wastewater treatment, civil component prototypes in a region may have positive benefits. As an alternative to civil prototyping, many components could be part of a “Best Practices” or “Standard Details” database that could eliminate duplicate efforts at different sites, thus increasing the reliability of civil design and construction and potentially reducing engineering costs.

## STRUCTURAL ENGINEERING

### Structural Systems Overview

Structural systems in Alaska are highly influenced by design variables such as climate, soil conditions, site topography, and building size. Structural components of these systems are also dependent on climatic conditions, soils and foundation types, building configuration, and access to construction materials. With the huge diversities found across Alaska regarding these influences, structural design becomes a highly individualized and site-specific effort. While these diversities present unique challenges to prototypical designs, they do not necessarily preclude prototype methodology altogether.

In consideration of climatic conditions, Alaska's snow fall is significantly different around the state. Valdez, the state's undisputed snow fall capitol, has ground snow loads that reach up to 160 psf whereas in Barrow ground snow loads are quite light at 25 psf. Such differences play a significant role in how structural design is completed. With greater snow loads, structural member sizes need to be increased to carry the loads. Whether a structure is wood, steel, or concrete, in every instance the structural components within the overall system will be larger and heavier from the superstructure (i.e., the above ground structural systems) all the way down to the foundation and ultimately the soils that carry the load. Increases in snow loads thus result in more material which corresponds to higher costs.

Similar to the way snow loads play a role in increased structural member sizes, high wind areas like Bethel and high seismic zones like Unalaska will result in significantly different structural sizes than areas like Barrow which have both reduced wind and seismic loads. To further complicate the challenge of structural design in Alaska, the geological conditions (i.e., site soil) below the building itself will play a significant role in how the foundation is designed.

A building with identical external design variables (i.e., snow, wind, and seismic) like those experienced in a relatively homogeneous climatic area such as Anchorage may still have significantly different subsurface soil conditions. When the elementary prototypes for ASD were constructed in the 1990s, nine elementary schools had nine different soil conditions. So while the superstructure could have been identically designed, each foundation still required modifications to be structurally acceptable for the individual locations.

Besides the variability in design loads, there are many types of structural systems available from which to choose. Structural systems vary from steel decks with open web steel joists and steel wide-flange girders with diagonal braced frames to wood I-joists with glued laminated beams and plywood sheathed shear walls. Steel beams on concrete masonry walls and long span precast concrete beams with precast insulated concrete walls are also some of the many structural systems frequently used in Alaska. The choice of structural system is influenced by the size of the school, the size and span of its public spaces, the desired durability, the means available to ship construction materials, and the availability of local

materials for use in construction. Most of the structural systems noted above can be found in almost any region of Alaska.

Most equipment used in construction is available in larger communities located on the road system, but the smaller communities, and in particular those not on the road system, must have equipment brought to the site. The building methods and equipment required for construction are generally driven by the type of structural system used. For example, long span roof systems (e.g., in gymnasiums) typically require cranes with a longer reach and a greater lifting capacity. In some cases the cost of transporting a crane to the site may be cost prohibitive, requiring the designer to consider shorter spans and lighter structural elements which may influence the architectural design as well.

A school's foundation design is further influenced by the competency of underlying soils, the depth of annual frost penetration, and permafrost conditions. Underlying soils vary from sands and gravels (considered excellent), fine-grained silts and clays (considered good if not disturbed or allowed to get wet), peat (considered not acceptable for building support), and bedrock (considered a good foundation base but can be a challenge if it is too close to the surface and requires removal to place the building). The depth of the annual frost penetration influences the depths of foundations because the soils below the building should not be allowed to freeze unless they are located on permafrost where frozen ground should stay frozen.

As with civil design, permafrost continues to be an important variable in structural design. Permafrost can be in thaw stable soils that can support loads even when thawed, or in ice rich soils that would settle several feet if thawed. Permafrost across Alaska varies from stable well-frozen temperatures to just below freezing, which can be very sensitive to environmental changes, especially those where temperatures are increasing. Alaska is currently experiencing warming of permafrost such that some is close to thawing. In Bethel, for example, one site has experienced an increase in the temperature of the permafrost of about 1.5 degrees during the last 40 years. While this may seem insignificant, the temperature of the permafrost now hovers at 31.5F, up from 30F. If this trend continues the thawing of the permafrost will have significant impacts on existing and future structural designs.

Foundation systems in Alaska vary from concrete spread footings (the most typical found in Alaska) sitting on stable soils, timber pads on stable soils, or driven piling in peat or loose soils. Where bedrock is close to the surface, footings may be cast directly on bedrock with anchors drilled and grouted into the rock to secure the building. Permafrost foundations can be drilled and frozen back piling, driven piling with small pilot hole, or timber post and pads. In many cases, passive cooling is necessary to keep the permafrost from thawing, using either thermal piles or thermal probes placed adjacent to piling. Thermal piles or probes use a passive cooling approach that lowers the ground temperature in the winter and is inactive during the summer.



Soil conditions vary from site to site and influence the choices an engineer can make about which floor system to use. In regions that have structurally suitable soil and that are generally not affected by permafrost, concrete slabs constructed directly on grade are common and quite economical since the ground serves as the supporting structure. However, when the grade is not suitable to support the floor system as is typically found in poor soil areas with high peat content or water saturated sites, an elevated floor system may be necessary. Areas with permafrost also need to have elevated floor systems since it is important to keep the soils away from building heat that would melt the frozen ground. Elevated floor systems are influenced by design variables such as the loads imposed by its own weight (dead load) like wood or concrete toppings for the floor surface and loads imposed by the occupant or furniture and equipment (live loads). All of these variables are necessary considerations for the structural design.

Structural systems are the backbone of any school and must consider the many variables imposed from the natural environment to those imposed by Building Life Safety Codes. They are particularly vulnerable to the subtleties of the site and therefore will almost without exception require modification from site to site. As noted, this does not render prototypical design concepts useless, rather it is something to be aware of when considering prototypical construction. It is more reasonable and cost effective to design a foundation to the specifics of the site on a case by case basis than to design a single foundation or superstructure to meet the vast array of extremes found in the state.

## **Regional Analysis of Design Variables Affecting Structural Design**

### ***Climatic Region: Southeast***

Structural systems in Southeast Alaska vary widely and include wood frame, steel frame, masonry, cast-in-place concrete, and precast concrete. Variations in design depend upon climate, soils, foundation types, availability of materials, construction equipment, and building methods, which all contribute to the complexities in the region.

This region also has a wide range of community sizes and great diversity in the type of transportation systems required to deliver materials. From urban (Juneau) to quasi-urban (Sitka and Ketchikan) to remote outposts like Klawok and Hoonah, the region's diversity presents unique challenges to school development.

### ***Climate***

The Southeast Alaska climate is characterized by moderate snow, wind, and seismic conditions. Temperatures are relatively warm. Snow loads are modest at around 30 psf to 50 psf but drifting snow, as a result of wet wind driven snow, is a major design consideration. Design wind speeds over the region vary from 100 mph to 120 mph. For this area the roof structures are designed for the lower end of the

snow loads found in the state. Similarly, lateral force resisting systems are designed for the average range of wind and seismic forces. Given the relatively lower end of forces driving structural design in the Southeast, superstructure systems are generally lighter than the remainder of the state resulting in less material related cost. This can be offset, however, by transportation cost to the site.

#### *Soils and Foundation Types*

Soil conditions vary widely in the region with stable soils that support standard concrete foundations, to peat or other poor soils which require pile foundations. Coastal areas with shallow bedrock allow for concrete pads cast directly on bedrock. Seasonal frost penetration in this region is less than 30 inches, so foundations can be somewhat shallower than regions with greater freeze depth.

#### *Construction Materials and Building Methods*

Generally, the aggregate required for concrete and structural fill is available locally, making the use of concrete cost effective and highly desirable. Delivery of materials and construction equipment depends on barges, or in communities not on the water or with insufficient docking capabilities, on air service. Roads are limited in the region and not connected to areas outside the region, so barge and air service are always utilized. Building methods in this region can be limited by the equipment available in the community or by whether or not equipment can be mobilized to the community at a reasonable cost.

#### ***Climatic Region: Southcentral***

Structural systems in Southcentral Alaska include a wide range of possibilities. Wood frame, steel frame, cast-in-place concrete, masonry, and precast concrete systems are all frequently utilized and would be considered equally important and reliable at any given location with the region. The region has the largest urban communities as well as very small rural communities. Variations in design depend upon climate, soil conditions, seismic characteristics, foundation types, availability of materials, construction equipment, and building methods. With much of the region accessible to the road system, many of the most modern techniques, materials, and design considerations are feasible and practical while the more remote communities are substantially less accommodated.

#### *Climate*

Design roof snow loads vary from 40 psf to over 120 psf in this region, and drifting snow is a major design consideration. With the increase in snow loads from two to three times the moderate snow loads, there is an increase in the weight of the structural frame, columns, and foundations. Seismic design loading conditions vary from moderate to severe. Design wind speeds over the region vary from 90 mph to over 130 mph. The higher wind and seismic forces require more robust lateral force resisting elements, columns, and foundations. Temperatures are cold enough in the winter months that in some locations they influence components such as wall thickness and the detailing of adequate clearances for

roof insulation and ventilation. With such extremes in conditions, singular prototype design concepts present significant design challenges since structural member sizes affecting clearances for roof systems and wall structure may change dramatically.

#### *Soils and Foundation Types*

Soil conditions vary widely from stable soils that support standard foundations to peat or other poor soils which require pile foundations. Seasonal frost penetration in this region can be up to 15 feet deep in some areas and only 42" in others. Such extremes can be controlled by details such as installing insulation on the exterior of the wall which allows the footings to only be about four feet deep regardless of the depth of soil freeze. There are very limited areas of discontinuous degrading permafrost. Foundations in the region are generally standard concrete footings, timber pads, or piling depending on the soil bearing capacity.

#### *Construction Materials and Building Methods*

Generally, the aggregate required for concrete and structural fill is available locally, making concrete a widely used construction material. Other materials and construction equipment can reach sites year round by road, railroad, water, or air. Because of the use of the road system, building methods in most communities are not limited by equipment availability since equipment can readily be mobilized for a reasonable cost. This flexibility enables school designs in the region to be quite versatile and make use of virtually unlimited choices in materials. A prototype design utilized for the entire state would not enjoy this freedom in design, as it would encounter far more limited material choices.

#### ***Climatic Region: Southwest***

Structural systems in Southwest Alaska are generally wood frame or steel frame. Variations in design depend upon climate, soils conditions, foundation types, and the availability of materials, construction equipment, and building methods. The region is primarily rural with access to construction sites typically limited to barge or air transport. Transportation of materials and construction equipment is a significant design consideration and a limiting factor in design and construction in this region.

#### *Climate*

Design roof snow loads are generally around 40 psf to 50 psf and drifting snow is a major design consideration. These snow loads are in the moderate range for the state and do not require a heavier structural frame. Design wind speeds over the region are generally in the 120-130 mph range with some very high exposure factors (due to the lack of features like trees to block wind) for buildings on the coast that greatly impact structural design of building components and connections. Design wind pressures in this region are similar to and often much greater than that of a hurricane which starts at 75 mph. Seismic loading conditions are moderate and wind loading often controls design. The high wind loads

require more robust and more costly lateral force resisting elements, columns, and foundations which in turn adds size and weight resulting in higher material and transportation costs. Temperatures are cold enough in the winter months that they can influence components such as wall thickness and the detailing of adequate clearances for roof insulation and ventilation. The impact of low temperatures is accentuated by extremely high energy costs in this region, making highly energy efficient building envelope systems attractive.

#### *Soils and Foundation Types*

Soil conditions in this region vary widely. Conventional spread footings are rare because of poor soil conditions and lack of local aggregate for concrete. This region is underlain by highly variable permafrost conditions ranging from stable to marginally frozen to discontinuous (both frozen and unfrozen). Piling is the more common foundation system used in this region; however, piling can be either conventional driven piles or may need to be thermal where heat is extracted from the soils surrounding the piling to ensure the permafrost stays frozen.

Post and pad foundations supported by gravel pads are sometimes utilized for smaller structures; however, this system tends to experience differential settlement and require regular adjustments for movement of the pads. As such, these systems are only used for non-permanent or non-habitable structures. Floor systems in the Southwest tend to be framed and elevated above the ground with insulated soffits. Space below the soffit is open to the weather to ensure building heat cannot reach the fragile permafrost. Such systems are more expensive and require framing like a second floor and insulation like a roof.

#### *Construction Materials and Building Methods*

The aggregate required for concrete and structural fill may or may not be available locally, and shipping to sites in this region can be expensive. Other materials and construction equipment can reach sites by barge during part of the year, but the number of scheduled barges may be as few as one or two per year, thus making design and construction schedules highly critical. Delivery by air is available year round, but it is expensive and limits design flexibility. Roads in this area are only local. Building methods in this region can be limited by the equipment available in the community or by whether or not equipment can be mobilized to the community at a reasonable cost.

#### ***Climatic Region: Aleutians***

Structural systems in the Aleutians vary widely and include wood frame, steel frame, masonry, cast-in-place concrete, and precast concrete. Variations in design depend upon climate, soils, foundation types, availability of materials, construction equipment, and building methods. The region is further complicated by accessibility and characterized by notoriously inclement weather that contributes significantly to material and transportation costs as well as manpower and labor costs. There is no road

access with barge and air being the most reliable methods to transport materials and construction equipment. The region is virtually all rural in nature.

### *Climate*

Design wind speeds over the region are generally 130 mph with some very high exposure factors for buildings on the coast similar to the Southwest region. The Aleutians are a very active seismic region with frequent and sizable earthquakes. The high wind and seismic loads mean heavier, more robust, and more expensive lateral force resisting elements and foundations. Snow loads are around 30 psf and drifting snow is a major design consideration. These snow loads are in the moderate range for the state and do not require a heavier structural frame.

### *Soils and Foundation Types*

Soil conditions vary and while conventional concrete footings are the most common building foundation system, many sites have poor soils that require conventional driven pile foundation systems. Shallow bedrock is prevalent in some areas of this region and requires foundation systems of concrete pads cast directly on bedrock. Seasonal frost penetration in this region is less than 30 inches, so conventional foundations are generally placed at that depth.

### *Construction Materials and Building Methods*

The aggregate required for concrete and structural fill may or may not be available locally, and shipping to sites in this region can be expensive. Other materials and construction equipment can reach sites by water year round, but there may be a limited number of scheduled barges. Delivery by air is available year round, but can be more expensive especially due to bad weather and the potential for planes to be grounded or required to be turned back to the original airport. The roads in this area are only local. Building methods in this region can be limited by the equipment available in the community or by whether or not equipment can be transported to the community at a reasonable cost.

### ***Climatic Region: Interior***

Structural systems in the Interior vary widely and include wood frame, steel frame, masonry, cast-in-place concrete, and precast concrete. Variations in design depend upon climate, soil conditions, seismic characteristics, foundation types, availability of materials, construction equipment, and building methods. Similar to the Southcentral region, a portion of the Interior has reasonable access to the road system and many of the most modern techniques and materials, and remote communities are more limited to barge and air service. The region has some of the largest communities with good road access as well as many small rural communities with no road access.

### *Climate*

The Interior is characterized by moderate snow, wind, and seismic conditions. Design wind speeds over most of the region vary from 90-100 mph. Design roof snow loads are generally around 50 psf and drifting snow is a major design consideration. Wind, snow, and seismic loads are in the moderate range for the state and do not require significantly heavier lateral force resisting elements, structural frames, or foundations. Winter temperatures can be extremely cold (-50°F) and often impact components such as wall thickness and the detailing of adequate clearances for roof insulation and ventilation. Summer temperatures in the Interior are some of the warmest (+90°F), making this region's temperatures the most variable in the state. These extremes impact mechanical design more than structural, but since mechanical systems have both heating and cooling, systems and equipment loads are larger.

### *Soils and Foundation Types*

Soil conditions vary widely from stable soils that support standard concrete foundations, to peat or other poor soils which require pile foundations. Seasonal frost penetration in this region can be greater than 15 feet in some areas and only around 48-60 inches in others. Such extremes can be controlled by details such as installing insulation on the interior side of the exterior walls which allows foundations to be only 4-5 feet deep and still keep the soils under the building thawed. Foundations in the region are generally standard concrete footings, timber pads, or piling depending on soil bearing capacity and permafrost conditions.

### *Construction Materials and Building Methods*

The aggregate required for concrete and structural fill may or may not be available locally, and shipping to sites in this region can be expensive. Other materials and construction equipment can reach sites by water during part of the year but with limited barge schedules, or by air year round. Some parts of this area are reachable by roads and railroad, and in other areas the roads are isolated to the local community only. Building methods in smaller communities with less accessibility can be limited by the equipment available in the community or by whether or not equipment can be mobilized to the community at a reasonable cost.

### ***Climatic Region: Arctic***

Structural systems in Arctic Alaska are generally wood frame or steel frame. Variations in design depend upon climate, soil conditions, foundation types, availability of materials, construction equipment, and building methods.

### *Climate*

The Arctic climate is extreme and characterized by highly variable snow and wind conditions. Design wind speeds over the region vary from 100 mph to 120 mph. Seismic design loading conditions are moderate. Design roof snow loads are generally around 40-50 psf, and drifting snow is a major design consideration. The wind, snow, and seismic loads are in the moderate or slightly above moderate range for the state and do not require a significantly heavier lateral force resisting elements, structural frames, or foundations. Temperatures are cold enough that structural components such as wall thickness and clearances for roof insulation and ventilation are often impacted.

### *Soils and Foundation Types*

Soil conditions in this region vary widely, but permafrost is the most prevalent. Conventional concrete footings are rare because of frozen soil conditions. The more common foundation system for this region is piles with or without passive cooling. Another foundation utilized in this region is shallow concrete foundations over insulation over horizontal flat loop thermoprobe systems that keep the underlying soil frozen.

Post and pad foundations supported by gravel pads are sometimes utilized for smaller structures, but these systems often experience differential settlement and require regular maintenance to adjust for the movement of the pads. The floors tend to be framed and elevated with insulated soffits with the space below the soffit open to the weather. Given the relative consistency in soil conditions (permafrost) and the limited use of foundation options, the Arctic region shows some promise in the design of a prototypical foundation system, but requires the most individual site modifications compared to other regions.

### *Construction Materials and Building Methods*

Materials and construction equipment can reach sites by water during a very limited window of time in the summer months with limited barge schedules. Delivery by air is available year round, though it is costly and very limiting to material sizes and weights. Though some communities have road access to the Interior and Southcentral regions, roads in this area are very limited and generally only local. Building methods in smaller communities with less accessibility can be limited by the equipment available in the community or by whether or not equipment can be mobilized to the community at a reasonable cost.

## **Viability of Component Prototyping - Structural Design**

*For all regions*, the use of structural prototypes for frame or foundation requires some adaptation for each site because of the variation in the environmental factors and in the soils conditions.

### *Southeast*

In Southeast Alaska variables influencing design are not extreme and would require only modest changes that would generally not affect the designs of other systems.

### *Southcentral*

In Southcentral Alaska extreme variables in wind speed, soil conditions, and snow loads make a one-size-fits-all prototype more challenging when applied across the region much less the state.

### *Southwest*

In Southwest Alaska many areas that are relatively homogeneous once above the ground, thus making superstructure design potentially more suitable for prototype design.

### *Aleutians*

In the Aleutians region, design variables are not substantially extreme and would generally require only modest changes which would not affect the design of other operating systems. As such, regionally applicable prototyping may be somewhat feasible.

### *Interior*

The many variables encountered in the Interior make the one-size-fits-all prototype substantially more challenging when such a solution is considered for regional application.

### *Arctic*

While the weather is extreme, there is relative homogeneity in the Arctic region that may allow for prototypical structural design to a greater extent than in other regions. This potential is limited to the region only given the extremely different conditions found here in comparison to the rest of the state.

## **Structural Components Prototyping Summary**

Due to the wide variability of building design loads and foundation types across Alaska, there is little opportunity to create a true prototypical structural design that could be used throughout the state for any facility, including schools. To design a prototype with a superstructure that resists the high seismic loads of Unalaska, the high coastal winds of Gambell, the high snow loads of Valdez, and the extreme cold of Barrow, is neither practical nor cost effective whether from a facility or component perspective.

Extreme conditions aside, the project team's experience with prototypes demonstrates that it can be cost effective to have a pre-designed structural system that can be fine-tuned to meet the specific conditions of a particular site type. Though this involves additional design cost, such expense is easily offset by savings in the constructed structure. This model has been proven to work well for school



prototypes in Anchorage, Fairbanks, and the Matanuska-Susitna Borough, even though each district utilizing prototype designs encountered design variables within their district that required structural modifications for each school design.

It is important to note that even if two schools in the same district have essentially the same snow, wind, and seismic loads, the soils conditions will vary from site to site, thus requiring different foundations. In the case of a prototype used in Anchorage, one school is on gravel that supports concrete spread footings and another is on clay/silt that supports concrete spread footings, but the latter had lower soil bearing pressure and required larger footings. The same prototype school was placed on another site with peat and loose soils that required a driven piling foundation and a structural floor slab instead of concrete slab on grade. Even with radically different foundation designs, the prototype model worked well and saved the district money overall.

It may be possible to create several adaptable prototypical structural foundation systems (e.g., concrete spread footing, pile, timber post and pad) that could be reviewed and adapted on a per site basis depending on the specifics of the region. While this approach may negate some of the inefficiencies of a prototype model, it could serve as a basis of design, a system from which site-related conditions would cause the design to evolve and be modified to meet the specific design criteria.

## **MECHANICAL ENGINEERING**

### **Mechanical Systems Overview**

Mechanical systems in Alaska are highly influenced by climate, available fuel sources, building size, construction method, water supply, and availability of skilled operations and maintenance (O&M) personnel at the district and local levels. Each region of the state has a variety of differences in these areas that significantly affect the process of determining which mechanical systems are most appropriate.

Since one of the major functions of a building mechanical system is to keep a building at temperate conditions on the inside, the mechanical systems are heavily influenced by weather. Various temperatures, wind intensity, and precipitation patterns all drive varying requirements and capacities of mechanical equipment across Alaska.

Fuel sources also drive the selection of mechanical equipment. Natural gas-fired equipment has the greatest variety of types of equipment available for heating a building. Fuel oil has very limited options as to what equipment is available and how it can be installed. Electric equipment has almost as much variety as natural gas equipment, but it drastically affects the electrical service entrance size to the facility.

The size and construction method of a facility also has major impacts on the mechanical systems. A building on pilings has different options for routing mechanical utilities than a building on grade. Large urban schools have different requirements than small village schools.

The availability of domestic water from a municipal utility affects facility plumbing systems. The quantity of water and its pressure affects the choices of plumbing fixtures and sometimes pressurization systems. It also affects the source of supply for the fire sprinkler system. By State code amendment, all Alaskan schools with 50 or more students must have a fire sprinkler system. These systems require a large quantity of water to be available, and in rural areas the domestic utility is often not able to deliver it.

In terms of O&M, large schools tend to have larger and more sophisticated mechanical systems that need to be controlled by digital control systems. These computer-based controls can be quite complicated to operate and require a skilled technician available to keep them operating properly. In urban areas, designers anticipate well-trained, reliable O&M personnel or contract professionals to be readily available, but in rural or remote regions such personnel may not be expected. The availability of competent O&M staff is a very important design consideration for mechanical systems in schools.

## **Regional Analysis of Design Variables Affecting Mechanical Design**

### ***Climatic Region: Southeast***

#### *Climate*

This climate region has the warmest temperatures in the winter and some of the coolest temperatures in the summer. This leads to relatively small heating plants in the facilities and usually no inclusion of mechanical cooling.

Ventilation for buildings in Southeast is important due to the climate's high relative humidity. Buildings with insufficient air changes will tend to develop condensation on interior surfaces, which may encourage microbial growth (i.e., mold) and degrade the building. This is especially true with buildings that have high occupant loads, such as schools. Maintaining warm fresh air movement throughout a building helps maintain a lower inside relative humidity, thereby reducing the likelihood of condensation formation. Ventilation system air intakes must be protected from water entrainment during rainfall periods. This is usually done with large sized louvers that reduce air intake velocity. Natural ventilation is not typically used in commercial buildings in Southeast due to humidity issues.

#### *Available Energy Sources and Heating Systems*

A variety of available energy sources in Southeast include hydro-electricity, biomass, fuel oil, and propane. Many communities from Skagway to Ketchikan are supplied with electricity from hydro-electric dams. The dams capitalize on the abundant water from mountain snowmelt and rain, providing a renewable energy resource. As a result, electricity costs in several Southeast communities are some of the lowest in the state, which has the potential to make electrically based heating systems very practical. Many buildings utilize electric resistance heating in baseboards, unit heaters, duct-mounted heating coils, air handler heating coils, and in-floor radiant systems.

The availability of vast forest resources in Southeast provides opportunities for wood biomass heating. This typically involves a wood-fired hydronic boiler that is fueled using split logs, chips, or pellets. The challenges proposed by this resource are acquiring and storing fuel, and operating and maintaining the equipment. For commercial installations, drying and storing large amounts of wood is challenging due to the space required to do so. Wood biomass heating is a labor-intensive heating fuel and is not used for many commercial projects.

Communities without access to hydro-electricity alternatively rely on fossil fuels for heating and domestic water. Due to the absence of roads between Southeast communities, fossil fuels are transported primarily by barge. Fuel oil and propane are the two fossil fuels used in Southeast. Most locations utilize fuel oil for boiler-fired hydronic systems because it is significantly less expensive than

propane. Propane is used primarily for cooking in some more remote locations where electricity is not readily available.

#### *Construction Considerations*

Commercial buildings in this region tend to be constructed as slab on grade facilities. This allows for underfloor sewer utilities that are not in danger of freezing, but no other mechanical utilities are routed below slab. Mechanical utilities tend to be routed in the ceilings. Alternatively, structures built primarily with wood are often designed with underfloor crawlspace, which can be either above or below ground level. Underfloor crawlspace allows routing of mechanical utilities under the floor with a reduced danger of freezing.

#### *Plumbing Considerations*

Most communities in Southeast Alaska have modern public water systems that are capable of providing potable and fire protection water service to commercial buildings; however, in some of the smaller and remote communities water may be drawn from on-site wells. Bulk water storage, water treatment equipment, and fire pumps for fire sprinkler protection are common mechanical applications in locations without adequate water service.

#### *Operations and Maintenance*

Mechanical systems must be designed to be simple, robust, and easily maintained so they can operate adequately in this region's maritime environment.

### ***Climatic Region: Southcentral***

#### *Climate*

Climate in this region can be cold for long periods, but it is not the protracted intense cold seen in the Arctic or the Interior. It also does not get overly warm, although it does get warmer than the Southeast. It is generally not windy or excessively humid. Consequently, extreme protection measures for mechanical systems in this region are usually not required.

#### *Available Energy Sources and Heating Systems*

The standard available energy sources in Southcentral are natural gas, fuel oil, electricity, and propane. The local supply of natural gas in Cook Inlet has made that resource the primary source of heating energy. Most buildings in Southcentral are located near natural gas utilities, which extend from Anchor Point up to north of Wasilla. The viability of natural gas provides more options for heating equipment than other locations in the state. Commonly used commercial building equipment includes boilers, roof top units, unit heaters, and over-head infrared heating. Gas-fired hydronic boiler systems typically employ fintube, unit heaters, duct mounted coils and in-floor radiant for heating spaces. Roof top units

are common for offices, malls, and large commercial retail stores where combining heating, ventilation, and cooling into one unit on the roof reduces the amount of HVAC equipment needed and opens up floor space inside the building. Gas-fired unit heaters and radiant heaters are commonly used in warehouses and maintenance shops where ventilation systems typically run intermittently.

With the advent of condensing technology (which allows heating systems to run at lower temperatures and reclaims heat from combustion exhaust), operating gas-fired equipment has become more cost effective, and has generally reduced the space requirements of heating equipment. However, the implementation of condensing technology has created a new set of design considerations, which include the handling of acidic condensate in the boiler flues, safe disposal into mechanical room floor drains, and learning to maintain more sophisticated electronically controlled equipment.

Some Southcentral communities fall outside of the natural gas service area such as Chickaloon, Whittier, and Willow, and their primary heating fuel is fuel oil. Heat is provided using fuel-oil fired boilers and hydronic heating equipment. Domestic water is heated using fuel-oil or indirectly using the boiler. Cooking in these locations is performed using propane or electricity. In the past, electricity has been used for heating in some commercial buildings in Southcentral, but it is not used often due to the availability and lower cost of natural gas.

#### *Equipment Sizing*

Anchorage is the largest community in Southcentral Alaska and in the state as a whole. Consequently, Anchorage has some of the largest school mechanical systems in the state. Ventilation system styles and sizes in Anchorage are typically driven by code required ventilation rates. Due to Anchorage's size the schools have large student populations, and ventilation rates tend to be high. Natural ventilation is not practical given that ambient temperatures are cold most of the school year and allowing large amounts of uncontrolled outside air through the facility causes great discomfort, equipment damage, and high fuel bills. Large air handlers are employed to address ventilation and cooling requirements. In the interest of energy and cost savings most schools utilize Variable Air Volume (VAV) air handling systems and employ control strategies such as demand controlled ventilation (i.e., airflows based on CO<sub>2</sub> concentrations) and economizer cooling. Schools do not use mechanical cooling. Many other communities in Southcentral utilize similar ventilation designs.

#### *Construction Considerations*

Buildings in this region tend to be constructed as slab on grade facilities. This allows for underfloor sewer utilities that are not in danger of freezing, but no other mechanical utilities are routed below slab. Mechanical utilities tend to be routed in the ceilings. The buildings are large, commercial-grade structures with steel framing and concrete decks between floors, so there is room for utilities, and there are few problems for sprinkler systems with concealed combustible spaces.

### *Plumbing Considerations*

Most communities in Southcentral Alaska have large and modern public water systems that are capable of providing potable and fire protection water service to commercial buildings; however, in some of the smaller and remote communities water is drawn from on-site wells. These remote locations typically also provide bulk water storage and fire pumps for fire sprinkler protection.

### *Operations and Maintenance*

The larger communities in this region have school districts with maintenance staff that are capable of operating and maintaining sophisticated digital control systems.

## ***Climatic Region: Southwest***

### *Climate*

Snow in the Southwest is relatively dry compared to Southcentral and Southeast, and the wind blows prevailing winds are common. As a result, most air inlets and outlets to buildings are provided with large hoods, rather than louvers, to create low-velocity air inlet conditions to reduce snow entrainment and to protect wall openings from direct exposure to blowing snow, which can easily block louvered openings. Since many buildings are on pilings, outside air intakes are frequently installed under the buildings to further remove the possibility of snow intake.

### *Available Energy Sources and Heating Systems*

The primary fuel source in Southwest is fuel oil, which is commonly stored in large above grade fuel storage tanks on site. Commercial buildings are typically heated using cast iron boilers that supply heating water to fin-tube, unit heaters, and duct mounted coils. Boiler plants are typically designed with two or three boilers, with each boiler sized to cover a portion of the entire building heating load. This allows smaller boilers to be more heavily loaded keeping them in a more efficient operating range.

Cast iron boiler technology has improved in efficiency due to multi-pass combustion venting, allowing fuel oil boilers to attain efficiencies of approximately 87%. For large buildings such as schools, this potentially allows for significant energy and cost savings. Electricity in Southwest communities is provided by diesel-fired electrical generators operated by regional community utility companies. Schools are typically the largest electricity consumers in communities so mechanical equipment is usually designed to keep electrical consumption as low as possible. This includes variable speed pumps and variable speed fans, and utilizing controls to operate equipment only when needed. School cooking is typically done using electric appliances, since propane has limited availability and is generally more expensive to use.

### *Equipment Sizing*

Due to relatively small building size, older village school ventilation systems in the Southwest tend to be broken up into two zones: one zone for classrooms and administration areas, and another zone for the gymnasiums. The classroom and administration air handlers are generally constant volume with moderate ventilation loads. Newer and larger schools facilities built in the Southwest (such as Bethel) in the last 5-10 years have used VAV systems, but they are the exception.

Classroom and administration ventilation zones are typically scheduled to operate during normal school hours. Gymnasiums on the other hand are typically scheduled to operate during school hours plus week nights and sometimes all day Saturday. In many remote communities, the gymnasium serves as a community gathering space in addition to education and athletic programs. Potlucks, movies, funerals, festivals and commonly held in school gymnasiums as well as school sporting events. Therefore, ventilation rates for gymnasiums tend to fluctuate greatly and inconsistently from week to week. The gymnasium zone in older school facilities is commonly served by a constant volume air handler that operates on a basic schedule, and is provided with manual-override panels for timed operation during special uses.

With the cost of Variable Frequency Drive (VFD) technology coming down over the years, constant volume gym air handlers are now commonly operated with VFDs to adjust fan speed based on the occupancy load, which saves money on fan motor electricity. CO<sub>2</sub> detectors are also commonly used today to operate gymnasium air handler settings based on indoor air quality, minimizing the flow of outside air and reducing fan speed with low occupancy.

### *Construction Considerations*

Facilities in this region are typically built on pilings to hold them above the threat of seasonal flooding and unstable soils. As such, there is no below grade space under the school to route mechanical utilities. A protected underfloor assembly has to be constructed to route plumbing waste lines. This is done in a number of ways. One is a whole underfloor area space built large enough for piping to route through it with maintenance access. This is common when there are a number of plumbing fixtures distributed throughout the school. With consolidated plumbing groups, there is often just a lowered utilidor under a portion of the school. Either of these lowered floor designs requires additional heat in this space to protect the plumbing. Air leaks in the floor envelope are a problem and have devastating effects on the plumbing, even up into plumbing walls above the floor. The third common option is to use arctic pipe suspended below the building flooring structure. Although this pipe is well-insulated, it is still exposed to the cold weather and consequently is difficult to keep from freezing.

### *Plumbing Considerations*

Most communities in Southwest Alaska have public water systems that serve the schools; however, the quality and reliability of the source varies. In most cases, water is taken from the surface or relatively shallow wells, and it typically contains organics and iron. If the school is receiving water from the village utility, it is usually adequately treated. But if the water is taken from a source on site, it then requires a dedicated treatment process at the school. If the water is not adequately treated, plumbing piping and fixtures in the schools become fouled with mineral deposits.

Due to the small nature of many village water systems, many facilities receive relatively low water pressure, especially at the furthest points in the water distribution system, low-pressure fixtures are typically installed (such as tank toilets rather than flush valve) and/or water pressure boosters are installed at the water service entrance. Low water pressure also hinders fire protection systems, so most schools have dedicated fire sprinkler water storage tanks and fire pumps. Fire water storage tanks and their interconnecting utility lines require heating for much of the year to ensure the availability of water for fire protection when needed.

### *Operations and Maintenance*

School HVAC control systems vary greatly in the Southwest. Some districts and/or schools have well-trained personnel who understand more technical control systems, such as Direct Digital Control (DDC), while others are limited on skilled personnel and utilize electronic controls based on time clocks and manual on/off operation. O&M requirements of building equipment are some of the most significant factors in designing mechanical systems for remote schools.

### ***Climatic Region: Aleutians***

In general, mechanical systems for commercial buildings in the Aleutians are similar to the Southwest region due to similar energy resources, community sizes, and the availability of trained personnel.

### *Climate*

The climate in this region is characterized by temperatures similar to the Southeast in that they do not get very cold or warm. Smaller heating systems are designed due to mild winter temperatures, with more attention given to handling and avoiding rain entrainment into exposed mechanical systems. Outside air intakes are typically placed on the leeward side of buildings, or under building overhangs to avoid direct wind exposure. Air intake hoods are also sized to reduce intake velocity and given long vertical intakes to allow moisture to drop out. Sometimes interior baffles are used for this same purpose. Boiler stack outlets are located to deter rain from coming in by utilizing wind directional boiler caps. Sealing and flashing wall and roof penetrations are also very important due to wind-driven rain.



### *Available Energy Sources and Heating Systems*

With the exception of Kodiak, the primary energy source in this region is fuel oil for all remote villages. As in the Southwest, this leads to using boilers for heating hydronic systems. The hydronic systems tend to be baseboard fin-tube and hot water coils for ventilation air handlers. The City of Kodiak supplements its fuel oil systems with electricity produced by local wind turbines, which contribute to maintaining the city's reasonable electric rates.

### *Equipment Sizing*

Since villages in this region tend to be quite small, the school buildings tend to be small as well. Many of them have one air handler to serve the entire school ventilation needs, or sometimes two air handlers as in the Southwest. The City of Kodiak is the exception. It is a moderately sized city located adjacent to a large Coast Guard base, so it has a large population and large school facilities similar to the Southcentral region.

### *Construction Considerations*

Buildings in this region tend to be constructed on grade. This allows the plumbing under the ground floor to be protected from freezing, whether within a crawlspace or by a slab on grade.

### *Plumbing Considerations*

In village communities with school enrollments less than 50, fire sprinkler systems are not required. Of the schools large enough for a sprinkler system, they generally have a large water storage tank and a fire pump to operate the sprinkler system. In the City of Kodiak there is a substantial water utility system that is capable of providing water quantity and pressure sufficient for fire protection.

### *Operations and Maintenance*

School HVAC control systems vary greatly in the Aleutian region. Many schools utilize electronic controls based on time clocks and manual on/off operation. Some districts have centralized maintenance personnel that travel from village to village maintaining and fixing equipment, while on-site custodial staff provide basic system checks and general upkeep. The severe weather in the area may restrict travel of the maintenance staff for extended periods, so on-site personnel must be able to keep the facilities operating without technical support.

## ***Climatic Region: Interior***

### *Climate*

The Interior climatic region is characterized by extreme cold, which requires that outside air should be pre-heated before being mixed with return air at air handlers. Preheating helps to avoid condensing moisture in the return air when it is mixed at the air handler, and allows the air handler coil to be

smaller than it would be if sized for the full outside air load. The addition of the preheating coil requires two sets of filters: one set used prior to the preheat coil in the summer, and one set used in the air handler in the winter. This is an important distinction because summer air has many bugs, pollen, seeds, etc., which will foul the preheat coil, whereas a filter upstream of the preheat coil in the winter has the potential to ice over. As airside heat recovery systems have become more practical to install and operate, Interior schools have been implementing heat recovery systems to conserve and reduce building energy use.

#### *Available Energy Sources and Heating Systems*

The primary energy source in Interior Alaska is fuel oil. Fuel oil is transported to communities in the region primarily by truck. Remote Interior communities adjacent to river systems receive fuel oil shipments by barge because they are not connected to the state highway system. Commercial buildings are typically heated using cast iron boilers that supply heating water to fin-tube, unit heaters, and air handler coils. Boiler plant redundancy and improvements in fuel oil cast iron boiler efficiency are also similar. Boiler plants in the Interior tend to be larger than in other regions due to the long, cold winters.

Natural gas is also used in some areas of Fairbanks. It is transported by road or rail from Anchorage and stored in bulk tanks. At this time no Interior schools are heated using natural gas, though conversions of existing boilers to multi-fuel burn systems are underway in the Fairbanks area.

In a few locations, schools are using biomass for heating energy. Tok School, for example, is using wood chips as their heating fuel.

Schools are typically the largest electricity consumers in small rural communities, so mechanical equipment is usually designed to keep electrical consumption as low as possible. This includes variable speed pumps and variable speed fans, and utilizing controls to operate equipment only when needed. School related cooking is typically done using electric appliances, since it tends to be less expensive and more easily obtained than propane.

#### *Equipment Sizing*

Due to the Interior's cold climate, larger mechanical rooms are needed for heating plants, and larger spaces needed for air handlers with preheat coils and energy recovery systems. Mechanical spaces tend to take up a higher percentage of building footprint than in other climatic regions of the state. This becomes especially true for smaller schools in rural areas.

#### *Construction Considerations*

Schools in urban areas such as Fairbanks and North Pole are built as slab on grade construction, and as such the underfloor utilities are protected from the intense cold. In several rural areas, schools are built

on pilings to protect permafrost soils from the building's heat. As in the Southwest, it becomes more difficult to protect the utilities from freezing under the elevated building. Plumbing chases are often constructed where plumbing fixtures are raised above the floor to keep the p-traps out of the floor envelope. Even with a heated floor envelope, air leaks have often led to freezing of below-floor p-traps.

#### *Plumbing Considerations*

Similar to Southcentral, larger communities in the Interior, such as Fairbanks, have public water systems that are capable of providing potable and fire protection water service to commercial buildings while several smaller and remote communities draw water from on-site wells or from a local utility. Remote locations also tend to require bulk water storage and fire pumps for fire sprinkler protection. Rural facilities that do have local water service, typically have water service entrances with a recirculating system that circulates water between the school and the water main to help prevent freezing of the domestic and fire water supply of the school.

#### *Operations and Maintenance*

HVAC control systems vary greatly in the interior. Fairbanks has access to skilled technicians either in the school districts or available from within the local community. Schools in rural areas often rely on itinerant maintenance technicians for system upkeep and repairs.

### ***Climatic Region: Arctic***

#### *Climate*

The Arctic region is characterized by intense cold and windy conditions. The snow tends to be very dry, light, and grainy. Arctic schools have the additional challenge of keeping blowing snow out of the ventilation systems. The very fine snow can be entrained far into a ventilation system where it then melts inside the facility. Arctic Tee hoods and other ductwork configurations are necessary to resist the entry of blowing snow, and snow traps with drains are sometimes added to the ductwork to deal with snow melting inside a facility.

Ventilation systems in schools in the Arctic are similar to the Interior region due to the extreme cold, which requires that outside air should be preheated before being mixed with return air at the air handler. Preheating helps to avoid condensing moisture in the return air when it is mixed at the air handler, and allows the air handler coil to be smaller than it would be if sized for the full outside air load.

#### *Available Energy Sources and Heating Systems*

The primary energy source in the Arctic is fuel oil, which is transported to village communities by barge. Similar to other regions in Alaska with fuel oil systems, commercial buildings are typically heated using cast iron boilers that supply heating water to fintube, unit heaters, and duct mounted coils. Boiler plant

redundancy and improvements in fuel oil cast iron boiler efficiency are also similar. Boiler plants in the Arctic tend to be larger than in other regions in the state due to the long, cold winters.

Natural gas is used in Barrow for heating plants and electrical generation, since gas fields are developed in close proximity to the community.

Electricity in other Arctic communities is provided by diesel-fired electrical generators operated by local and regional utility companies, which generally results in high electricity costs. Schools are typically the largest electricity consumers in many Arctic communities, so mechanical equipment is usually designed to keep electrical consumption as low as possible. This includes variable speed pumps and variable speed fans, and utilizing controls to operate equipment only when needed. School related cooking is typically done using electric appliances since electricity tends to be less expensive and more easily obtained than propane.

#### *Equipment Sizing*

The Arctic region includes larger communities such as Barrow and Kotzebue, with schools that have somewhat larger and more sophisticated systems. Other schools in the region tend to be smaller, but of sufficient size that rudimentary digital control systems are often employed.

#### *Construction Considerations*

All schools in this region are built on pilings to protect the underlying permafrost soils. As such their utilities are exposed to the cold wind and freeze-ups are common despite the best efforts of contractors and maintenance personnel.

#### *Plumbing Considerations*

Arctic communities on the North Slope have public water systems that are capable of providing potable and fire protection water service to commercial buildings. Each village typically has a high volume pump in the public water circulation system that can handle commercial fire flows, so most of the village schools do not have fire pumps. Water service entrances in these communities usually have recirculating systems that circulate water between schools and the water main to help prevent freezing of the domestic and fire water supply.

Other villages in the Arctic region that are not connected to water utility systems tend to rely on water storage tanks and fire pumps for schools sprinkler systems. The water storage tanks and their interconnecting piping must be kept heated for most of the year to ensure that the water is available when needed.

### *Operations and Maintenance*

Control systems throughout schools in this region are similar, but they differ in complexity depending upon the size of the school. Heating and electrical system failures in this region require an immediate response to protect massive damage to facilities. Itinerant maintenance personnel are used to supplement on-site resources. Travel of maintenance personnel is complicated by blowing snow and surface fog, so local personnel must be able to deal with equipment failures quickly. Simple, robust systems are needed – even at the expense of energy efficiency – and redundant systems for heating and utility protection are often employed.

## **Viability of Component Prototyping - Mechanical Design**

### *Southeast*

This region would be a difficult area for which to provide mechanical prototype systems. Areas with access to hydroelectric power would tend to favor an electric-based heating system such as heat pumps. Areas without inexpensive power will tend to favor oil-fired boilers for heating. These are two very different heating schemes that are fuel source dependent. The two different schemes will also affect the electrical service entrance size and configuration.

### *Southcentral*

The schools in the urban areas of southcentral Alaska tend to be larger and have a greater array of mechanical systems available to them, with capable technicians to support those systems. This region is the only one that currently has significant access to natural gas, allowing for a greater variation of systems solutions. Since much of Southcentral has similar mechanical equipment requirements, prototype components could be considered across the region, though small school and large school concepts would need to be developed to work with the various size schools in the area.

### *Southwest*

Schools across this region have the potential to have similar mechanical concepts since they are mostly of similar size. Gymnasiums have the potential for the same mechanical system inclusive of a dedicated air handler with a variable speed fan. Due to the use of pilings, fuel oil, facility size, and student population, these schools will be different than the ones in the Southeast and Southcentral regions, and will require different mechanical systems to support them.

### *Aleutians*

Like most regions, the schools across this region are either small in rural areas or larger near more urban areas. Smaller schools could have similar mechanical systems, but they would be different than the systems in the larger schools. Rain resistant features used on the schools in this region are not typically used on other schools in Alaska.

### *Interior*

Schools in the Interior range from quite large in Fairbanks to very small out in the villages. Consequently, across this region it will be difficult to have one prototype system that works for all of them. Also, the systems needed to deal with the severe cold of this region are not needed by the facilities with more temperate areas such as the Southeast and Aleutians.

### *Arctic*

Schools across the Arctic tend to be similar to each other due to the extreme climate in the region; however, larger mechanical rooms, freeze protection, and blowing snow protections are special considerations that may not be necessary in more southern regions of Alaska.

## **Mechanical Component Prototyping Summary**

Due to the wide variability of requirements across climate regions, there is little opportunity to create prototypical mechanical systems across the state. The variance in climate, fuel sources, and building sizes does not reasonably allow a one-size-fits-all solution. The oil-fired mechanical equipment used in the Interior and Arctic regions is rather different from the gas-fired and electric equipment used in the Southcentral and Southeast regions.

That said, there may be some opportunity to reduce variability in mechanical systems within climate regions. For this to work, the buildings need to be of similar size and use the same fuel source. As an example, there are several regions which have a larger school in a more urban setting and a number of smaller schools in outlying rural settings. Within a given school district the smaller rural schools could be similar, but the larger urban school would have correspondingly larger, more sophisticated, systems. Schools generally consist of a classroom wing, a gymnasium, a multipurpose room usually used as the cafeteria, a kitchen, and sometimes a vocational/technical area. Each of these areas could have similar mechanical systems among schools. The closer the schools are configured to each other, the closer the mechanical systems could be to an actual prototype.

For instance, gymnasiums lend themselves to a single zone air handler that runs at variable volume depending upon the number of people in the gymnasium. Similarly, a group of classrooms could have a standard system, although the system would vary substantially depending upon how many classrooms are involved. Just a few classrooms favor a different mechanical system than a dozen or more classrooms.

Having this sort of standardization would assist the maintenance personnel for a given school district. The benefits would come from improved maintenance capability because personnel would not have to learn many types of systems. This should translate to reduced operational costs if systems are operating as intended.

## **ELECTRICAL ENGINEERING**

### **Analysis of Design Variables Affecting Electrical Design**

Electrical systems in Alaska are not affected nearly as much by their locations in the different climate regions of the state as they are by structural, architectural, and mechanical systems. Electrical systems are primarily driven in support of the design of the buildings they are installed in and the types of equipment being supported. Typical electrical systems for schools can be broken down into three primary categories: Power, Lighting, and Special Systems.

#### *Power*

Power systems for schools typically start with service entrance and metering equipment on the exterior of the building for connection to the local utilities. This portion is most affected by the geographical location of the school. The service will be either overhead or underground, depending on the type of utility preference, which varies from region to region. The type and rating of the gear will be dependent on the environment it is installed in. From the exterior service gear, the power will either go into the building to a Main Distribution Panel (MDP), or it will go to a transfer switch to allow a generator to provide backup power to the school. Again, whether a generator is provided for the school will vary from region to region and district to district depending on how reliable the power from the local utility is and if the school is designated as a disaster shelter for the community.

A generator is typically provided in a weatherproof enclosure and located outside of the building. If it is in the Arctic region, it will most likely have a walk-in arctic enclosure. In warmer climates, it may just have a weatherproof housing. Since air intake systems for generators will vary regionally, protection against wind-driven snow is an important consideration. Inside the building, the MDP will serve branch panel boards located throughout the school or in dedicated electrical rooms to provide power to all electrical circuits. The number of panels, size, and ratings will depend on the architectural layout of the school and the equipment it serves.

#### *Lighting*

Lighting systems for schools consist of interior lighting and exterior lighting, along with lighting control systems. Exterior lighting is primarily located near entrances, vehicle parking, and along ramps, pathways, and sidewalks. Light Emitting Diodes (LEDs) are typically used for all exterior lighting in Alaska due to their energy efficiency, highly controllable light source, and increased reliability and performance in cold weather. Lighting near coastal areas will have corrosion resistant housings, and lighting in extremely cold environments may require special drivers to start and operate in cold temperatures. Exterior lights are usually controlled with a photocell to turn the lights on at dusk and off at dawn. Interior lighting has historically been mostly fluorescent sources; however, LEDs are rapidly becoming a more viable alternative from a life cycle cost perspective.

The type and style of lights are unique from school to school since the ceiling types, room arrangements, and activities vary widely. Lighting controls are becoming more complex and moving toward automatic controls to minimize the amount of energy used (or wasted). Occupancy sensors, daylight sensors, and dimming, intelligent, or wireless control systems are rapidly being used throughout schools.

#### *Special Systems*

Special systems for schools consist of fire alarm systems, telecommunication systems (wired and wireless), intercom systems, master clock, gym or auditorium sound systems, security, and CCTV systems. These systems do not typically vary at all by weather or region; they vary by the school programming and architectural layouts.

### **Viability of Electrical Component Prototyping**

#### *Prototype Power Components*

A component prototype for power systems would not be a simple solution. For example, if electrical service equipment is selected as a component prototype, there would need to be three or four different prototypical scenarios for the outdoor service gear. In Southeast Alaska (near the coast), buildings would have NEMA 4 stainless gear designed for an underground feed from the Utility. In Northwest Alaska (near the coast), gear would be configured for overhead power distribution. In Interior Alaska, buildings have NEMA 3R gear that may require heater elements for metering due to the extreme cold.

In addition, the service size will change from school to school depending on the size of the school, the type of mechanical equipment, and the final load calculation performed by the Engineer of Record. Also, the generator type, size, and enclosure will depend on the geographical location of the school, the size of the school, and the equipment selected that it will supply.

One possibility for utilizing component prototypes for power systems would be to standardize particular gear or generator manufacturers so that the districts can minimize the amount of spare parts to keep on hand. The downside, however, would be the potential of increased initial cost of construction if specific items are sole sourced. Although this may bring a benefit for long-term operational costs, when equipment is sole sourced there is a very real risk of having the manufacturer raise their prices since they have no competition during bidding.

#### *Prototype Lighting Components*

Due to extremely rapid advancements in Solid State Lighting (LEDs), the technology is changing so fast that it would be difficult to utilize specific lighting fixtures as a component prototype. Per information from Acuity Lighting, which is one of the largest lighting manufacturers in the world, LED chips are being replaced with a more efficient version about every 6 months, and the light fixtures themselves are being



replaced with a more efficient version every 18-24 months. As a result, by the time a component light fixture is selected for a prototype plan, it is likely to be outdated and possibly unavailable before it would even be installed.

In addition, lighting fixtures are uniquely selected to coordinate with the ceiling types provided, mounting heights, or where selected to highlight or compliment architectural features of the building, so unless the ceilings or spaces are included with the component prototype, it may not be practical to have a single light fixture prototype since it may not be compatible with the site-specific school application.

The most viable method for utilizing component prototypes for lighting systems would be to either update the component prototype every 6 months to reflect the changes in technology, or specify the lighting component prototype in more general terms. This would be most practically done in the Ed Specs. For example, the Ed Spec would require that all luminaires shall be LED type, with a color temperature of 4000 degrees Kelvin, with a minimum efficiency of 80 Lumens per Watt, and a minimum L70 lamp life of 60,000 hours. This would give the project some baseline efficiencies for the lighting systems and provide long-term energy benefits of a high quality, energy efficient lighting design. This would help eliminate the possibility of a designer picking a stylish light fixture that may not be very energy efficient or have the long-term maintenance benefits that would be advantageous from a life cycle cost perspective.

#### *Prototype Special Systems*

Due to extremely rapid advancements in the technology of special systems such as fire alarms, telecommunication devices, A/V components, etc., the technology is changing so fast that it would be difficult to utilize specific systems or equipment as a component prototype. For example, computer network equipment or CCTV digital storage systems may become obsolete every 12-18 months. Typically, between the time this type of equipment is specified and when it gets approved and ordered by the contractor, the original equipment that was specified is no longer available or is not the latest technology.

One possibility for utilizing component prototypes for special systems would be to standardize a particular manufacturer so that the districts can minimize the specialized training required to operate these systems. The downside, however, would be the potential of increased initial cost of construction if specific items are sole sourced. Although this may bring the benefit of having the district maintenance staff be more familiar with a particular system, when equipment is sole sourced, there is a very real risk of having the manufacturer raise their prices since they have no competition during bidding.

## CHAPTER 6 – CONCLUSIONS

### FACILITY PROTOTYPING

The project team examined the benefits and disadvantages of prototypical school design and construction from national and local perspectives in order to gain insight into previous successes and failures in the development of statewide prototypical school design and construction programs. From this investigation, four common variables that predict the viability of prototypical school programs became apparent: growth, enrollment, homogeneity, and time.

The research demonstrates that the success of a prototype depends on population increases sufficient to merit the construction of multiples of the same school design within a short window of time. Homogeneity in programmatic needs and environmental surroundings is also crucial to constrain modifications of the design. When design changes exceed minor modifications, the owner cannot benefit from cost and time savings promised from prototypical strategies. Time is a factor and a variable that corresponds to the speed in which technology and educational program delivery models change. Of the variables noted in the research, the time factor is the most intangible and the least predictable. The less growth, enrollment, homogeneity, and time align favorably, the less likely a prototypical program will be of any advantage.

National research did not find any example or record of a statewide prototypical school program that was considered viable by the various states' Education Departments. Programs were determined to be too complicated and insufficiently economical to consider a continuance of the program. Statewide prototyping across the nation was found to be impractical as a result of the overwhelming diversities found within a state's geography, climate, community population, and educational programs. Even with sufficient growth in a population, diversity in place of homogeneity represents an obstacle prohibiting prototypical strategies.

Facility and component prototypes alike must share similar size, site, and environmental realities in order to be viable for multiple users. Given the extremes in diversities found in other states and the lack of prototype success as a result, Alaska's own set of unique diversities only increase the probability that a statewide prototype program for school design and construction would be unsuccessful.

In review of previous studies related to prototyping of schools in Alaska, conclusions similar to the national research results can be made about Alaska's potential for success. Due to substantial in-state diversities in physical characteristics, sociological make-up, and educational delivery models, it is unlikely a State-wide prototype program would be successful.

Additionally, it should be noted that in both the national and state-level research results, examples were found where individual school districts had experienced some measured success of using prototypical school models. In every case, growth, enrollment, homogeneity, and time were such that reasonable success could be predicted. Terms of success at the district level were measured through economic, educational, and social benefits. Economic success was realized in reduced short-term capital costs savings (both in design and construction) and in long-term O&M costs (achieved through standardization of facility components and the subsequent benefits received through O&M efficiencies). Educational success was demonstrated through the provision of additional classrooms to alleviate overcrowding in a timely manner. Social benefits were gained not only through cost savings and educational facility relief, but through the impartiality found in providing similar facilities.

Equipped with an understanding of what variables influence the success or failure of a prototyping program, the project team explored firsthand the benefits and challenges of prototype school design and construction in Alaska. The research performed examined existing schools, interviewed stakeholders around the state, investigated the many variables that influence design and construction decisions, and evaluated the findings. Information gained through the research enabled the project team to form a clear picture of the benefits and disadvantages of school prototyping in the state at this point in time, and to establish a resource of information for considering the merits of prototyping well into the future.

The benefits and disadvantages of statewide prototyping in Alaska are as follows:<sup>22</sup>

### **Benefits**

- At the district level only, there is potential for economic savings both in short term capital gains and in long-term operational and maintenance efficiencies when initial designs are well-thought-out, tested by construction, evaluated, and modified as may be necessary to minimize deficiencies.
- Growth in district student population can be efficiently and quickly accommodated through the design, development, and construction of prototype schools.
- Prototype schools promote districtwide uniformity or equity within the physical environment of the school facility itself.
- Prototype schools contribute to efficiencies in maintenance staff training and operational understanding of equipment and systems leading to greater energy efficiency.

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<sup>22</sup> All benefits are relative to district development. Statewide development is believed to be improbable and unlikely.

- There is no discernible or measurable difference in the delivery of education making it any more or less desirable than a non-prototypical school.

### **Disadvantages**

- Most districts are currently experiencing static or declining student enrollments. The need for new school construction related to increased student enrollments is thereby diminished.
- Most districts have significant diversity in geologic/soil conditions, topography, climate, community populations, and energy sources (conventional or alternative). Diversity adversely influences the utilization of prototype designs.
- Districts generally encourage community involvement in the school planning process and invite personalization of schools, which in turn can lead to programmatic changes. The greater the public voice and involvement in the design process, the greater the chance of introducing changes within the design will negate the use of a prototype.
- Differing educational programs for elementary, middle (junior high), high school, and K-12 schools, would require multiple prototypes solutions. (This does not preclude the value of prototyping for any one of the programs.)
- Districts with extreme diversity in design variables have the potential for creating inefficient over-designed schools.

## **COMPONENT PROTOTYPING**

Component prototyping is fundamentally challenged by the same factors as facility prototyping. Additionally, advances in technology are happening so quickly that components are often outdated, if not obsolete, by the time a construction project is completed. For example, LED technology is currently being updated in approximately six-month intervals. As such, reliance on a lighting fixture prototype is impractical for any length of time beyond construction or installation at one given point in time.

Major component systems have regionally-specific design requirements due to different climatic conditions and energy sources. School facility size is an additional variable challenging component prototypical design. School size determines appropriate system sizing and spatial requirements to house the system. Design efficiencies are lost through sizing modifications. Thus, it is unlikely that a statewide initiative for major component prototyping would realize significant cost savings.

However, component prototyping at the district level, and possibly at the regional level is likely viable. Interviews with district facility staff revealed that the use of standardized component systems coupled with energy saving technologies like Direct Digital Control, potentially have the greatest opportunity for

long-term cost savings. The utilization of standardized components could theoretically allow for associated standardized operations and maintenance (O&M) training programs, which could potentially provide additional efficiencies and cost savings. Optimized operational efficiencies can only be achieved by having a well-trained maintenance staff available to operate and maintain complex energy efficient "state of the art" mechanical systems.

In addition to providing for efficient system operation, maintaining an effective preventative maintenance program extends component life, reduces replacement cost, minimizes catastrophic system failure, and improves classroom environmental quality.

District participation in programs facilitating operational efficiency, viable O&M training, and component standardization would be beneficial to the long-term operations of new and existing schools, whether prototype or non-prototype. Many districts already emphasize the importance of maintaining and promoting efficiency programs for existing buildings with substantial savings being realized and reinvested in the educational infrastructure.

The benefits and disadvantages of component prototyping in Alaska are as follows:<sup>23</sup>

### **Benefits**

- Standards for highly effective component systems could theoretically produce long-term savings for districts through the use of energy efficient components and creating O&M efficiencies.
- Increased efficiency in O&M staff training could theoretically result in optimal equipment performance, improved energy efficiencies, and operational cost reductions.
- Increased potential for economic advantage through quantity purchasing agreements may be achievable. Also, potential conveniences and repair efficiencies may be afforded in parts warehousing and supply.
- Component prototyping is currently encouraged and desired by many districts across the state.
- Potential for information sharing with other districts may be initiated. Equipment recommendations and maintenance techniques can be shared if regional application is considered appropriate.

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<sup>23</sup> All benefits are relative to district development. Statewide development is believed to be improbable and unlikely.

## Disadvantages

- Component systems would need to be identified by associated environmental requirements (and constraints), modified for a diverse range of facility sizes, and require multiples of the same system to be designed and constructed within a short timeframe to realize any theoretical cost savings. The probability of aligning these three factors into an economical prototypical program is unlikely.
- The rapid pace of component innovation would require near constant monitoring of available products to select components with the best performance, efficiencies, and cost.
- With minimal growth currently projected for many district student enrollments, component prototype applications will most likely be related to retrofitting existing facilities in the foreseeable future. Replacement components must be compatible with existing systems in aging schools, potentially limiting any perceived effectiveness. Careful evaluation of existing systems across the district would be necessary prior to any decision to utilize a certain pre-selected system.
- Specific components have the potential to become proprietary and potentially reduce competition and increase cost through sole source procurements. (State regulations currently do not allow for sole source procurement; therefore, 4AAC31.080 would possibly need to be modified.)
- School facility size dictates appropriate component sizing. Various sized versions of the component prototype would need to be developed or modified for appropriate facility application.

## CONCLUSION SUMMARY

Across the nation, statewide facility prototyping was found to be impractical as a result of the overwhelming diversities found within a state's geography, climate, community population, and educational programs. Alaska's own set of unique diversities only increase the probability that a statewide prototype program for school design and construction would be unsuccessful. Substantial in-state diversities in physical and environmental characteristics, sociological make-up, district enrollment size, and educational delivery models make a successful statewide prototype program unlikely.

There is potential for measured success in using prototype school models at the individual district level. This study found examples of successful district level prototypical school programs particularly within elementary schools where similarities in program requirements, school facility and enrollment size were

sufficiently homogeneous and in combination with steady to rapid growth periods in attendance area student enrollment.

Success of a prototypical program is highly dependent on community growth with a correspondingly significant growth in student enrollment. With few exceptions, most school districts in Alaska are currently experiencing static or declining student enrollments. Until this trend changes, there seems to be little to no need to consider the implementation of a prototypical school design and construction program.

Component prototyping is fundamentally challenged by the same factors as facility prototyping. Diversity in climate, school facility size, soil conditions and energy sources play a significant role in the design, construction, and installation of facility equipment. Additionally, rapidly changing technology in the design and construction industry makes prototypical design particularly challenging.

Component prototyping at the district level and possibly the regional level demonstrates the greatest potential for viability. Successful standardization of components at the district level was found during the research around the state. In particular, component standardization in combination with standardized operations and maintenance training programs showed the greatest potential and opportunity for long term cost savings. Operational efficiencies achieved by well trained maintenance staff and the proper operation of complex “state of the art” mechanical systems is a key ingredient in a district’s potential to realize long term operational savings.

When diversity is minimized and student enrollment is such that multiple schools are needed over a relatively short period of time, prototypical design and construction have a reasonable opportunity to be viable. In every instance for prototypical design to realize its full potential, it is necessary to design, construct, evaluate, and modify prior to repeated replication of the prototype.

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