THE UNIVERSITY OF CALGARY

AN ENERGY MANAGEMENT PROGRAMME FOR GRANDE PRAIRIE PUBLIC SCHOOL DISTRICT

by

JAMES A. LOVE

A MASTER'S DEGREE PROJECT

SUBMITTED TO THE FACULTY OF ENVIRONMENTAL DESIGN

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The undersigned certify that they have read and recommend to the Faculty of Environmental Design for acceptance a Master's Degree Project entitled

AN ENERGY MANAGEMENT PROGRAMME FOR

GRANDE PRAIRIE PUBLIC SCHOOL DISTRICT

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ABSTRACT

AN ENERGY MANAGEMENT PROGRAMME FOR
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by James A. Love

Completed in partial fulfillment of the requirements
for the degree Master of Environmental Design.

Faculty of Environmental Design
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Development of an energy management programme for schools operated by Grande Prairie Public School District was undertaken under the auspices of Alberta Education. Emphasis was placed on energy conservation measures not requiring large capital investments.

Organizational, motivational, technical, and financial considerations were analyzed. Detailed analysis of past patterns of consumption was performed for the Grande Prairie schools. A comparative assessment was made of data on 1977 utility purchases by eighteen other Alberta school systems.

Substantial variations in annual energy consumption rates were found to exist among the schools located in Grande Prairie. The average consumption rate and the ranges of consumption rates for the Grande Prairie schools were similar to those for schools operated by the other Alberta school systems which were studied.

Daily monitoring of purchased energy consumption in the Grande Prairie schools was initiated during the 1977-78 winter. Additional information was obtained with special instrumentation.

Annual energy savings of 15 to 55 percent were found to be possible through reduction of demands placed on environmental control equipment. These savings could be realized without significantly affecting the teaching environment in any adverse manner. Major factors limiting the savings potential were the climatic conditions and the generally inadequate functional planning and design of the schools. Administrative, custodial, and maintenance staff were found to be the key personnel in implementing conservation measures.

These findings from the 1977-78 study period were used to formulate a pilot energy management programme to be implemented and evaluated during the 1978-79 school year.

ACKNOWLEDGEMENTS

The Grande Prairie Energy Management Project was funded by Alberta Education through a contract with Grande Prairie School District No. 2357 and a subcontract with the University of Calgary. The provincial steering committe for the project included representatives from Alberta Education (School Buildings Branch and Research and Planning), Alberta Energy and Natural Resources, and the Alberta Department of Public Works. I would like to thank these gentlemen for their cooperation in carrying out the research project.

The research work was undertaken by a team, and I would like to thank the individual members for their contributions. Dr William A. Ross, who also served on my Master's Degree Project committee, shared his enthusiasm for energy conservation and his interest in developing energy management techniques with me. Dr. Grant A. Ross taught me much about managing a research project, a facet of investigation which can be as crucial to success as competent problem solving. David Heeney spent long days developing computer programmes for data analysis and representation, and for report production. Franki Craig, Danie Rousseau, and Joan Stapleton carried out many of the laborious tasks required to accumulate basic information for the project in its early stages. Joan New acted as project secretary. Enid Sweetnam set new records for typing in producing the manuscript and Dorothy Lloyd provided assistance with graphics.

Alberta Power Limited and Northwestern Utilities Limited contributed information and measuring equipment needed to evaluate energy use.

The Calgary and Edmonton Public School Boards were helpful in furnishing information on aspects of their research into physical upgrading of schools and into design of new schools in order to improve the energy efficiency of the stock of schools in Alberta.

Prof. James Waugh is to be thanked for overseeing the elevation of the original research report to a document worthy to be called a Master's Degree Project. Dr. Glyn Roberts, Department of Educational Administration, contributed to my understanding of both the management aspects of the project when the research was underway and of the substantive problems of management themselves.

Above all, I would like to thank all the people employed by or otherwise associated with Grande Prairie School District No. 2357 for their patience amd helpfulness during the first year of the project. Mr. Derek Taylor, Superintendent of the District, was invaluable in acting as a liaison between the Steering Committee, the Grande Prairie Public School Trustees, and School District Employees. The other people who contributed to the project are too numerous to mention individually but they are remembered.

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INTRODUCTION

Due to changing resource values during this decade, components of energy supply and demand in Canada are being subjected to conscious scrutiny; reducing growth in consumption of petroleum and natural gas has become a national objective (EMR,1976) (a list of abbreviations is included on page 215). Fuels derived from these two resources presently satisfy most of our annual energy demand, but readily accessible deposits of petroleum and natural gas are rapidly being exhausted.

Operation of buildings accounts for more than one quarter of fossil fuel use, making the architectural environment a major consideration in planning for conservation. Theoretical and empirical studies indicate that improved building operation practices can produce 15 to 35 percent reductions in annual energy requirements of individual buildings (Dubin, 1976). Such conservation measures are advantageous because they involve negligible capital expenditures and can produce immediate benefits. They, together with other measures for effecting improved energy performance, are among the techniques used in energy management. The Grande Prairie Energy Management Project was commissioned to explore the potential of energy management as an approach to energy conservation in Alberta schools.

The study originated with a decision by Alberta Education to fund a pilot energy conservation programme in Grande Prairie School District No. 2357. The sponsor specified that measures which would not require major capital expenditures were to be the focus of the local effort, and that a research report should be produced making the findings of the Grande Prairie study available to other agencies and administrative bodies. The Board of District No. 2357 subcontracted the research work to a group at the Faculty of Environmental Design, University of Calgary.

The goal of the project was, as stated in the research proposal, "to develop an energy management programme which will minimize energy consumption in the Grande Prairie School District facilities, while maintaining an environment conducive to the teaching process". The project team was to:

(i) Assess energy use in the Grande Prairie School District facilities.

(ii) Develop a management programme aimed at improving energy performance in the Grande Prairie School District facilities.

(iii) Implement, monitor and evaluate specific measures for improving energy performance in various buildings in Grande Prairie School District.

(iv) Use the information gathered during the project to estimate savings attainable in buildings such as the ones under study.

(v) Integrate the results of this study with those underway elsewhere in Alberta concerning school building design and retrofit.

(vi) Prepare a report on the project for distribution to Alberta school districts and other agencies.

A two year time span was allotted for completion of the project. The research contract was approved by the University of Calgary in 1977.09. This interim report details findings from the first ten months of research. During these initial ten months, detailed measurement and evaluation of energy utilization in Grande Prairie Public School District has been accomplished, and conservation techniques have been tested. This effort has laid the groundwork for full implementation of an energy management programme in the school district during the second year of the project.

1. STATEMENT OF THE PROBLEM

The subject of this research study is the development of energy management techniques for schools. Energy conservation may be viewed from several different perspectives - those of the local school district and the nation as a whole being two of the possibilities. Problems facing Grande Prairie Public School District are discussed below, together with the results of a preliminary "energy audit" of the local buildings. The impact of schools on aggregate Canadian energy consumption is then briefly analyzed. Some of the benefits to be realized through a research study of energy management for schools are reviewed. Finally, the physical organization of the report is outlined.

1.1 The Problem from the Grande Prairie Perspective

An expenditure of less than $200 000 for utilities might appear relatively minor in a total budget of $6 000 000, the amount disbursed annually by Grande Prairie School District. However, unlike business enterprises, a school district cannot simply write utility costs off as tax deductible expenses. Since district budgets are based on fixed grants, utility expenditures compete with other district interests for revenue. Savings in utility expenditures are therefore much more significant to a school district than cursory examination might reveal.

Results of a survey, undertaken by the Grande Prairie Public School District administration and compiled in Table 1.1, revealed that Grande Prairie faces higher energy costs than most other Alberta school systems. While Grande Prairie spent $55 000 on electrical services in

Table 1.1. Comparative utility costs for selected locations in Alberta.

	Cost	
	Electricity	Natural Gas
Consumption	72 GJ (20 000 kWh)	275 GJ (269 MCF)
Grande Prairie	$688.01	$164.88
Edmonton	$426.65 *	$115.13
Calgary	$510.60	$118.45
Medicine Hat	$224.00	$77.59
"International"	-	$600.00 **

* Based on 150 kVA of demand

** Based on international commodity equivalent-priced natural gas at the 1976 world price for oil (Source: W.A. Ross)

(This study was based on electricity and natural gas consumption as indicated by the 1975.02 utility invoices for Parkside School)

Source: Grande Prairie School District No.2357

1973, by 1976 this item had risen to more than $110 000. If the $55 000 increase were available for other purposes it could hire needed maintenance staff, purchase educational supplies, fund special programmes, and secure other benefits. More disconcerting to the Grande Prairie administration is the converse implication of continuing inflation - continued erosion of the spending power of the school district. It was the spectre of these economic tradeoffs which spurred Grande Prairie School District No. 2357 to seek a means of cost control for utilities. The District administration's concern is therefore more aptly described as "dollar conservation" than energy conservation per se.

1.2 Description of the Project Locale

Energy may be counted among the precious commodities in Grande Prairie. This city of 17 000 lies north of the 55th parallel in Alberta's Peace River District (see Figure 1.1), and is subjected to severe extremes of cold. The mean annual temperature of 1.4 degrees Celsius (DOT, 1975) serves as a reminder that local weather remains cool throughout the year compared with other North American regions (see Table 1.2).

As an organization dedicated to elementary and secondary education, the Grande Prairie public school system is typical of Alberta school systems in its basic goals and operation. School planning discloses roots in the neighbourhood unit concept - one elementary school may be found in each of the four quadrants of the city (see Figure 1.2). The three buildings used for instruction at the junior high school level are grouped around the Administration and Maintenance building near the centre of town. An academic and vocational high school lies at the northwestern perimeter. These buildings are used by 200 teachers and 3350 students. A noninstructional staff of 80 deals with general administration of the school district and maintenance of physical plant.

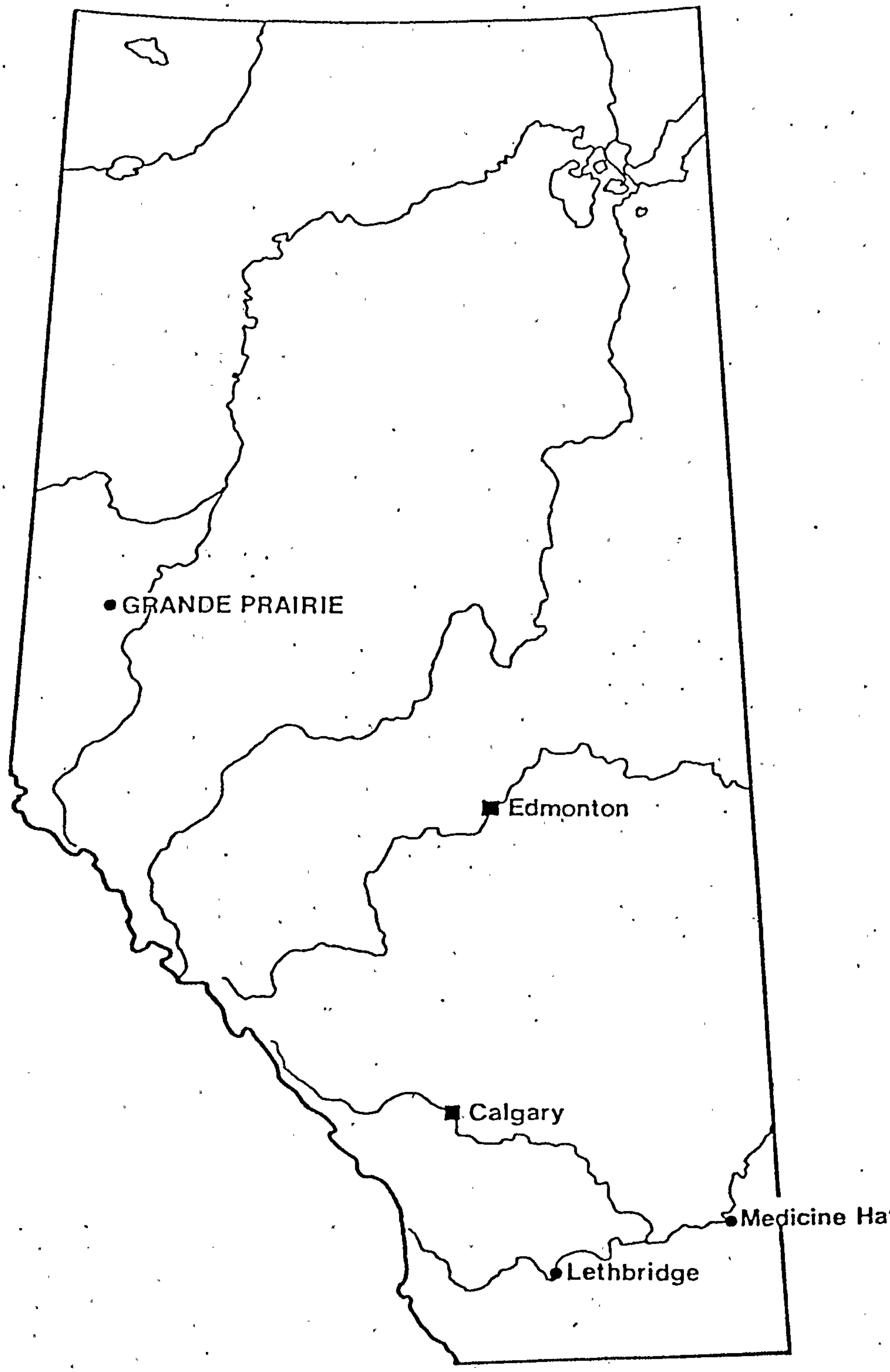


Figure 1.1 Map of Alberta.

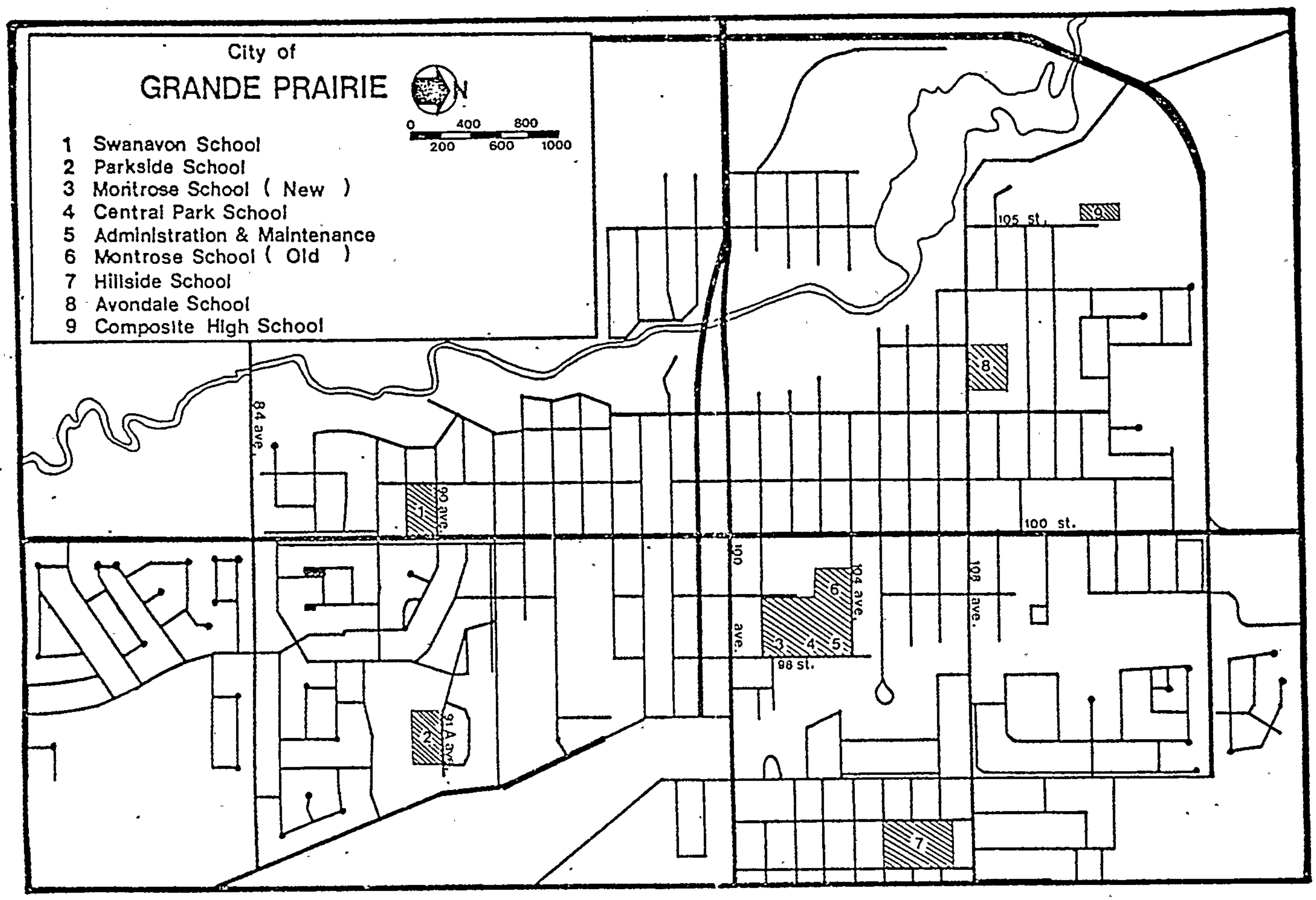


Figure 1.2 Map of Grande Prairie, Alberta.

Table 1.2. Climatic information for selected North American sites.

Location	2.5% Design Temperature (degrees Celsius) January	July	Mean Daily Temperature (degrees Celsius)	Average Celsius Degree-Days
Grande Prairie	-38.3	27.2	1.5	6107
Edmonton	-32.2	28.3	2.7	5723
Calgary	-31.6	29.4	3.9	5279
Lethbridge	-31.1	31.1	4.8	4802
Medicine Hat	-32.2	33.9	4.5	4918
Ottawa	-25.0	30.6	5.3	4846
Washington D.C.	-7.2	33.3	12.2	2667

1.3 Energy Mini Audit

In the spring of 1977 a two day inspection of school district facilities was undertaken by J.A. Love, the present project coordinator. It was immediately evident that a minimized first cost approach coupled with design planning based on pre-1973 oil prices had resulted in the construction of buildings not only unsuited to local conditions, but also exhibiting characteristics inimical to human comfort, efficient energy use, and general durability.

Walls were typically uninsulated. Cracked expanses of concrete block and split roof membranes were evidence of unstable foundation conditions. Buried fibreboard ductwork had collapsed, increasing loads on fan motors and constraining the supply of warm air to some of the schoolrooms. Strips of light around door frames revealed apertures through which infiltration could occur.

Demands placed on the building environmental control systems appeared to be excessive. Thermostats were found at settings as high as 27 degrees Celsius. Spaces well illuminated by daylight were simultaneously flooded with light from flourescent fixtures. In some cases illumination provided for corridors exceeded that provided for classrooms. Vacant rooms were found to be fully illuminated. No specific set of building operating procedures was in effect. These observations suggested that some savings could be effected at minimal capital cost, although a thorough conservation effort might require investments in upgrading of structures.

Table 1.3. 1976 energy consumption rates of Grande Prairie School District No.2357 buildings (based on utility company records).

Building	First Year of Operation	Area (m^2)	Consumption (W/m^2) Natural Gas	Electricity	Total
Avondale Elementary	1956	2 781	42.0	5.3	47.3
Hillside Elementary	1959	3 506	42.4	7.3	49.7
Parkside Elementary	1973	2 511	37.7	9.8	47.5
Swanavon Elementary	1957	2 334	60.1	8.6	68.7
Old Montrose Junior High	1950	4 083	52.8	3.4	56.2
New Montrose Junior High	1961	5 617	49.5	4.1	53.6
Composite High	1962	14 694	44.8	12.1	56.9
Administration and Maintenance	1961	1 158	51.3	5.6	56.9
Central Park Auxiliary Building	1929	874	67.1	1.0	68.1

Table 1.4. 1976 expenditures for energy for Grande Prairie School District No.2357 buildings (based on utility company records).

Building	Cost ($/m^2) Natural Gas	Electricity	Total
Avondale Elementary	1.16	2.34	3.50
Hillside Elementary	1.29	3.18	4.47
Parkside Elementary	1.13	4.37	5.50
Swanavon Elementary	1.76	3.90	5.66
Old Montrose Junior High	1.50	1.64	3.14
New Montrose Junior High	1.27	2.08	3.35
Composite High	1.22	3.53	4.75
Administration and Maintenance	1.52	2.67	4.19
Central Park Auxiliary Building	2.10	0.65	2.75

Administrative staff assembled further information needed to assess energy use in district buildings. Utility billing records were retrieved for each month of 1976, and calculations of energy consumption rates and cost were performed (see Tables 1.3 and 1.4). Since utility records are subject to occasional errors and are sometimes based on estimates the tabulated results contained some minor inaccuracies. However they were drawn from the only available source of information on consumption of purchased energy. Requirements for natural gas were found to range from 49.1 to 82.7 W/m^2, almost a two fold variation. Even more pronounced was the range in electricity consumption rates - from 1.0 to 12.1 W/m^2. Assessment of these figures and variations reinforced the conclusion drawn from the inspection that energy savings were feasible.

Table 1.5. Summary figures on 1976 energy consumption and expenditures in Grande Prairie School District No. 2357 (based on utility company records).

	Natural Gas	Electricity	Total Purchased
Total Consumption	50 600 GJ (539 000 Th)	9 600 GJ (2 690 000 kWh)	60 200 GJ
Average Consumption Rate (W/m^2)	48.4	8.2	56.6
Total Expenditure	$49 400	$111 600	$161 000
Average Expenditure ($\$/m^2$)	1.33	3.00	4.33
Average Unit Cost	0.87 $/GJ (0.0916 $/Th)	11.62 $/GJ (0.0414 $/kWh)	2.67 $/GJ

Notes:

1/ In 1976 Grande Prairie experienced 5557 Celsius degree-days of heating compared with the annual average of 6173.

2/ Total area of Grande Prairie Public School District buildings is 37 558 square metres.

3/ The utilization factor for school district facilities in 1976 was 87 percent (this is a measure of the students in attendance compared relative to the system capacity.

The average unit cost of electrical energy was found to be thirteen times the figure for natural gas (see Table 1.5). Inefficiencies of the thermal electric generation process, more substantial capital costs for the electrical network and government pricing policies are the major factors leading to a higher average unit cost for electricity. The difference was significant because it was a reminder of the dichotomy between energy and dollar conservation.

Determining the extent of savings which could be realized in practice was not possible. No information was available on energy utilization of schools in Alberta. The particular fuels used, energy prices paid, and weather experienced in Grande Prairie were among the factors which could make comparison with other North American locations misleading. One study (Lentz, 1976) hypothesized that a prototypical school meeting 1975 standards and located in the north central area of the United States would require 55 W/m^2 at 5000 Celsius degree days of heating. This compares with the Grande Prairie average of 56.6 W/m^2 at 5557 Celsius degree days in 1976, suggesting that the Grande Prairie system was not extremely inefficient on the whole. A study of commercial buildings in Calgary yielded an average specific energy need of 68 W/m^2 in buildings using energy primarily for environmental control (EVDS, 1978), although the diversity of occupancies constituting the sample precludes a rigorous comparative evaluation. Based on the inspection and subsequent analysis, a reduction equivalent to between 10 and 15 percent of 1976 utility expenditures (about $20 000) was estimated to be feasible through improved management of operations and facility use.

1.4 The Problem from the National/Provincial Perspective

Present scenarios regarding supply and demand of purchased energy show Canadian demand outstripping domestic supply in the late 1970's. The cause is not only resource depletion, but also projected increases in rates of energy consumption. Yet, for political and economic reasons, "The overall objective of the National Energy Strategy which the Government of Canada has adopted is energy self-reliance". Nine policy elements comprise this strategy. They are directed at reducing demand for nonrenewable fuels, increasing proven reserves of nonrenewable fuels, substitution of more abundant resources for less abundant resources, and increasing flexibility in resource use (EMR, 1976).

Increasing prices for petroleum and natural gas is an important lever in moving Canadian society toward these goals. It makes energy conservation a particularly attractive proposition from a financial viewpoint. Although the specific target of the programme is to reduce the average rate of growth in energy consumption to less than 3.5 percent per year, some authorities assert that zero growth in energy consumption is both reasonable and desirable (Brooks, 1976a). Advocates of the latter scheme claim benefits in direct retail costs to consumers, in reduced investment costs for energy resource development, in improving the balance of payments, and in reducing negative environmental consequences of nonrenewable energy use. They also point to international inequities in resource use and to possible effects of continued growth on the quality of life in Canada. In either case, energy conservation is essential to prolonging the lifetime of more accessible nonrenewable resources; somehow Canadians must learn to live with more expensive petroleum and natural gas. Rational self interest would dictate pursuing conservation until the return became less attractive than alternative investments; zero growth advocates argue that we must move beyond what they call "economic efficiency" to a "conserver society" ethic.

Energy consumption per student in Grande Prairie amounted to 17.2 GJ in 1976; given 5 000 000 school age children in Canada, a very rough estimate of 86 billion GJ is obtained for all schools in the country. This compares with 1300 billion GJ currently used for residential space heating (CMHC, 1976) and 11 000 billion GJ for all sectors (Brooks, 1976b). Clearly energy conservation in schools can be but a small part of the solution to the nation's difficulties. On the other hand, a 10 percent permanent reduction by schools would be equivalent to a month's production each year (9 billion GJ) from the Great Canadian Oil Sands plant in northern Alberta. It is also part of the character of energy use and energy conservation that real change will have to be a result of millions of small decisions made daily by individuals; widespread attitudinal change is a prerequisite to major changes in patterns of consumption. No single grand action can suffice and no particular effort can be insignificant.

1.5 The Relevance of the Grande Prairie Project

Guidelines for reducing energy consumption abound in periodicals, manuals, and fact sheets. These documents tell what steps to take but they do not commonly discuss how recommendations are to be carried out, what obstacles may be encountered, or how regulation of building operation is to be optimized. They tend to neglect the problem of ensuring long term continuation of improved performance. Some analyses of cost effectiveness exclude important considerations, as will be demonstrated in a subsequent chapter. Many questions pertaining to conservation efforts are left unanswered; reliable answers become particularly important in formulating a specific energy management programme for a school district.

Information and knowledge are two keys to success in planning (as well as in implementation). Through research the team sought information and knowledge necessary to effectively plan for energy conservation in Alberta schools. Although savings in Grande Prairie were of first priority, also desirable was the evolution of an approach which could produce savings for these other administrative units as well. To construct and assess such an approach several areas of investigation were defined. The amount to be learned testifies to the relevance of the Grande Prairie project.

1.5.1 Technical Considerations

Although described as an organizational approach to conservation, energy management necessarily incorporates technical elements. The building is a physical entity made functional by machinery and other equipment which consume energy. Specifying conditions for human physiological comfort is a scientific exercise as evidenced by publications like the ASHRAE Handbook (ASHRAE, 1977). Before recommending any conservation measure a sound understanding of its physical consequences must first be developed, and this too is a technical matter.

The determinants of building energy performance were necessarily among the first items to be investigated. Until recently the dynamics of building performance have been largely ignored. Design choices were intended to satisfy requirements for human comfort during worst case weather conditions as defined by static analysis. To establish the causes of particular consumption rates a more sophisticated model, incorporating dynamic effects, must be formulated. Due to project constraints elaborate modelling was not feasible, but efforts were made to obtain some useful empirical data and to develop a basic understanding of dynamic performance. By making a quantitative assessment of dynamic performance opportunities for conservation could be better identified.

Implementation and evaluation of conservation measures involved many technical questions, some of which only became evident during the course of the research. Suffice it to say that these technical questions did not appear in any available case studies on conservation.

1.5.2 Facility Use Considerations

This category includes factors affecting energy demand patterns in the building - what demands are placed on the physical plant, the impact of these demands, and whether these demands are amenable to modification. One exemplary constraint placed on energy management became evident during the initial mini audit. Many thermostats were enclosed in protective metal casings as protection from physical abuse; some unprotected thermostats were badly damaged. Such conditions would impede the use of measures such as reducing interior temperatures during off hours.

The mention of off hours introduces another major item to be studied - the scheduling of facilities through the week and the calendar year, since this affects the application of conservation measures.

Demands placed on equipment by building users during hours of occupancy affect levels of consumption - thermostat settings, the switching of lights, operation of exhaust hoods, and so on. Somehow a quantitative assessment of these items had to be made.

1.5.3 Financial Considerations

The disproportionate charges for energy in different guises have already been mentioned. However the tale is further convoluted by the structuring of prices which varies with the form of energy consumed, and even with the appetite of the consumer. No effort to reduce energy use could be responsibly conducted without some attention to the financial consequences, since these are bound to be a client's major concern.

1.5.4 Organizational Considerations

Since energy management is an organizational approach to conservation, the organization owning and maintaining the facilities in question had to be analyzed. This was to provide information on existing regulation of energy use, and on new management functions which might become necessary. As education is the primary purpose of the school district, some understanding of how this purpose is served was necessary to place energy management in proper perspective with respect to other ongoing activities. It also appeared to be worthwhile determining which functions would be within the capacity of the school district to perform, and which would require some additional assistance or expertise.

To be successful energy management must become a "grooming" function, one which is performed with meticulous regularity year after year. It was necessary to develop a framework which would ensure such longevity.

1.5.5 Educational Considerations

Apart from studying the causes of existing consumption patterns and the potential for change, processes for effecting change had to be researched. Adaptation to a new state of organizational capability would require education of both the organization and the individual within it. Educating the organization means changing functions (such as those defined by job descriptions) so that adherence to the energy management programme would be fairly independent of particular personalities. This concept had to be cultivated. Of course the individual could not be neglected, necessitating an exploration of attitudinal change.

1.5.6 Acquisition of Supplementary Information

It was intuited that some problems and opportunities in managing energy utilization in school systems might become evident only in the course of research and development.

One immediately identifiable unknown at the initiation of the project was the level of energy requirements in school systems other than Grande Prairie Public School District. This information was needed to formulate a savings estimate for school buildings, one of the project objectives.

1.6 Report Format

All of the forgoing considerations will be addressed in this report, which proceeds from more theoretical and more general subjects to topics and results more directly related to the specific problem of implementing an energy management programme in Grande Prairie Public School District.

Chapter 2 describes how the project work was executed. Chapter 3 examines the concepts of energy conservation and energy management as they apply to school systems. Chapter 4 explains the techniques and problems of evaluating the efficiency of energy use in school buildings. Chapter 5 deals with the organization of the primary and secondary educational system in Alberta, particularly as it affects or has the potential for affecting energy management in schools. Results of a survey of energy expenditures and consumption by selected Alberta school systems are also discussed. Chapter 6 discusses two alternatives to improved operation - new design and retrofit. Chapter 7 details and analyzes past patterns of energy consumption of the Grande Prairie buildings which were studied. Chapters 8 and 9 deal with the technical and financial aspects of implementing energy management in Grande Prairie Public School District. Results from the "energy use inventory" of the Grande Prairie facilities are presented in Chapter 10. Chapter 11 discusses the implementation of conservation measures in the Grande Prairie buildings. Chapter 12 summarizes results of the energy consumption monitoring programme which was conducted simultaneously with the implementation of conservation measures. Chapter 13 discusses observations and conclusions from the first year of work. Finally, Chapter 14 presents recommendations for the second year of activity in Grande Prairie.

2. THE PROJECT PLAN

Six objectives were set for the project. Section 1.5 discussed knowledge which might usefully be acquired in achieving these objectives. A project plan was devised as a basis for agreement with the sponsors on how the research group would proceed. The following elements were specified:

- (i) liaison
- (ii) literature search
- (iii) involvement of user groups
- (iv) monitoring
- (v) inventorying
- (vi) energy management program development, implementation, and evaluation.

These elements had a common thread - all were to produce information either to guide the research effort or to enrich the energy management program. The exploitation of several information sources facilitated corroboration and elaboration of conclusions drawn from any single source.

2.1 Liaison

Liaison was to ensure that as work progressed on the Grande Prairie project it would continue to meet the expectations of both the contractor (Alberta Education) and the subcontractor (Grande Prairie School District). Although the contract agreement specified general directions for the project, these had to be continuously refined as information was gathered and concepts were developed. Ongoing critical review of this process by representatives of the project sponsors improved the likelihood of their receiving a satisfactory product. It also allowed the research team to capitalize on the special expertise of these representatives. The provincial steering committee for the project included officials from two branches of Alberta Education (School Buildings, and Planning and Research), from Alberta Energy and Natural Resources, and from Alberta Housing and Public Works.

Liaison ensured that efforts in Grande Prairie were coordinated with building design and "retrofit" (physical upgrading) studies simultaneously being funded by Alberta Education. Direct links were also established with the Edmonton and Calgary groups responsible for these projects.

Local liaison was maintained through Mr. D. Taylor, Superintendent of the District, and his associates. Since the greatest frequency and intensity of experimental and data collection activity occurred at this level, frequent communication was essential.

2.2 Literature Search

Energy conservation in schools and other buildings has been the subject of numerous case studies, theoretical analyses, and experimental programmes. Accounts of such work were an inexpensive and helpful guide to research and development. Material from diverse but pertinent fields of endeavour contributed to refinement of the energy management concept.

Information obtained from the literature search had to be refined as field work progressed since discussions of conservation often lack specificity regarding technical, motivational, and/or organizational considerations. Major considerations are sometimes overlooked. Problems of implementation, evaluation, and ongoing management are frequently neglected. Seldom is special consideration given to climatic conditions encountered in Canada. These important questions had to be resolved to develop a practical energy management programme.

2.3 User Involvement

Involvement of user groups reflected a major concern of the project. It was desired to investigate the potential for changing school building performance by changing conduct and behaviour of the users themselves. To approach this rationally, it was necessary, as part of the research, to determine the actual impact of users on consumption.

Through user participation in planning and executing conservation strategies, their understanding of the problem and commitment to a concrete response were sought. Because of their familiarity with the school system and local conditions, users were also able to provide a wealth of information germane to the project.

Six user groups were identified:

(i) students

(ii) teachers

(iii) community groups

(iv) administrators

(v) custodial staff

(vi) maintenance staff

Each one of these groups has a distinct set of characteristics. Each one has a different relationship to other user groups and to physical plant operation. The first four use the building as a stage for activity, while the latter two are charged with ensuring that facilities remain physically functional.

The goal of the project has been to minimize energy consumption, but also to maintain an environment conducive to the teaching/learning experience; this may be interpreted to mean an environment acceptable to the occupants. Rather than simply imposing change by directive, the research team sought to work cooperatively with the user groups in achieving the goal. Apart from winning acceptance of the conservation programme, this encouraged user contributions. These people provided information essential to assessment of building performance, being familiar with operating histories, environmental weaknesses, and architectural details of facilities which they occupy or service. They also participated in the implementation of conservation measures and in the collection of data. They gave the research team feedback on conservation measures, and made suggestions about possibilities for energy savings. The assistance rendered by users significantly benefitted the research effort.

The one user group (if it can be referred to as a group) not directly contacted was the collection of community groups ranging from Brownies to bingo clubs. Because of the diversity and number of these groups, time requirements for their involvement would have been excessive; each group also spends very limited amounts of time in a building.

2.4 Monitoring and Inventorying

Monitoring and inventorying were unobtrusive measures (Webb, 1966) employed to provide further information for the assessment of energy use. "Monitoring" designates measures involving repeated observations, while "inventorying" designates measures involving observations at a single point in time. Monitoring was useful in observing factors which undergo significant change over time, while inventorying was useful in observing relatively constant factors.

Many factors influence energy consumption rates - weather, building use patterns, building characteristics, and plant operation. Some determination had to be made of the relative impact of each of these factors on building performance. Particularly important to elucidate was the relative impact of each user group on energy consumption rates. Monitoring and inventorying supplied much of the data needed to answer these questions.

2.4.1 Monitoring

Monitoring activities included sampling of energy consumption rates, accumulation of weather data, and observation of demands placed on building equipment.

Quantitative data on energy consumption furnish the most direct measure for evaluation of building performance. Records of consumption can be used to assess changes in performance over time and to compare relative efficiencies of several buildings. Such records can be employed in analyzing the factors shaping performance. Four sources of information were available:

(i) records maintained by the utility companies for billing purposes.

(ii) records of meter readings performed at regular intervals by custodians.

(iii) records produced by automatic devices installed by the utility companies.

(iv) records produced through time lapse photography of meter dials by research team members.

Table 2.1 summarizes qualities of each of these techniques; a couple of general observations are worth noting:

(i) By using a diversity of measurement techniques, limitations of individual techniques were somewhat offset.

(ii) The metering devices must fulfill legal requirements for accuracy; error attributable to the meters themselves is negligible.

Table 2.1. Summary of advantages and disadvantages of different data collection techniques for monitoring building energy consumption.

Information Source	Advantages	Disadvantages
Utility Records	-records are available on a "monthly" basis -records must be accurate on an annual basis -the dates at which readings are made are recorded -estimated readings are marked as such	-the "monthly" interval may vary from 2 to 6 weeks -different buildings are not read at the same intervals -errors in meter readings are not uncommon -estimates are frequently substituted for actual readings
Meter Readings	-recording can occur at 24 hour intervals -all buildings can be read at the same interval	-sampling occurs only 5 days per week -the time of day at which the reading occurs varies errors in readings are not uncommon -the information was available only after the project started
Automatic Demand Recorder	-recording can occur at 15 minute intervals -the intervals are fixed -the data acquisition times are known	-equipment is available on on a limited basis -the information was available only after the project began -the tolerance of readings is limited by the available recording equipment
Time Lapse Photography of Meter Face	-recording can occur at intervals of a few minutes -the interval is known -the data acquisition times are known	-equipment is available on a limited basis -the equipment requires skilled handling at 2 to 3 day intervals -the equipment is highly vulnerable to damage

No records are maintained on consumption rates of individual building systems (lighting, space heating, water heating, etc.); natural gas and electricity are metered at the building boundary only. It was usually necessary to estimate consumption rates for these individual systems due to the resources needed (manpower, equipment, and financial) for direct measurement.

Reasonably accurate estimates of relative impact on building consumption rates could be made for most electrical equipment, given precise information on installed capacities and overall hourly patterns of consumption for a building. Estimates were not so easily formulated for natural gas consuming systems. For instance, energy requirements for hot water heating are a function of many factors which cannot be directly observed (demand for hot water, leakage, and system running losses). Where feasible, an effort was mounted to directly measure such system requirements.

Grande Prairie has a well equipped meteorological station at the airport, so available records for the local area were very precise. However microclimatic variations between the airport (4 kilometres west of the city) and school sites were a possibility. A recording thermograph was successfully operated at one school site to provide data for testing this possibility, but measurement of temperature, wind, and other factors at every school site was not feasible. Since the meteorological station is a relatively minor one, basic solar data are not collected.

More difficult to monitor was the pattern of demands placed on building systems (light switching, thermostat setting, etc.) by users. Casual observations were made whenever the research team was working on site, and some structured surveys were carried out. This was adequate to draw some basic conclusions about user behaviour patterns, and was supplemented by comments from different user groups.

2.4.2 Inventorying

As mentioned above, data gathered through inventorying supplemented that obtained through monitoring. Members of the research team procured information on:

(i) energy consuming equipment including heating, lighting, and auxiliary systems

(ii) school building enclosure systems (walls, windows, roofs, etc.)

(iii) equipment operation schedules

(iv) plant maintenance schedules

(v) facility use schedules

While recording this information was usually straightforward, elucidating its implications vis a vis performance was sometimes very difficult. The many possible combinations and permutations of factors affecting consumption aggravated this problem.

2.5 Energy Management Programme Development Implementation and Evaluation

"Programme development, implementation, and evaluation" designates the overall process of refining the concept of energy management for school systems - the sequence of problem statement, problem analysis, problem response applied repeatedly and at many levels of complexity as the technical, facility use, financial, organizational, and educational facets of energy management were probed.

This process involved experimentation with conservation measures. It involved technical evaluation using information from monitoring and inventorying. It involved systems analysis of the organizational environment to identify obstacles constricting rigorous regulation of energy use. It involved calculations of the financial consequences of different decisions and experiments. A survey of Alberta school districts and divisions was conducted to estimate the efficiency of the school building stock as it presently exists. It was, as the heading states, a process of "development, implementation, and evaluation." The remainder of this report outlines the results of each stage of following this process.

3. DEFINING ENERGY MANAGEMENT

Energy conservation and energy management were both of concern to this study; a clarification of terminology and basic concepts at this point may serve to avoid confusion in subsequent discussions. Conservation is defined as protection from waste. Energy utilization and conservation involve a private or social choice of the character and hence of the energy intensity of human activity; what constitutes energy waste is a value judgement which may vary among different elements of society (as was pointed out in the introductory remarks on economic efficiency of energy use compared with the conserver society viewpoint).

Energy management is a process of economic rationalization of resource use; it involves continuing adjustment of energy utilization subject to constraints such as human comfort, statutory regulations, manpower productivity and various cost factors. Cost factors include purchased energy costs, capital costs, and manpower costs. Since the relationships among constraints are subject to change, decisions regarding responses to constraints must be reviewed at regular intervals.

Energy management is a subset of the activities encompassed by energy conservation. It attempts to achieve the most efficient deployment of resources once the character of a human activity has been chosen. Economically efficient use of energy requires that consumption be reduced to the point where the cost of saving one more unit of energy becomes greater than the cost of using one more unit of energy. Most people would agree that energy used in buildings is wasted if:

(i) saving it would not impair the functioning of the buildings

(ii) saving it offers a financially attractive return

The present trends and forecasts of large cost increases for purchased energy consumed in buildings suggest that increased allocations of capital and manpower to reduce consumption of fossil fuels is becoming more attractive economically (increasing manpower productivity is almost always attractive and is a constant goal of skilled management). Optimistically, rational life-cycle costing techniques recognize all pertinent constraints and economically allocate expenditures accordingly at the planning/design stage; realistically, uncertainty and other factors can seriously complicate such decision-making. Decisions about allocation must be reassessed in later periods - economic substitution in 1978 may be uneconomic substitution in 1980. In practice reallocation may be difficult due to physical constraints - adding 2 centimetres of insulation to a roof in the design phase bears a negligible additional labour cost; adding the same two centimetres after construction is completed would bear a much larger additional labour cost.

Energy management at the school district level must contend with varied time intervals in its controlling function, from periods spanning decades to intervals of a few hours. It encompasses activities ranging from planning of new schools to adjusting thermostats. Of course not all decisions bear the same consequences - they are regimented according to a hierarchy of cost importance.

The Grande Prairie research study was commissioned primarily to examine energy conservation measures which would not require extensive capital expenditures. This left two complementary and closely related routes - increasing the productivity of manpower and increasing the amount of manpower used. Increased manpower output can be applied to reduction of energy required in use and operation of school buildings.

As a decision-making function energy management is highly dependent on information. Three types of information are required:

(i) Constraint definition.

Energy management requires knowledge of optimization processes and constraints (mentioned above).

(ii) Feedback.

Energy management requires feedback on progress toward goals dictated by the optimization processes.

(iii) Alternatives definition.

Energy management requires information on alternative responses to changing constraints. To counter increasing energy costs the organization must know what remedial possibilities exist, the costs of remedial action, the extent of potential savings from remedial action, and the means of implementing remedial action.

Definition of changing constraints and definition of alternative responses require a specialized expertise. These two activities necessitate the development of new approaches, the acquisition of techniques from numerous fields of endeavour, and the synthesis of such approaches and techniques into practically applicable programmes. Individuals with a professional background would probably be required to ensure that such work was competently performed. Because constraints do not usually undergo significant changes over very short time intervals, the absence of local expertise in such planning may not be critical if it is provided on a consultative basis when necessary. Feedback is largely a repetitive function and can be incorporated at the local level without the acquisition of a special expertise.

Energy management incorporates theory and practice from a varied range of disciplines including management science, psychopedagogy, and engineering. It involves people and buildings, a mixture of social, organizational, institutional, and technical problems, a complex of actions and interactions.

The remainder of this section is devoted to elucidating some basic concepts of energy management.

3.1 The Information System in Energy Management

As mentioned above, the information system in energy management has three components; these may be characterized as being either routine or developmental activities. Regulation of building operation must become routine under energy management, and information feedback is a routine requirement of regulation. Information feedback and plant regulation are necessarily locally maintained functions.

A continuous record of information on building energy consumption is necessary to:

(i) identify potential energy savings

(ii) plan conservation strategies

(iii) regulate operation of physical plant

(iv) evaluate the effectiveness of the energy management programme

(v) motivate building staff and users.

Utilities record consumption for billing purposes, but the information provided in monthly statements is inadequate for most energy management purposes. Table 2.1 lists some of the shortcomings of utility records in this respect. As one source comments: "Feedback from the monthly or yearly invoice accounting system is too slow to allow the rapid operator response necessary for successful energy conserving building operation" (Biggs, 1977). However, evaluation of performance over periods shorter than a month is a theoretically complicated task because of the number of variables which must be accounted for (over longer periods many of these variables behave in a random manner and can be neglected without introducing significant error) (ASHRAE, 1976). A substantial effort was made during the first year of the project to develop satisfactory criteria for assessment of performance over time intervals of less than a month. Large amounts of data on patterns of building energy consumption were collected to obtain a better knowledge of short term behaviour.

Moving from an invoicing system for consumption monitoring to a more refined monitoring system requires development. Once the monitoring system is established, it becomes routine.

Verification of performance may be imagined as an auditing function. Auditing involves methodical examination and review of a situation concluding with a detailed report of findings. In accounting, financial auditing provides a guide to the performance of a business. In energy management, auditing of consumption provides a guide to the performance of buildings. Four types of energy audit have been identified (EMR, 1977):

(i) The Historical Audit

This is a review of energy performance based on available accounting records.

(ii) The Diagnostic Audit

This is used to isolate the energy flows for specific areas or components of a building.

(iii) The Periodic Audit

This is a review of energy performance at planned regular intervals.

(iv) The Continuous Energy Audit

This involves steady monitoring of energy flows.

Information obtained from the various types of audit will be of use to different actors in the school system. The building operator will require very short term information in order to react effectively to dynamic conditions. The principal of a school (as chief building administrator) will require less detailed information at less frequent intervals as a check on operations, as will the district supervisor of maintenance. These individuals all have day-to-day involvements with teachers, students and support staff who use and operate school buildings. The district central administration, one step further removed, may require differently structured information to assess performance on a system wide basis and to inform external consultants.

The feedback system itself should be as economical as possible in overhead costs of time and effort. It should also satisfy the information requirements of individual actors as precisely as possible.

3.2 Motivation in Energy Management

Increasing employee productivity (without increasing capital investment) can be achieved through a more effective allocation of manpower to tasks or through manpower accomplishing more in current roles. Motivation is pertinent to both these options; a tendancy to consider conservation in planning and to conserve in action must be established. In his organizational role the individual must strive for greater energy productivity in the most appropriate manner.

"An Examination of Measures Designed to Encourage Energy Conservation from the Perspective of Motivation Theory" (Lazar,1975) summarizes basic points to be considered in encouraging conserving behaviour:

(i) The challenge is not simply to create a tendency to behave in a manner which conserves energy, but to make such a tendency stronger than those which lead to energy consumption.

(ii) New behavioural tendencies may be fostered by intrinsic and/or extrinsic motivational techniques (reasons or rewards).

(iii) Reward and punishment systems work but they produce only symptomatic change. They leave the cause of the problem untouched.

(iv) A reward should be significant, immediate, and apparent.

(v) Giving reasons attacks the causes rather than the symptoms of behaviour. When intrinsic motivation is made to work, it works long and well.

(vi) One can offer reasons to conserve but they can be used as reasons to do otherwise - to consume while prices are low, to not believe that local action will make any difference.

(vii) One must believe that levels of energy consumption are a problem and that conservation is the solution.

(viii) People will avoid behaving in a manner that is demonstrated to be inconsistent with their sense of identity. Excessive energy use ("waste") is inconsistent with many Canadian values.

(ix) Cognitive dissonance may inhibit conservation. Change that implies a denial of what is held dear may be resisted. The use of a historical perspective and of appealing new images can reduce such resistance. Alternative (and more attractive) images of a future energy conserving society must be offered.

(x) The individual must have feedback to control his use of energy: "He who wishes to conserve must know how much he consumes."

It must be recognized in implementing a management programme that efficient utilization of energy is not the primary concern of most individuals in a school system. However, more efficient energy utilization can be achieved without hampering primary concerns such as teaching and recreational activities.

Just as the information system must be planned to operate with economy of time and effort, so the management programme as a whole must be planned to operate with economy of time and effort. If energy management activities become too onerous in terms of the benefits (as perceived by users), they may be largely neglected. By identifying the impact of specific user groups on energy consumption, efforts to improve performance can be focussed where they will have the greatest leverage.

By combining observations on human motivation with some principles of management science the following components of a motivational programme were formulated.

3.2.1 Awareness

As a price inflating effect, changing resource availability and values are experienced by school users as consumers through contact with the market place. As a resource issue, changing availability and values are experienced by school users as citizens through contact with the communications media. These outside influences generate a certain level of "background" awareness, but this had to be sharpened to focus on the specific problems of the school district.

Individuals had to be made aware that the cost of electricity and natural gas had become a major expense to the school district. They had to be convinced that conservation was necessary as a form of cost control.

3.2.2 Incentive

Apart from knowing that a problem existed, each person had to be given appropriate reasons for taking personal responsibility in an appropriate manner for conservation.

The question of what specific kinds of incentive to use arose frequently in discussions with the steering committee and with school administrators. There was strong support in some quarters for the employ of material rewards for users whose buildings showed improved performance. Some felt that these rewards could be "symbolic" (such as a piece of audiovisual equipment for a school as a collective), while others felt that rewards should take the form of a bonus paid to individuals for performance. The concept of material rewards was resisted by the research team for various reasons. Some of these reasons were perceived to be possibly transient circumstances (such as a lack of information on baseline performance of schools), while others were thought to exclude material rewards as an approach on more permanent grounds. Some reasons for this stance were:

3.2.2.1 Measurement

There was no proven accurate and economical technique for evaluating the efficiency of building performance over short intervals. Yet section 3.2 (above) states that rewards should be "significant, immediate, and apparent" (guideline iv). Even available longer term (and supposedly more accurate) techniques for evaluating performance do not specify tolerances. Without a precise measure of building performance rewards could not be rationally related to user behaviour. An "irrational" system could penalize individuals making genuine efforts or benefit noncontributors. This could have a net negative incentive to participate in the programme.

3.2.2.2 Allocation

To be equitable and acceptable to participants, rewards to individuals would have had to be based on merit. Yet it was not known, at the time research was initiated, what the relative influence exerted by different user groups on performance of a building was. Determining this, given the number of factors affecting building performance, might never be feasible to the degree of precision required in a material reward system.

3.2.2.3 Rising Prices

The rate of increase of energy costs in Grande Prairie will probably negate any decreases in dollar costs achieved through conservation within three or four years. If a bonus were employed to motivate users, this could increase the actual level of expenditures above their original level.

As the guidelines also suggest, material rewards might produce only symptomatic change. If at a future date the School District had to abandon material rewards due to financial hardships in other areas, it might have to face a very difficult dilemma. Saving money through cutting bonuses could simply lead to increased costs if energy conserving behaviour ceased.

3.2.2.4 Spillover Effects

If staff were reimbursed for improved performance in energy use, they might come to expect such rewards for other activities. Conversely people already contributing to the welfare of the district in other ways might feel that rewarding individuals for one specific form of contribution was inequitable. The potential appeared to exist for creating friction in employee relations.

3.2.2.5 Alternative Incentives

It was reasoned by the research team that if motivation could be achieved through means other than material rewards, this would be desirable. It would avoid the costs and complications involved in material rewards, and possibly be even more effective.

Excluding material rewards as incentives left two possibilities: reasons (intrinsic motivators) and nonmaterial rewards (extrinsic motivators). The question was how these alternative incentives could best be introduced into the school system environment. Energy use and conservation involve far reaching social issues; schools are beginning to introduce aspects of these issues in the classroom. However, individuals may or may not accept the validity of the "energy crisis" as a reason for conserving. As the literature on educational administration states (Clear, 1971), this sort of issue lies in the "personal domain" - things that either have little direct relevance to the organization and/or are extremely personal. Individuals may accordingly accept or reject a conservation campaign founded on the premise of declining resources; they may even become hostile if they feel their personal domain is being trespassed. Broader acceptance of conservation may be achieved by emphasizing its importance as a local cost control tool.

Teachers and administrators agree that in terms of internal organizational mechanics there is a high legitimacy for administrative influence (the "organizational maintenance domain"). Within schools it is the role of principals and administrative staff to set policies and procedures for economic school operation. Individuals must be persuaded that levels of consumption can be reduced without major upset, and that such reductions are a reasonable and effective form of cost control. If an individual holds additional personal convictions favouring energy conserving behaviour, this will further motivate him.

Given this analysis, reasons could be used as motivators, and propagated through the existing management structure. In many ways there is nothing special about electricity and natural gas as commodities. Administrators and other employees are already charged with responsible application of resources, human or otherwise. When interviewed, most principals confirmed that they believed energy management was in keeping with their administrative role, and was a responsibility compatible with their duties. The main difference concerning the energy resource is that use is somewhat less easily monitored and regulated in terms familiar to administrators and other employees.

Nonmaterial rewards can complement reasons and can also be propagated through the existing management structure. They can be as effective as (or even more effective than) material rewards in altering human conduct and behaviour. These rewards take the form of recognition, personal or professional satisfaction, and information feedback (Seligman, 1978).

A prime example of nonmaterial rewards acting as motivators is evident in the interest of the school district administration in conservation in the first place. The central administration stood to gain no personal or symbolic material benefits (in any direct sense) from conserving energy. Their reward lay in the professional satisfaction of efficiently operating the school district and also in recognition from the Board for competent management. There is no reason why these motivators could not be applied at other levels in the school district.

This would require a serious commitment to the programme by administrators. They would have to demonstrate a sincere and continuing interest in the efforts of their subordinates to conserve energy and would have to set a personal example.

Educators may also become more aware of energy utilization and conservation as energy related issues become incorporated into the curriculum. The school building itself, as an energy consuming artifact, could also be used as a teaching aid, increasing the awareness of students and staff.

3.2.3 Information

It is not enough simply to arouse the concern of users regarding energy conservation - it is also necessary to ensure that they are made aware of appropriate responses. Otherwise the programme will be ineffectual.

3.2.4 Responsibility

Each employee and department must know precisely what his/its responsibilities are. General exhortations to conserve can be quite fruitless. By delegating specific duties it is readily possible to judge whether individual responsibilities are being met. This will also minimize counter productive uncertainty and confusion.

3.2.5 Communication

Channels of communication pertinent to energy management should be established or reinforced. The formality and complexity may vary with the size and functions of the buildings.

An elementary school principal deals with fewer people and a smaller building; a high school principal has academic and administrative assistants, several custodians, and numerous departments to manage. In each case, an appropriate means of perceiving and resolving conflicts and problems must be found.

3.2.6 Feedback

Although this is a restatement in part of the article on incentives, the following comments are important enough to merit redundancy. Each member of the school district must believe that his participation in conservation is meaningful. People must have feedback on performance. The energy auditing system can provide information, but it must be widely disseminated to be effective.

More than information feedback is required; administrators must express their interest in the efforts and achievements of subordinates in making the programme work.

3.3 Organization for Energy Management

The importance of defined responsibilities in motivating conserving behaviour has been mentioned. Grande Prairie Public School District, like most school systems, has a hierarchical management structure, iluustrated in Figure 3.1. The chart includes three of six user groups (teachers, students, and community groups are not included). The user groups represented in the chart may be categorized as "secondary" since their function is to ensure that certain wants and needs of the other, "primary", users are satisfied. To this end, they will already have certain responsibilities. These existing responsibilities and relationships had to be considered in organizing for energy management, as will be discussed in later chapters. The organizational chart allows the reader to better understand some of these management problems.

Administrative supervisory staff in the school district are largely recruited from the teaching staff, with the exception of the central office business staff, the high school business manager, and the maintenance supervisor. As a result the interest and orientation of the administrative staff is almost entirely toward the educative function. This is reasonable in view of the chief functions of the school district, but has some drawbacks in terms of energy management and plant administration in general: the maintenance function tends to be regarded as a necessary appendage but not a direct and continuing concern of the administration. Consequences of this viewpoint as they affect energy use will be discussed in later sections, but the primary implication in this regard is that more attention will have to be given by administrators to use and operation of facilities than has been customary in the past.

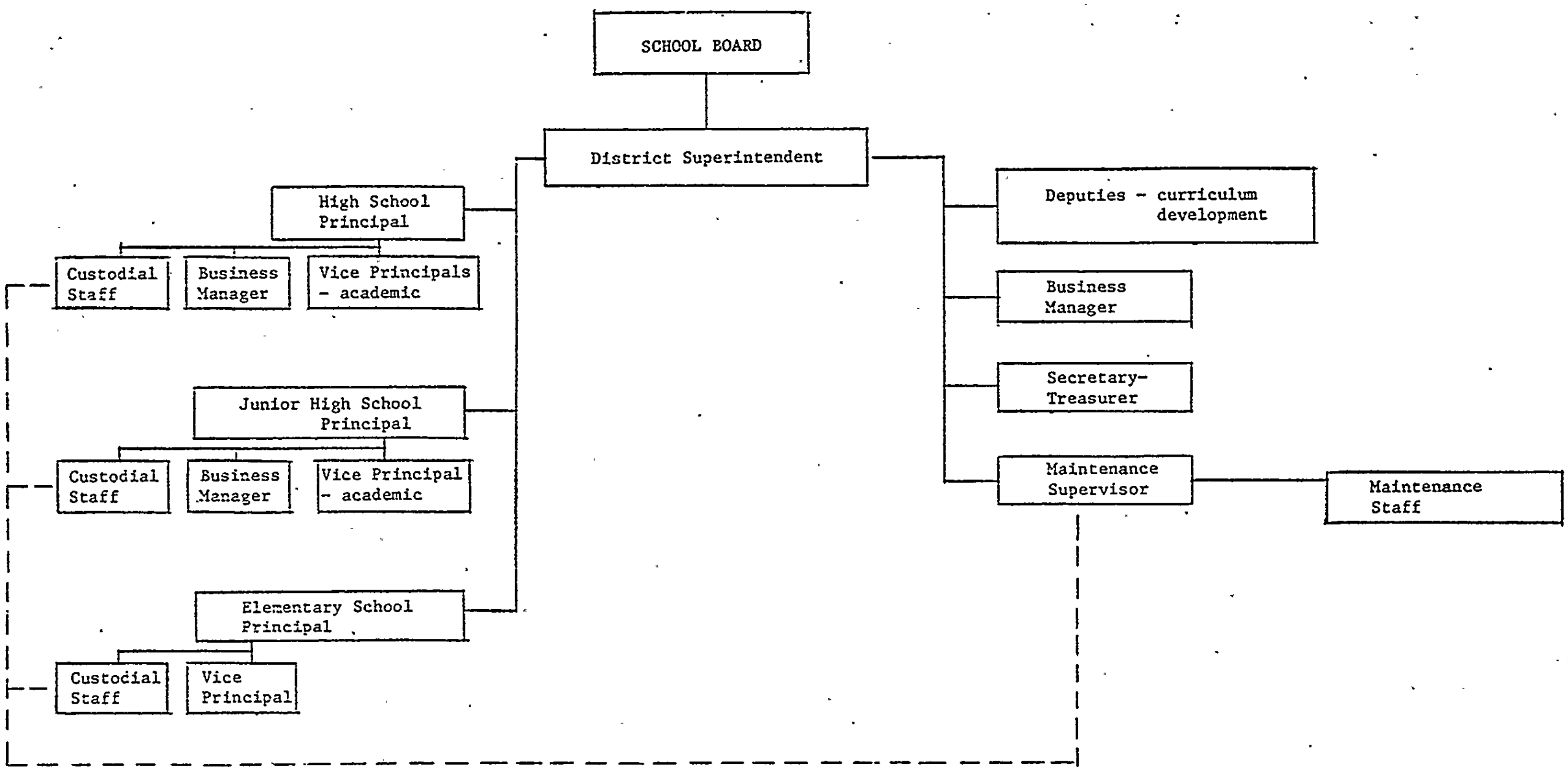


Figure 3.1 Grande Prairie School District No. 2357 Personnel Chart.

4. EVALUATING ENERGY UTILIZATION IN SCHOOLS

Determining and comparing efficiency of energy utilization in buildings cannot be an exact practice. The basic problem lies in establishing what the minimum energy requirements for a building would be with economically optimized operation, so that actual performance can be evaluated.

Efficiency is defined as the ability to produce the desired effect with a minimum of effort, expense, or waste. Basic mechanical efficiency is the ratio of useful work achieved by a system relative to the energy supplied to the system. Another type of efficiency measure is the so-called "second law efficiency", the ratio of the minimum energy required to perform a task to that actually used. Neither of these standard definitions is easily applied to buildings.

Although energy supplied to buildings by utilities is subject to continuous monitoring, energy supplied by the sun varies with season, weather, and time of day. The work performed by buildings is in some respects so diverse that it defies measurement. Obtaining a meaningful calculation for the energy efficiency of a building can therefore be a difficult task.

Four classes of criteria can be considered when evaluating energy utilization in schools:

(i) Those which evaluate school system productivity with regard to energy use.

(ii) Those which evaluate the efficiency of use once energy has been transported to the building boundary.

(iii) Those which evaluate efficiency of use based on demands at the point of resource extraction.

(iv) Those which attempt to deal with life-cycle energy demand of buildings.

All these types of measures are interrelated. Each type yields a different, but complementary, perspective on efficiency. The following subsections discuss each of the categories in more detail.

4.1 Productivity

Indicators of productivity are commonly employed in manufacturing processes, and indicators describing productivity of energy use are rapidly gaining acceptance. Modern school systems may consume as much energy as small industrial enterprises, although operating buildings with the attention accorded an industrial process is still uncommon. Such an approach demands more structured evaluation of building performance.

A common industrial indicator of system energy performance is energy units purchased per unit of output. Educational jurisdictions may be said to have two forms of output - primarily more competent individuals, but also, in their buildings at least, quantities of environmentally regulated space. Energy use per unit of gross floor area is more closely related to building performance, but energy use per student can have some value as an indicator of resource allocation. This is perhaps more clearly stated by breaking the energy use per student indicator into two subcomponents - energy use per gross floor area and gross floor area per student (the first indicator is the product of the latter two). It may then be seen that efficient buildings below utilization capacity may not necessarily be an efficient allocation of resources.

Monetary expenditures for energy may also be used in measures of productivity, but since energy tariffs vary over time and with geographic location, measures based on expenditures lack consistency needed in comparative evaluation of building performance. They may be of greater value in assessing the relative financial impact of changing energy costs on different school systems.

4.2 End Use Efficiency

Because utilities meter each customer's consumption for billing purposes, a fairly accurate record of purchased energy use over time can be retrieved for most buildings. However, more than a simple record of consumption is necessary to evaluate performance; some satisfactory basis for comparison of use in different time periods and between buildings must be established.

The basic function of the built environment is the sheltering of man's activities from fluctuations in weather. The building enclosure system acts as a passive separator between the exterior and the interior climates. The building environmental control equipment is the active element, consuming fuels to maintain the interior environment within finer bounds than can be achieved by the unaided passive element (Table 4.1 contains some typical figures on energy consumption rates of building systems). One is therefore concerned with the amount of energy expended to maintain certain interior conditions. These conditions are temperature, ventilation, humidity, and lighting levels required for human comfort, usually as defined by professional bodies such as ASHRAE,

Table 4.1. Annual energy consumption rates for a prototypical school at 5000 Celsius degree days (Lentz, 1976).

	Energy Use (W/m^2)	Percent of total
by system		
Heating	35.8	65.1
Light and Power	10.3	18.7
Water Heating	4.4	8.0
Fans	1.5	2.7
Cooling	1.5	2.7
Auxiliary	1.5	2.8
TOTAL	55.0	100.0
by end use energy form		
Total Electric	14.8	26.9
Total Non-Electric	40.2	73.1
TOTAL	55.0	100.0
by approximate total resource demand		
Total Electric	49.3	55.1
Total Non-Electric	40.2	44.9
TOTAL	89.5	100.0

Note: Grande Prairie School District No. 2357 facilities consumed an average of 48.4 W/m^2 natural gas and 8.2 W/m^2 electricity in 1976 at 5557 degree days.

the American Society of Heating, Refrigeration, and Air Conditioning Engineers. Some measure of meteorological conditions must also be available to determine the climatic stress which the passive and active elements of the building must resist to maintain the specified interior environment. These circumstances include ambient temperature patterns, quantities of insolation, and humidity ranges.

Apart from energy required to maintain a specified state within a given space in the face of adverse external conditions, it may also be worthwhile examining the "density" and "quality" of the sheltered activity, if only at the conceptual plane. If more of an activity is adequately supported by one building than by another, ceterus paribus, the former building is the more efficient; this is directly related to the idea of system productivity, which has already been introduced. Qualititative judgments of use value were evidenced during the winter of 1976-77 when selected consumers lost their fuel supply due to shortages in the northeastern United States.

One way of coping with the number of factors to be considered and obtaining baseline data for evaluation of building performance is through computer modelling. This is perhaps the most accurate means of estimating building energy requirements under "typical" weather conditions and with "normal" patterns of building operation. Hour by hour calculations of theoretical demand for energy are performed for an entire "year". Utility records are usually used to "calibrate" results in the case of existing buildings. On an annual basis, simulations can produce relatively precise estimates. Such simulations can be a valuable and necessary tool when designing new facilities or planning major modifications to plant. However simulations have capability and cost limitations which significantly reduce their value in assessing operation of existing buildings, especially on a continuing basis. Computer models can be relatively costly to construct and operate. They require weather information which may not be available for smaller cities. They cannot account accurately for the "human" factor and for other factors which may produce significant fluctuations in consumption over periods of less than a year.

One alternative is to indirectly measure efficiency by comparing energy supplied to buildings performing similar functions. However, analysis using such comparative measures must be tempered with an understanding of their limitations as criteria. Any pair of school buildings, for instance, may differ both in physical characteristics and in use patterns. Thorough evaluation must proceed from general comparative data to specific analysis of building systems and activity programming.

For comparative purposes, electricity and natural gas use can be assessed on the basis of gross floor area (annual average Watts per square metre). Gross floor area is a readily obtained statistic, as it is one basis for insurance assessments. It is related to net floor area, a good measure of the "working space" in a building, although the ratio of the two varies among buildings. Although some portions of building energy demand are generated largely volumetrically (such as space conditioning) others are not - lighting, hot water heating, and operation of auxiliary equipment. Purchased energy consumed per unit of gross floor area per annum is the measure most commonly employed in the literature on energy management. It is sometimes referred to as the "specific energy need" of a building.

The indicator described above does not show how effectively energy is spent in achieving each requirement (heating, lighting, ventilation, etc.) nor does it contribute to evaluating energy performance over shorter periods of time.

Virtually no records of energy use according to building system have been published. Such data is necessary to effectively plan conservation measures. For some building systems accurate estimates of consumption can be made or can be calculated from indirect measures. Others are more difficult to evaluate except by direct measure. Short term records are similarly of value in more accurately determining the pattern of energy expenditures within a building. These kinds of information were sought in the course of the first year of the Grande Prairie study, and were supplemented by observations of facility use, inventories of energy consuming plant, and records of facility operating schedules so that a balanced evaluation of end use energy requirements could be formulated.

A third way of evaluating building performance is to use records of past performance for purposes of comparison. However these records must be much more precise than records which are presently used to account for building energy consumption. The development of this type of indicator for use in the Grande Prairie schools is discussed in later sections.

4.3 Total Resource Demand

This is a variation on measuring end use efficiency. Total resource demand encompasses not only quantities consumed within the building, but extends the demand implications back to the point of resource extraction. A concrete Alberta example of different consumption values obtained with different kinds of measures is evident in electricity consumption; the supply of one energy unit of electricity requires the expenditure of roughly four energy units of fossil fuel at a thermal generating station. Most of the remaining energy is discharged as waste heat, while the balance is dissipated in transmission. This fact illustrates the fallacy of such approaches as using unnecessary artificial illumination for heating purposes.

Total resource demand accounting must express the losses and burdens involved in the processing, transportation, conversion, and delivery of various forms of fuel and energy to the site (Phipps, 1976; Jones, 1976).

4.4 Life-Cycle Energy Demand

Energy is consumed not only during lifetime operation of a building but also at the two boundary points of its lifetime: construction and demolition. The energy demands at these points are difficult to estimate; one authority places them at the equivalent of three or four years of building operation (Stein, 1976). A comprehensive analysis on a life cycle basis should attempt to consider the cumulative energy consumed to produce and maintain a building from initial site work through to final site clearance. Some building materials, for instance, are much more energy intensive in manufacture and in service than others.

One point particularly worth noting with regard to this criterion is that the existing stock of school buildings represent not only a monetary investment, but also an energy investment. More extensive use or more effective use of existing facilities could under certain conditions reduce the demand for new construction and for additional energy supply.

4.5 Measures Used in This Report

This general discussion has been undertaken to outline the full scope of techniques for evaluating energy use in school buildings. In most cases only end use efficiency measures will be used in the remainder of the report, although productivity of energy utilization and total resource demand will be specifically referred to in a couple of instances.

5. ORGANIZATION AND ENERGY UTILIZATION OF ALBERTA SCHOOL SYSTEMS

Although energy and dollar savings in Grande Prairie School District No. 2357 alone would be significant, the research work will be of much greater value if it can also benefit other school systems in Alberta. This chapter explores some considerations relevant to planning for energy management both in Grande Prairie and on a province wide basis.

The analysis begins with a brief examination of present provincial organization as it affects school district energy management. It then goes on to a statistical characterization of Alberta school districts. Finally, a survey of utility expenditures by selected Alberta school systems is reviewed. Information from the survey was needed to perform a comparative evaluation of energy utilization in Grande Prairie Public School District.

5.1 School System Organization in Alberta as it Affects Energy Management

Canadian provinces differ in the organization of elementary and secondary education. Some provinces have largely decentralized educational organizations, while others have a stronger central authority.

Different provincial approaches to the planning and development of facilities illustrate the variations in organizational philosophy. In New Brunswick, for instance, construction and upgrading of schools is handled directly by the provincial department of education (as is the development of energy management programmes for individual schools). Alberta is one of the provinces in which much responsibility is delegated to the local educational system. In Alberta local school districts analyze space requirements, assemble proposals, obtain assistance in capital funding from the provincial Department of Education and tender entire building projects. The decentralization of such functions is the most notable characteristic of elementary and secondary education in Alberta, insofar as energy management is concerned.

The Department of Education has a School Buildings Administration Branch which "assists school boards as autonomous corporate bodies to plan, build, operate, and maintain school buildings in order to facilitate the desired school programmes". A second purpose of the Branch is "to enable government support for educational facilities in accordance with provisions of The Alberta Act, The Department of Education Act, The School Act, The School Buildings Act, and other relevant Statutes, and Regulations pursuant thereto". Alberta Education contributes substantially to local operating and capital budgets through grant programmes.

The School Buildings Branch provides consultative and advisory services regarding facilities; Field Work Inspectors travel throughout the province to offer advice, referral, and information. The Branch participates in workshops, one of which is held annually by the school buildings maintenance people of the province through their maintenance association.

The School Building Quality Restoration Program is one programme developed by the School Buildings Branch; it assists school boards financially and technically where the failure of selected building components is involved. Thus, while local school systems are autonomous, they are not without guidance and assistance as far as physical facilities are concerned.

Because administrative responsibility for education is highly decentralized, Alberta Education does not have records of energy utilization in school buildings, nor does it have information on gross floor areas of provincial schools. A computerized information system on school buildings is currently in the midst of a four year development programme. The "School Facilities File" will eventually contain more than 130 pieces of data on each school in the province, including floor areas, enrolment, and structural characteristics. Most of the information will be construction cost breakdowns for building systems. No data collection is planned for items such as environmental control systems, insulation, or building energy consumption.

Although the province customarily receives sets of drawings for schools built with provincial aid, these are not sepias (and hence cannot be copied), are often incomplete or outmoded, and are not accessible for general use (to feed the information system mentioned above, floor plans of each school in the province are being drafted). Drawings in the possession of Grande Prairie School District were also incomplete and copies were not available.

The provincial Department of Education does maintain computer files on each school district and school building, including data on the chief administrator, name, address, and enrolment.

5.2 School Systems in Alberta: A Statistical Review

There are about 140 school systems in Alberta, operating 1368 schools and serving 429 000 students. Basic statistics are presented in Table 5.1.

Table 5.1. Alberta school systems: basic statistics.

School System Type	Number of Systems in Category	Number of Schools in Category	Enrolment in Category
School Divisions	30	314	66 070
Counties	30	342	86 168
Public School Districts	26	472	192 666
Roman Cathlic School Districts	44	220	75 578
Other			
Consolidated School Districts	3	3	585
Catholic Public School Districts	1	2	742
Protestant Separate School Dist.	2	8	4 878
Regional High School Districts	3	7	2 254
Total Other	9	20	8 459
TOTAL	139	1 368	428 940

As mentioned above, records do not presently exist either of building energy utilization or gross floor area. Proportional enrolments can be used as a rough indicator of relative impact on aggregate consumption by different size school systems (school system enrolment is related to space allocations, and by this relationship to energy utilization).

Table 5.2. Alberta school systems: number of systems categorized according to system student enrolment categories and system type.

System Type	less than 1000 students	1001 to 5000 students	5001 to 15 000 students	15 001 to 45 000 students	more than 45 000 students
Division	7	21	2	-	-
County	1	26	3	-	-
Public School	11	10	3	-	2
Roman Catholic	36	6	-	2	-
Other	7	2	-	-	-
TOTAL	62	65	8	2	2

Table 5.3. Alberta school systems: number of schools categorized according to system student enrolment categories and system types.

System Type	less than 1000 students	1001 to 5000 students	5001 to 15 000 students	15 001 to 45 000 students	more than 45 000 students
Division	42	234	38	-	-
County	12	262	68	-	-
Public School	16	39	60	-	357
Roman Catholic	41	33	-	146	-
Other	8	12	-	-	-
TOTAL	119	580	166	146	357

Table 5.4. Alberta school systems: student enrolment categorized according to system student enrolment categories and system types.

System Type	less than 1000 students	1001 to 5000 students	5001 to 15 000 students	15 001 to 45 000 students	more than 45 000 students
Division	4 948	50 413	10 699	-	-
County	2 911	57 771	25 486	-	-
Public School	5 112	19 037	19 212	-	149 305
Roman Catholic	14 803	10 122	-	50 653	-
Other	2 758	5 701	-	-	-
TOTAL	30 532	143 044	55 397	50 653	149 305

Table 5.5. Alberta school systems: selected statistics categorized according to system student enrolment categories.

Statistic	less than 1000 students	1001 to 5000 students	5001 to 15 000 students	15 000 to 45 000 students	more than 45 000 students
% of total students	7.1	33.3	12.9	11.8	35.0
Average Number of Schools per Jurisdiction	2	9	21	73	178
Average Number of Students per Jurisdiction	500	2200	6900	25 300	74 700

Tables 5.2 through 5.5 contain statistical information broken down according to five enrolment size categories; these categories were select-

ed based on observation of district operations, on discussion with educational administrators, and on analysis of the data by researchers.

It is evident that although systems with less than 1000 students number 62, or about 45.0 percent of the total, they serve only 7.1 percent of the students in the province. This suggests that they have a minor effect on aggregate energy performance of Alberta schools. These districts tend not even to have a maintenance team due to their small size (only 2 schools per system on average).

At the other extreme are systems with more than 45 000 students which number 2 (about 1.5 percent of the total), but serve 35.0 percent of the students in the province. These districts (the Calgary and Edmonton Public School Districts) have an extensive administrative structure, with a professional staff of architects and engineers, and specialized operating and maintenance departments.

In between are systems with between 1000 and 45 000 students which number 75 (about 53.5 percent of the total) and serve 58.0 percent of the students in the province. This class is further stratified into a large number of systems in the 1000 to 5000 students range, and other larger units.

From these distributions it can be inferred that the organizational problems in energy management will vary from one class of school system to another. For one thing, small systems may lack ready access to professional expertise, while large systems may lack intimate internal communications due to the size of the organizational structure. Both can hamper efficient energy utilization, but the remedies may have to be varied.

As was mentioned earlier, implementation of energy management requires a certain specialized expertise. While it may be economical for a large school system to maintain such expertise in house, the same may not be true of smaller districts. A possible remedy would be the provision of such expertise on a province-wide basis by Alberta Education in its "advisory and consultative role". Advantages of this option would be the development of a unit with a particular understanding of energy management for schools, providing continuity to the province-wide conservation effort. Such a unit would require the guidance of professionals with knowledge of buildings, environmental control equipment, organization and administration, technical conservation measures, and energy management techniques.

5.3 Survey of Alberta School Systems

A survey was conducted via questionnaire to obtain information on energy utilization in selected Alberta school systems. Since Grande Prairie was in the 1000 to 5000 student enrolment category, all system samples were drawn from this size range. Another consideration was manageability of data - systems with larger enrolments operate an average of 21 or more schools each[1].

The questionnaire requested the following information for each school in the sampled systems:

(i) name

(ii) number of levels

(iii) gross floor area

(iv) first year of operation

(v) 1977 expenditure for electricity

(vi) 1977 electricity consumption (in kilowatt-hours)

(vii) 1977 expenditure for natural gas

(viii) 1977 natural gas consumption (in thousands of cubic feet)

(ix) use of air conditioning (yes or no)

(x) heating system type (forced air and/or hot water)

The covering letter also requested information on any energy conservation measures which had been taken (if any):

(i) the reasons for implementing measures or programmes

(ii) which measures were taken

(iii) who was responsible for implementation

(iv) starting date for implementation

(v) whether measures were curriculum oriented

(vi) whether the measures involved monitoring of consumption

Forty systems were contacted, of which 24 replied (see Table 5.6). Only 15 systems were able to give a complete school by school account of energy consumption and expenditures. Some sets of data were so far removed from the norm that they were obviously totally incorrect. Other sets of data were close to the norm in most respects but exhibited suspicious discrepancies in some elements (the extremely low electricity consumption per student in System #11 for example). Some school districts could provide only dollar cost information, while others could not provide records of either expenditures or consumption.

Table 5.6. Response rates for the survey of utility expenditures in selected Alberta school systems.

	Number	% of Number Contacted
Schools Systems Contacted	40	100.0%
Replies	24	60.0%
No Information Available	6	15.0%
Limited Information Available	3	7.5%
Complete Reply	15	37.5%

Statistics on building energy consumption rates are presented in Table 5.7. These reveal significant variations in performance of buildings, both within and among districts. To put the following consumption rates in perspective, the energy efficient school construction project in Edmonton is aiming for a total specific energy need of 28 W/m^2 (250 $kWh/m^2/yr$). Average consumption rates for the sampled school districts were 47 W/m^2 (410 $kWh/m^2/yr$) for natural gas and 5.5 W/m^2 (48 $kWh/m^2/yr$) for electricity, totalling 52 W/m^2 (458 $kWh/m^2/yr$). The average range in specific need for gas was from 30 W/m^2 (260 $kWh/m^2/yr$) to 66 W/m^2 (580 $kWh/m^2/yr$) and for electricity was from 3.2 W/m^2 (28 $kWh/m^2/yr$) to 9.6 W/m^2 (84 $kWh/m^2/yr$). Extreme values ranged from 14 W/m^2 (120 $kWh/m^2/yr$) to 96 W/m^2 (840 $kWh/m^2/yr$) for natural gas, and from 0.4 W/m^2 (3.5 $kWh/m^2/yr$) to 27.9 W/m^2 (240 $kWh/m^2/yr$) for electricity.

Table 5.7. Response rates for the survey of utility expenditures in selected Alberta school systems.

School System Code Number	Natural Gas: Highest Specific Need	Natural Gas: Average Rate for the Unit	Natural Gas: Lowest Specific Need	Electricity: Highest Specific Need	Electricity: Average Rate for the Unit	Electricity: Lowest Specific Need
	Energy Utilization (W/m^2)					
1.	78	54	28	6.9	4.2	2.3
2.	290	170	140	14.4	11.2	6.9
3.	54	46	38	9.7	5.8	3.1
4.	82	52	14	4.7	3.2	2.1
5.	82	63	50	8.3	5.9	4.3
6.	54	49	32	11.6	4.8	0.4
7.	68	47	27	4.8	3.9	2.0
8.	42	37	26	9.5	5.1	1.9
9.	73	40	23	6.7	2.5	1.4
10.	96	47	22	13.1	8.6	4.9
11.	50	33	18	2.1	1.6	1.1
12.	64	38	26	27.9	6.5	4.9
13.	68	46	33	12.3	9.9	8.4
14.	46	40	22	6.5	5.1	2.1
15.	81	51	35	16.0	11.2	3.7
16.	-	-	-	-	-	-
17.	-	-	-	-	-	-
Grande Prairie	65	46	41	9.6	6.0	3.4
Grande Praire RC	61	56	39	4.7	4.4	3.6
AVERAGES	66	47	30	9.6	5.5	3.2

Notes: Systems #2 and #11 are not included in the averages due to peculiarities of the proffered data on consumption.
Systems #16 and #17 provided aggregate cost information only.

The average consumption rates and average ranges of consumption rates for the sample were very similar to the figures obtained for Grande Prairie Public School District.

One measure of the economic impact of utility expenditures on school systems is energy cost per student. Energy cost per student in a system will be a product of three factors:

(i) gross floor area per student

(ii) energy consumption per unit gross floor area

(iii) dollar cost per unit of energy consumed

Table 5.8. Basic information on selected Alberta school systems.

School System Code Number	Number of Buildings	Area (m^2)	Students	Area (m^2) per Student
1	8	16 101	1639	9.8
2	8	7 872	1739	4.5
3	4	12 701	1533	8.3
4	8	17 163	1192	14.4
5	4	13 784	2054	6.7
6	10	20 746	2408	8.6
7	5	13 126	1082	12.1
8	10	29 354	1971	14.9
9	15	29 643	2295	12.9
10	6	25 025	2469	10.1
11	7	29 373	4436	6.6
12	5	21 564	1507	14.3
13	6	14 309	1407	10.2
14	7	17 606	1886	9.3
15	6	21 954	2154	10.2
16	11	44 526	4404	10.1
17	9	18 264	3357	5.4
Grande Prairie	8	37 558	3351	11.2
Grande Prairie RC	4	9 257	1057	8.8
		AVERAGE		9.8

A substantial variation in gross floor area allocation per student was found to exist, with more than a twofold range between the maximum and minimum values. (see Table 5.8). Dollar costs and energy consumption

Table 5.9. Information on dollar expenditures and energy consumption per student for selected Alberta school systems.

School System Code Number	Electricity Expenditure $/student	Electricity Consumption MJ/student	Natural Gas Expenditure $/student	Natural Gas Consumption MJ/student
1	17.17	1300	14.32	16 800
2	19.63	1600	21.49	24 600
3	20.07	1520	15.77	12 000
4	22.26	1460	15.98	23 600
5	16.05	1240	12.07	13 400
6	19.96	1440	11.17	-
7	28.27	1510	16.45	17 900
8	38.96	2410	16.07	17 600
9	20.51	1110	20.53	17 400
10	22.07	2740	13.44	15 100
11	8.83	300	18.62	7 100
12	41.21	2940	14.39	17 100
13	22.53	3200	14.01	14 700
14	9.88	1510	3.98	11 700
15	29.03	3620	15.08	16 400
16	20.08	-	13.39	-
17	10.51	-	10.90	-
Grande Prairie	35.28	2520	18.80	16 400
Grande Prairie RC	21.36	1140	16.25	15 500
AVERAGE	23.07	1840	14.68	16 700

Notes: System #11 is not included in the averages because of peculiarities in the proffered cost data.

Although system #2 was not included in the averages of energy consumption rates because of data peculiarities, the proffered cost data appeared reasonable upon verification.

per student are shown in Table 5.9, while Table 5.10 contains figures on average prices paid by the sampled shool systems for energy. Tables 5.11 and 5.12 assemble data on all three factors determining cost per student for electricity and natural gas respectively.

Table 5.10. Average price paid per energy unit for selected Alberta school systems.

School System Code Number	1977 Expenditure for Electricity cents/kWh	$/GJ	1977 Expenditure for Natural Gas cents/Therm	$/GJ
1	4.8	13.30	9.0	0.86
2	4.4	12.20	9.2	0.88
3	4.7	13.10	13.8	1.31
4	5.5	15.30	7.1	0.68
5	4.7	13.10	9.5	0.90
6	5.0	13.90	8.9	0.84
7	6.7	18.60	9.6	0.90
8	5.8	16.10	9.6	0.96
9	6.7	18.60	12.4	1.18
10	2.9	8.10	9.4	0.90
11	9.2	25.60	28.3	2.69
12	5.0	13.90	8.8	0.84
13	2.5	7.00	10.0	0.95
14	2.4	6.70	3.6	0.34
15	2.9	8.10	9.7	0.92
16	-	-	-	-
17	-	-	-	-
Grande Prairie	5.0	13.90	12.1	1.14
Grande Prairie RC	6.4	17.80	12.9	1.22
AVERAGE	4.7	13.10	10.9	1.04

(Note: Systems #2 and #11 are not included in the averages)

Some examples may help to clarify the value of these tables. It is evident for System #2 that although utilization of space is very efficient, the extremely poor natural gas use efficiency of the buildings results in a higher than average cost per student. On the other hand, System #11 which has a relatively inefficient space allocation and exhibits average natural gas use efficiency pays only slightly more than average cost per student for gas since it benefits significantly from a low unit gas cost. Grande Prairie Public School District has an average natural gas consumption, but above average space allocation and unit en-

Table 5.11. Summary statistics on per unit costs for electricity for selected Alberta school systems.

School System Code Number	Floor Area (m^2) per Student	1977 Electricity Consumption (GJ/m^2)	1977 Electricity Unit Cost ($/GJ)	1977 Electricity Cost per Student
1	9.8	0.13	13.30	17.20
2	4.5	0.35	12.20	19.60
3	8.3	0.18	13.10	20.10
4	14.4	0.10	15.30	22.30
5	6.7	0.19	13.10	16.00
6	8.6	0.15	13.90	20.00
7	12.1	0.12	18.60	28.30
8	14.9	0.16	16.10	39.00
9	12.9	0.08	18.60	20.50
10	10.1	0.27	8.10	22.10
11	6.6	0.05	25.60	8.80
12	14.3	0.20	13.90	41.20
13	10.2	0.31	7.00	22.50
14	9.3	0.16	6.70	9.90
15	10.2	0.35	8.10	29.00
16	10.1	-	-	20.10
17	5.4	-	-	10.50
Grande Prairie	11.2	0.22	13.90	35.30
Grande Praire RC	8.8	0.14	17.80	21.40
AVERAGE	9.8	0.19	13.10	23.10

(Note: Systems #2 and #11 are not included in the averages)

ergy costs, giving it one of the highest ratios of cost per student.

Table 5.13 contains basic information on the buildings in the sample. Few schools were reported to be equipped with air-conditioning, which can be a significant energy consumer. Although, in Grande Prairie, older schools were found to be equipped with hot water heating systems and newer schools with forced air systems, this was not a consistent trend in the questionnaire data. The system with the oldest buildings (#5) also had the highest natural gas consumption rates, while

Table 5.12. Summary statistics on per unit costs for natural gas for selected Alberta school systems.

School System Code Number	Floor Area (m^2) per Student	1977 Natural Gas Consumption (GJ/m^2)	1977 Natural Gas Unit Cost ($/GJ)	1977 Natural Gas Cost per Student
1	9.8	1.7	0.86	14.30
2	4.5	5.0	0.88	21.50
3	8.3	1.4	1.31	15.80
4	14.4	1.6	0.68	16.00
5	6.7	2.0	0.90	12.10
6	8.6	1.5	0.89	11.20
7	12.1	1.5	0.91	16.40
8	14.9	1.2	0.91	16.10
9	12.9	1.3	1.18	20.50
10	10.1	1.5	0.99	13.40
11	6.6	1.0	2.69	18.60
12	14.3	1.3	0.84	14.40
13	10.2	1.5	0.95	14.00
14	9.3	1.3	0.36	4.00
15	10.2	1.6	0.92	15.10
16	10.1	-	-	13.40
17	5.4	-	-	10.90
Grande Prairie	11.2	1.5	1.14	18.80
Grande Praire RC	8.8	1.8	1.22	16.20
AVERAGE	9.8	1.6	0.93	14.70

(Note: Systems #2 and #11 are not included in the averages)

systems with newer buildings tended to have lower gas consumption rates. Even System #15, with air-conditioning had a relatively low requirement for natural gas. No such patterns were found to exist in the electricity consumption data.

Two school districts reported attempts at implementing energy conservation programmes, but were having problems with achieving sustained reductions or in simply implementing the programmes. As one letter stated: "To date measures have been implemented but have not been effec-

Table 5.13. Basic information on buildings in selected Alberta school systems.

School System Code Number	Number of Buildings	Average Age	Number of Air-conditioned Buildings	Number of Hot Water Heating Systems	Number of Forced Air Heating Systems	Number of Steam Heating Systems
1	8	1957	-	-	-	-
2	8	-	0	5	5	0
3	4	1956	0	2	4	0
4	8	1954	0	7	5	0
5	4	1951	0	4	4	0
6	10	1954	1	3	8	0
7	5	1958	0	2	4	3
8	10	-	0	1	9	0
9	15	1949	0	3	6	10
10	6	1965	0	5	3	0
11	7	1966	0	6	3	0
12	5	1963	1	6	3	0
13	6	1963	0	2	4	0
14	7	1940	1	3	1	1
15	6	1970	4	3	3	0
16	11	1952	0	4	11	0
17	9	1954	0	9	0	0
Grande Prairie	8	1962	2	2	6	0

tive because of lack of concern on the part of personnel." These systems both replied that they were monitoring energy consumption, but presumably this did not extend beyond recording of information on utility invoices, since no special approaches were mentioned.

5.4 Summary

Energy management is a nascent function in Alberta school systems, as elsewhere, and will require development at both the provincial and local organizational levels to ensure an adequate flow of information.

The survey results indicate that Alberta school systems have not yet achieved a rationalization of energy utilization. They also indicate that some difficulties are being encountered by those systems which are attempting to better regulate energy utilization. This may be in part a function of system size; different size systems may require different forms of consultative assistance in resolving their difficulties. A role may exist for the School Buildings Administration Branch to assist school systems in this regard on a continuing basis, particularly in view of the Branch's present advisory functions.

6. STRATEGIES FOR CONSERVATION

Alberta Education is sponsoring the investigation of three approaches to energy conservation in schools - more efficient operation of facilities, retrofit of facilities, and construction of new facilities. Other chapters of this report are largely concerned with strategies of reducing energy requirements through reducing demands on building equipment and through operating equipment more efficiently. However, one of the objectives of the Grande Prairie study is to also consider the merits of the other two strategies.

Table 6.1. Reductions in consumption rates which could be achieved if Grande Prairie School District No. 2357 buildings required only 3 W/m^2 electricity and 12 W/m^2 natural gas.

Building	1977 Natural Gas Consumption (W/m^2)	% Reduction Possible Through Replacement	1977 Electricity Consumption (W/m^2)	% Reduction Possible Through Replacement
Avondale	42.0	71.4	5.3	43.3
Hillside	42.4	71.7	7.3	58.9
Parkside	37.7	68.1	9.8	69.3
Swanavon	60.1	80.0	8.6	65.1
Old Montrose	52.8	77.3	3.4	11.8
New Montrose	49.5	75.8	4.1	26.8
Composite	44.8	73.2	12.1	75.2
Administration	49.5	75.8	5.6	46.4
Central Park	67.1	82.1	1.0	0.0

6.1 Obsolescence of Facilities in Grande Prairie

Table 6.2. Dollar savings which could be achieved by replacing Grande Prairie School District buildings with more efficient structures.

Building	Estimated Replacement Cost (Thousands of Dollars)	1978 Dollar Savings Natural Gas	Electri-city	Total	Total Saving as Percent of Replacement Cost
Avondale	1 192	3 142	3 031	6 173	0.5
Hillside	1 613	4 015	7 245	11 260	0.7
Parkside	1 916	2 860	8 316	11 176	0.6
Swanavon	924	3 760	6 119	9 879	1.1
Old Montrose	877	6 388	826	7 164	0.8
New Montrose	2 675	7 277	3 538	10 815	0.4
Composite	5 789	19 324	39 931	59 255	1.0
Administration	161	1 819	835	2 653	1.6
Central Park	279	1 806	0	1 806	0.6

An optimistic predicted energy consumption rate for an energy efficient school is 15 W/m^2 (130 $kWh/m^2/yr$) - 3 W/m^2 electricity consumption and 12 W/m^2 natural gas consumption (at 5000 Celsius degree-days). In Table 6.1, the reductions in gas and electricity consumption rates which would be realized at such rates are computed for each building in Grande Prairie School District. In Table 6.2, the reductions are translated into annual monetary savings in 1977 dollars. It is evident that the marginal savings in energy costs through replacement of facilities would not justify capital costs of new construction even if energy costs increased by a factor of four.

It appears that only if new facilities are necessary for additional reasons can the capital expense of new construction be justified. In such cases consideration should be given to phasing out the least efficient performers in a given school system.

6.2 Retrofit of Facilities

A detailed study was carried out under the supervision of the Calgary Board of Education on retrofit of facilities to reduce energy requirements. Basic information on the schools studied is contained in Table 6.3.

Table 6.3. Basic information on the Calgary schools for which retrofit measures were evaluated.

School	Gross Floor Area (m^2)	Consumption Rate (W/m^2) Natural Gas	Electricity	Total
Briar Hill	2 632	24.1	2.8	26.9
Marlborough Park	2 734	36.6	10.5	47.1
Lord Beaverbrook	23 515	25.4	8.7	34.1
Patrick Airlie	2 129	39.6	3.9	43.5
Terrace Road	2 184	19.5	5.9	25.4
AVERAGE		29.0	6.4	35.4

Possibilities considered by the consultants included addition of insulation, changes to mechanical systems, and some operational changes. The conclusion was that major energy savings from other than operational changes could be accomplished only with large capital expenditures and major mechanical system changes. It was further concluded that the physical changes investigated were not cost effective for the schools studied.

The results of this report do not appear to offer much hope for retrofit as a panacea for present energy consumption rates of Alberta school buildings in the immediate future. However, retrofit should not be summarily dismissed from consideration as a viable conservation measure in the short run. The following discussion outlines justifications for its application under certain conditions.

6.2.1 Specific Evaluation

Specific evaluation of an individual building and its component systems is required to determine the feasibility of retrofit. Among the factors to be considered are:

6.2.1.1 Energy Consumption Rates

The Calgary schools consume 25 percent less gas on average than those operated by the surveyed Alberta school systems, and 19 percent more electricity. However they also required only 44 percent of the average maximum natural gas consumption of buildings operated by surveyed Alberta school systems, and only 67 percent of the average maximum electricity consumption. The potential energy savings from retrofit may therefore be subject to extreme variation, with the Calgary buildings representing relatively efficient structures and a minimum potential for savings.

6.2.1.2 Local Utility Costs and Rate Structures

The average unit costs paid by the Calgary schools for natural gas and electricity were \$1.21/GJ and \$8.60/GJ respectively, compared with \$1.14 and \$13.90 in Grande Prairie. Service tariffs are also structured differently in Calgary, in some cases reducing the relative return from reductions in energy consumption. Such variations in cost factors will affect the local feasibility of retrofit.

6.2.1.3 Physical Characteristics of the Building

Review of the Calgary report revealed that the studied buildings are equipped with more sophisticated environmental control equipment than that installed in the Grande Prairie schools (and possibly in other Alberta school buildings). In particular, heating and ventilating requirements are satisfied by different systems, allowing more control over system operation. Buildings equipped with different mechanical systems may be amenable to or require different approaches to conservation from those buildings studied.

6.2.1.4 Estimated Service Life

The estimated service life of a building must be considered in planning for retrofit. School districts have standard forecasting techniques for determining probable future enrolment levels in specific areas, and hence the probable requirement for school buildings.

Although uncertainties and unforeseeable factors may create problems in using such rational planning techniques, they are the most effective planning tools available.

6.2.2 Expenditure and Work Load Balancing

While the monetary cost of realizing energy savings is an important factor in evaluating the economics of retrofit, there are other factors which may involve equally significant costs. If a school system waits until retrofit offers an attractive return on investment, it may face a sudden budget increase in order to pay for the upgrading. On the other hand, if retrofit is implemented incrementally in a school system's buildings, this would help to forestall a sudden drain on income. Another advantage of incremental retrofit is that in house labour could be employed on such projects when not engaged in other activities. In this case, the only "real" cost to the school system would be the cost of materials.

6.2.3 Human Comfort

If schools do not meet basic requirements for human comfort (discussed in Chapter 8), this is an additional justification for physical upgrading of facilities. Some work carried out under the Building Quality Restoration Program (such as installation of new lighting systems) has been based on this justification.

6.2.4 User Expectations

Users may expect that in return for their efforts to conserve energy, the school system should also make a contribution. This viewpoint was expressed by several users in Grande Prairie who felt that any dollar savings from more conservative use and operation should be "ploughed back" into upgrading of the school buildings.

All of the forgoing factors necessitate a specific evaluation of retrofit on a school system by school system and building by building basis.

7. ASSESSMENT OF GRANDE PRAIRIE ENERGY UTILIZATION FROM ARCHIVAL DATA

As stated in Chapter 4, thorough analysis of energy use in buildings must proceed from general comparative analysis to more specific evaluation of building systems and activity programming. This chapter examines characteristics of energy utilization in Grande Prairie School District as revealed by information obtained from utility invoices.

Data collected by surveying selected Alberta school systems made possible the most elementary step in a comparative evaluation of performance - comparison between members of a specific consumer group based on past performance.

As an additional check on energy use in Grande Prairie Public School District, consumption rates were compared with those for buildings belonging to the local separate school district. Grande Prairie Roman Catholic Separate School District No. 28 operates four schools within the same municipal boundaries as the public school system. An inspection of Catholic schools was carried out to supplement consumption records with observations on the facilities.

More intensive data collection was undertaken for the public schools to examine variations not only between buildings, but also over time.

7.1 Energy Consumption Rates of Selected Alberta School Systems

Table 5.7 contains statistics on reported 1977 energy consumption rates for several Alberta school systems. Grande Prairie was about 25 percent above average in electricity consumption and average in natural gas consumption.

Heating is the major environmental control load in Alberta schools. From Table 1.1 it is evident that heating requirements in five Alberta regional centres vary by up to 14 percent from the average annual value of 5366 Celsius degree-days (Calgary comes closest to the average value for these five centres). However visual inspection of natural gas consumption rates and geographic location of school districts showed little relationship between variations in natural gas consumption and heating requirements. Adjacent jurisdictions experienced discrepancies of 20 percent in more than one instance, while colder sites were observed to experience lower levels of consumption than warmer sites. Thus, in spite of measurable climatic variations within the province, geographic variations in consumption rates appear to be influenced more strongly by other factors.

7.2 Energy Consumption Rates in Two Grande Prairie School Systems

Tables 7.1 and 7.2 summarize statistics on 1977 specific energy need of buildings operated by the separate and public school districts in Grande Prairie. Overall system average consumption is 60.5 W/m^2 for the former and 57.2 W/m^2 for the latter. When total resource demand is considered, the figures are closer to 78 W/m^2 for the former and 80 W/m^2

Table 7.1. 1977 specific energy need and consumption rates for Grande Prairie Roman Catholic Separate School District No. 28 buildings. (based on utility company records).

Building	First Year of Operation	Area (m^2)	Consumption (W/m^2) Natural Gas	Electri-city	Total
Holy Cross	1954	2198	60.5	3.6	64.1
St. Clement's	1961	1712	57.4	3.6	61.0
St. Gerard	1963	1640	38.7	4.7	43.4
St. Joseph's	1965	3707	60.8	4.4	65.2
District Average Specific Need			54.3	4.1	58.4

for the latter. Differences in consumption lie in patterns of energy use. Electrical use is greater for the public school district, while natural gas requirements are lower.

It is interesting to note that Holy Cross School (1954) and the Old Montrose School (1950) exhibit similarly high rates of natural gas consumption. Both employ hot water heating systems and have similarities in construction detail. On the other hand, St. Clement's School (1961), which bears many similarities to Avondale (1956), consumed 40 percent more natural gas in 1977 on a per unit basis.

The two high schools, which comprise large segments of both school district's facilities (40 percent of gross floor area in both cases), exhibited markedly different performance. St. Joseph's consumed 27 percent more natural gas and 54 percent less electricity than the Composite High School. These schools, although of comparable vintage and located within several metres of each other, are constructed quite differently.

Table 7.2. 1977 specific energy need and consumption rates for Grande Prairie School District No.2357 buildings (based on utility company records).

Building	Electricity Consumption Rate (W/m^2)	Natural Gas Consumption Rate (W/m^2)	Total Purchased Energy Consumption (W/m^2)
Avondale Elementary	5.1	40.8	45.9
Hillside Elementary	7.3	41.9	49.2
Parkside Elementary	9.6	42.6	52.2
Swanavon Elementary	8.0	44.4	52.4
Old Montrose Junior High	3.4	52.3	55.7
New Montrose Junior High	4.2	44.6	48.8
Composite High	9.6	47.7	57.3
Administration Building	5.6	49.5	55.1
Central Park Auxiliary Building	1.0	70.0	71.0
District Average Specific Need	6.0	48.2	54.2

In terms of functional space planning, one would expect St. Joseph's School to be more efficient in natural gas use. However this is just one factor affecting consumption rates and, in this case, apparently other factors dominate.

Lower levels of lighting at St. Joseph's combined with fewer hours of usage explain some of the variation in electricity consumption rates.

7.3 Energy Consumption Rates in Public School District Buildings

Table 7.2 summarizes 1977 specific energy need and natural gas and electricity consumption rates for Grande Prairie Public School buildings (the administration and maintenance building is included in this comparison). To facilitate comparison normalized gas and electricity consumption rates (actual rates divided by average district energy consumption rates) are shown in Table 7.3, together with the percentage of total gross floor area which each building in the district represents.

Table 7.3. Rationalized 1977 energy consumption rates for Grande Prairie School District No. 2357 buildings.

Building	Percent of GFA	Rationalized Consumption Electricity	Rationalized Consumption Gas	Effective Consumption Electricity	Effective Consumption Gas
Avondale	8.3	0.72	0.85	6.0	7.0
Hillside	10.5	1.03	0.87	10.8	9.1
Parkside	7.5	1.35	0.88	10.1	6.6
Swanavon	7.0	1.13	0.92	7.9	6.4
Old Montrose	12.2	0.48	1.09	5.8	13.2
New Montrose	16.8	0.59	0.93	9.9	15.6
Composite	43.9	1.35	0.99	59.2	43.5
Administration	3.4	0.79	1.03	2.7	3.5
Central Park	2.6	0.10	1.45	0.3	3.8
			TOTAL	112.7	108.7

The percentage gross floor area is multiplied by the normalized rates to obtain figures included in the fourth and fifth columns, labelled effective electricity and natural gas utilization. From the normalized rates it can be seen that significant variations occur, with a couple of buildings exhibiting much higher than average consumption rates. The effective energy utilization figures show the combined impact of relative size and relative consumption rate on overall school system performance. Demand for electrical energy at the Composite High School predominates in determining system efficiency for that energy form. The same building also has a major influence on overall natural gas consumption.

Comparison of utility purchases from year to year was undertaken to examine the variability of annual consumption rates. Annual variations in weather (particularly temperature) markedly affect demand for natural gas, the main source of supplementary heat. Degree-days of heating are used as a measure of heating requirement; gas consumption can be rationalized by this measure of heating requirement to correct for yearly fluctuations in average temperature. Figure 7.1 shows natural gas demand at Avondale School over several years; one plot shows the actual consumption rate, while the other shows the consumption rate corrected for variations in annual heating requirements (a much flatter curve).

Annual electricity consumption rates for these buildings are not so dependent on weather and do not require such corrections.

Figures 7.2 through 7.5 show consumption of electricity and natural gas over several years for Grande Prairie Public School District buildings. Some variations in electricity and natural gas consumption rates were attributable to additions to and renovations of existing buildings. Additions were made to the Composite High School in 1974, to the Ad-

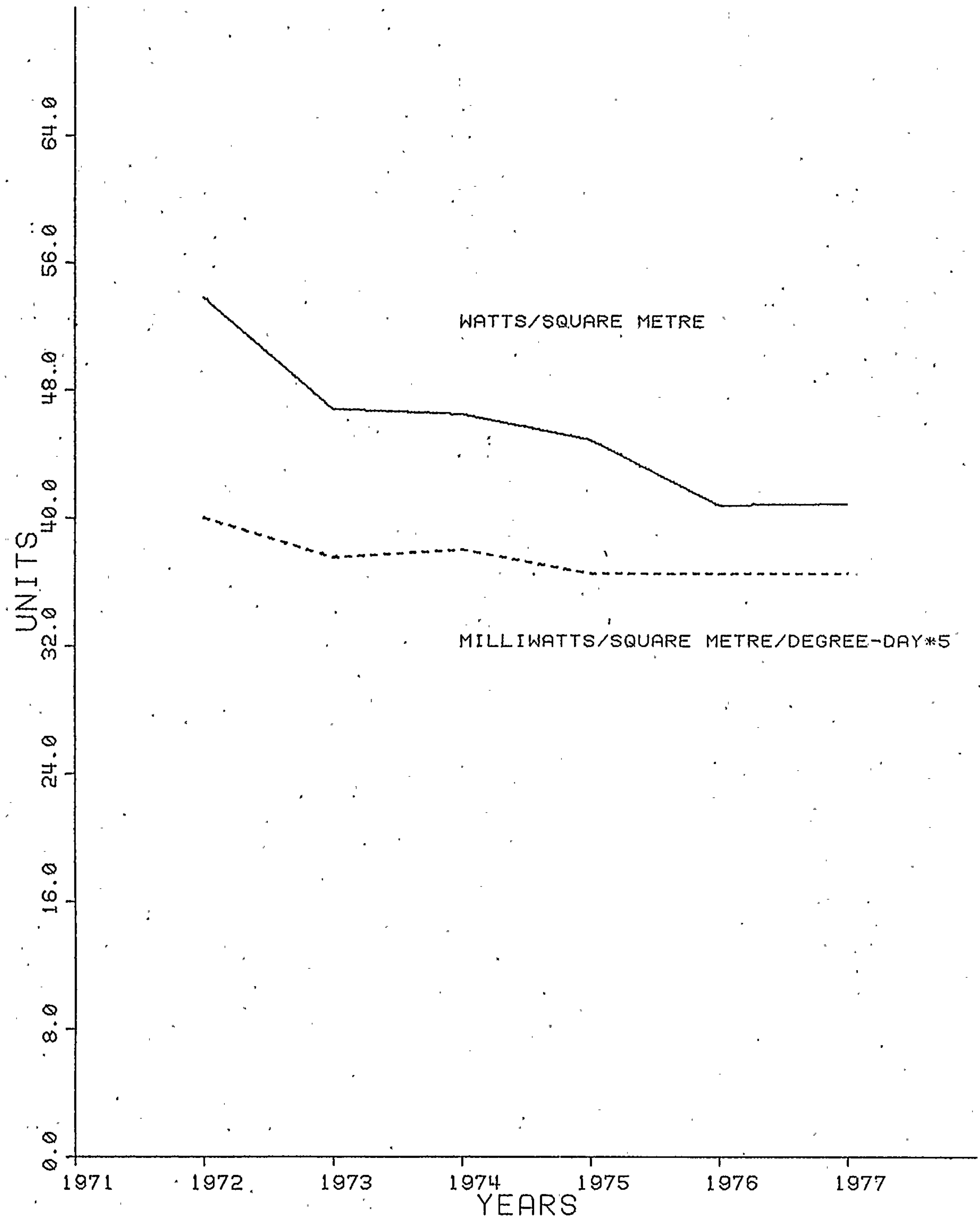


Figure 7.1 1972-77 natural gas consumption rates for Avondale School (based on utility company records). The plotted lines show actual rates and rates corrected for different annual heating requirements.

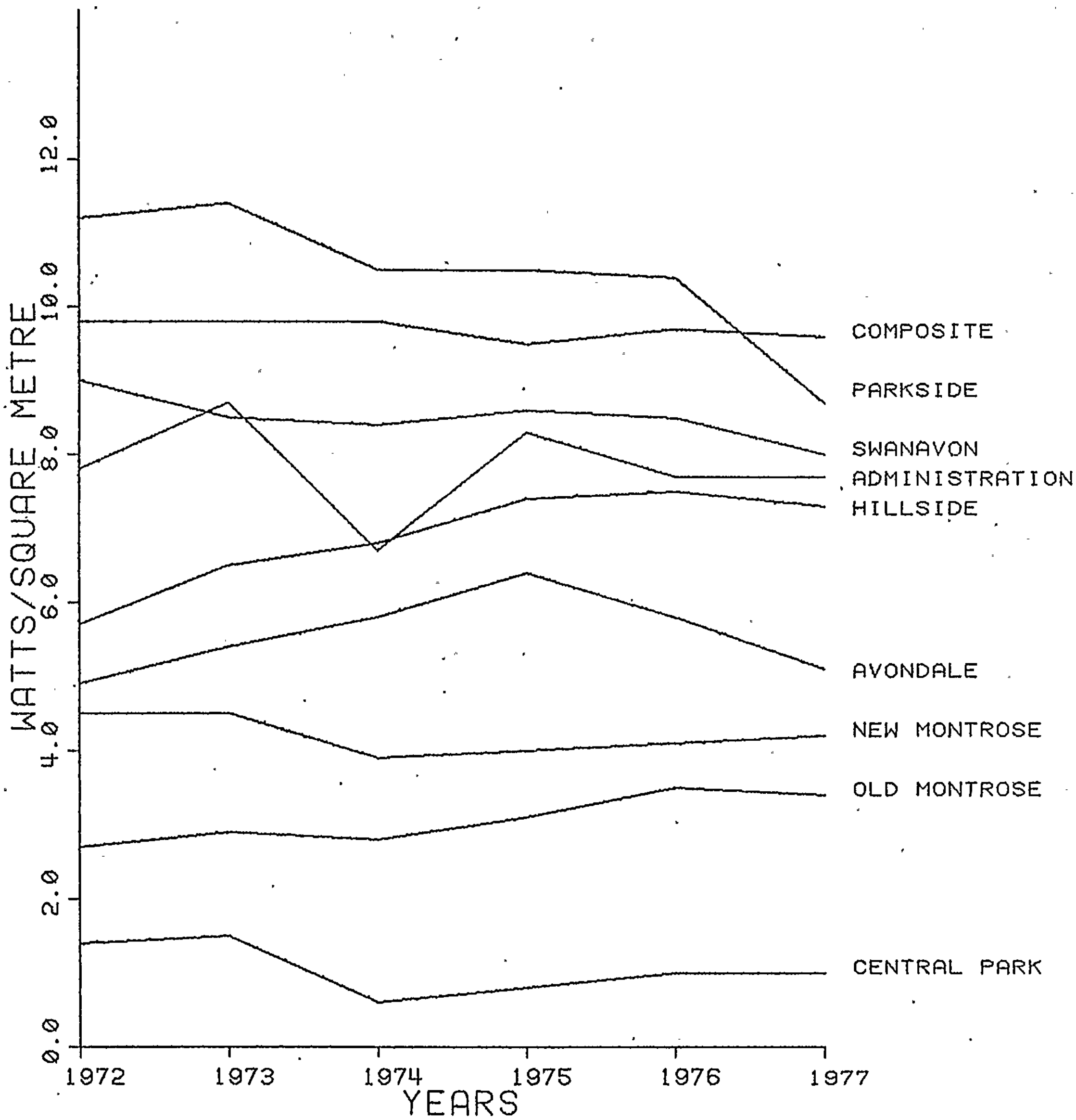


Figure 7.2 1972-77 electricity consumption rates for Grande Prairie School District No. 2357 buildings (based on utility company records).

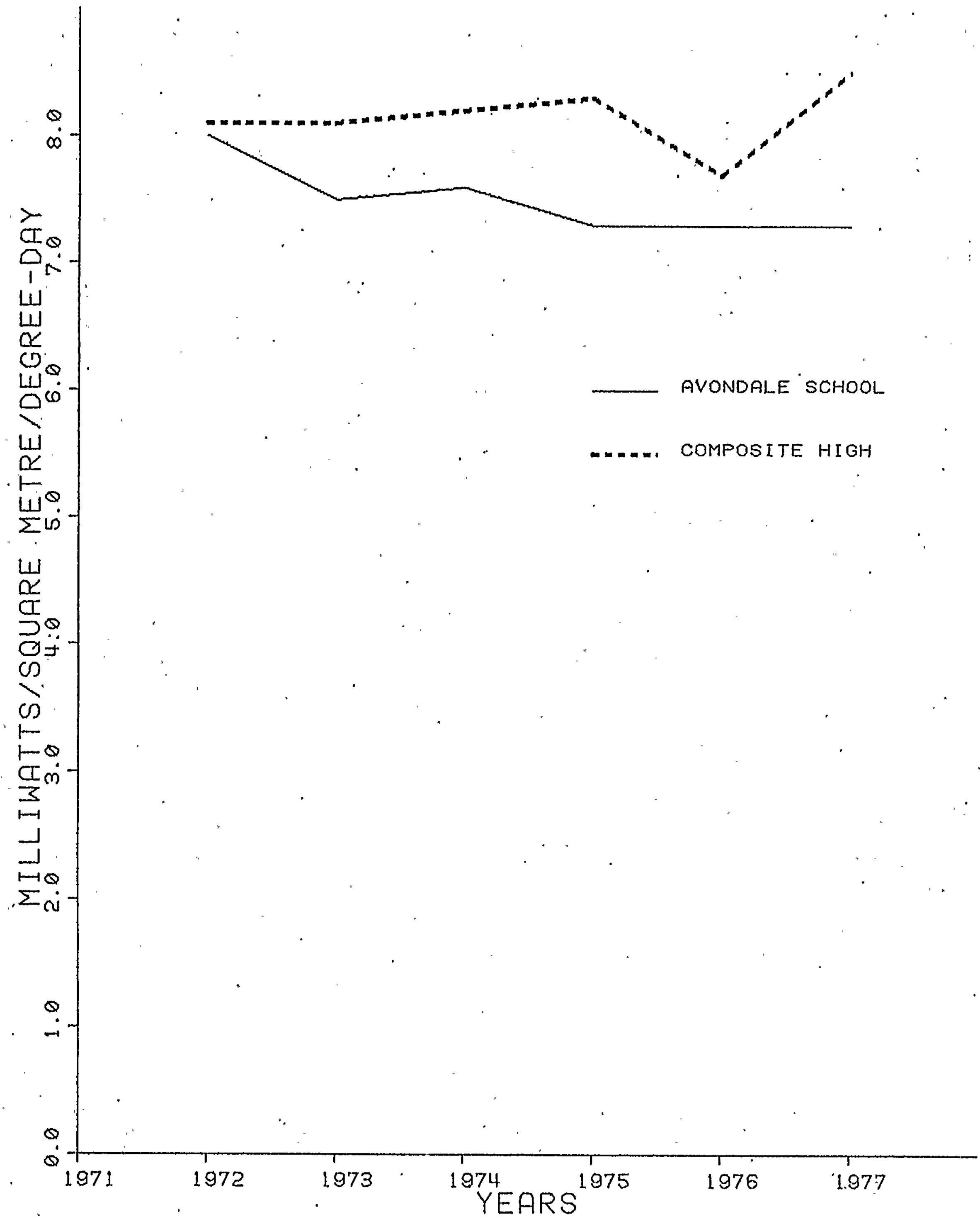


Figure 7.3 1972–77 natural gas consumption rates for the Avondale and Composite High Schools (based on utility company records). The plotted rates are corrected for different annual heating requirements.

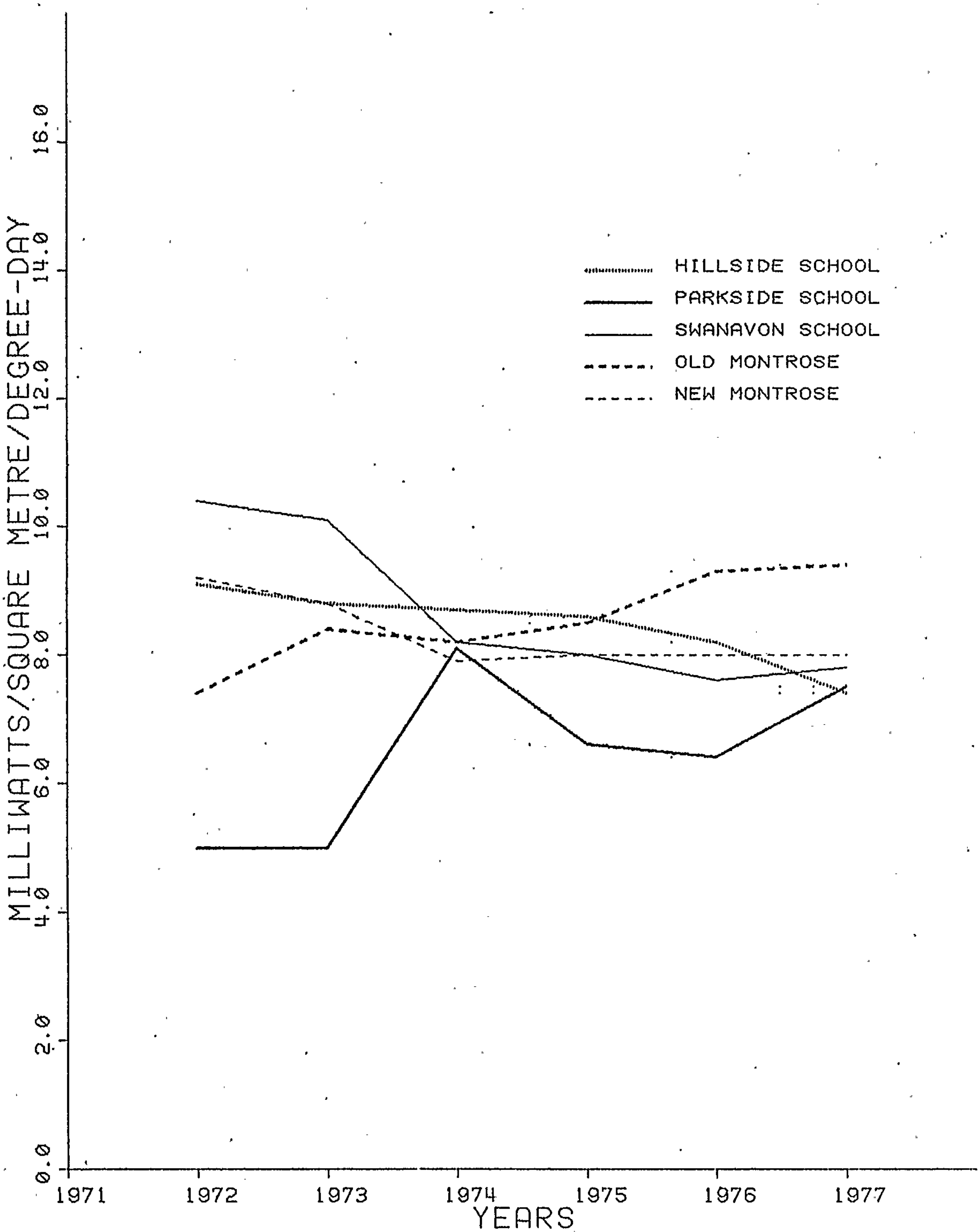


Figure 7.4 1972–77 natural gas consumption rates for the Hillside, Parkside, Swanavon, Old Montrose, and New Montrose Schools (based on utility company records). The plotted rates are corrected for different annual heating requirements.

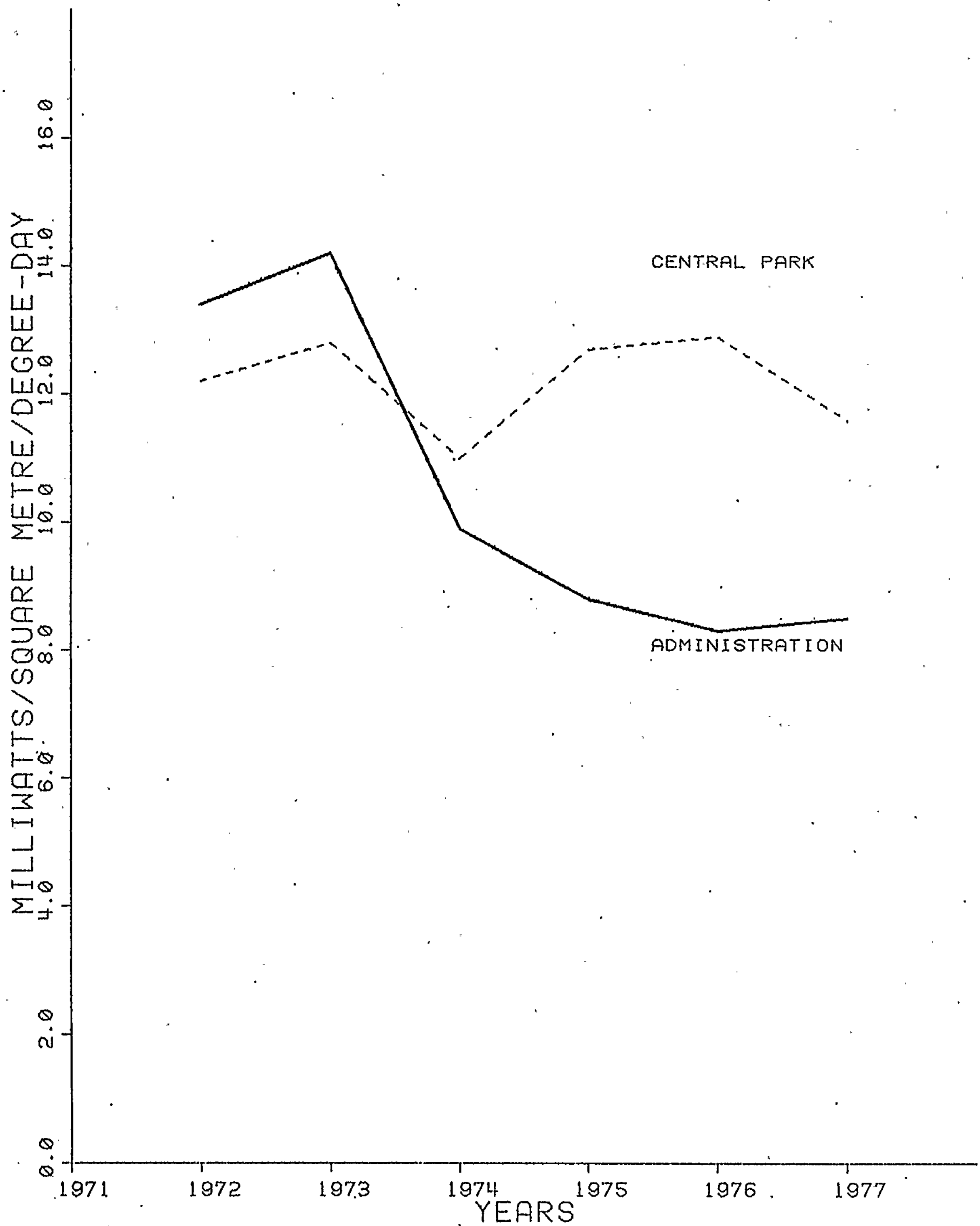


Figure 7.5 1972-77 natural gas consumption rates for the Administration Building and Central Park School (based on utility company records). The plotted rates are corrected for different annual heating requirements.

ministration building in 1973, and to Hillside School in 1977. The Old Montrose School was damaged by fire and renovated in 1977. Lighting was modified at the Avondale and Hillside schools in 1977. However significant variations in electricity consumption occurred independently of physical modifications, as is most dramatically illustrated by the 1977 decline in electricity consumption at the Composite High School (since the schools were not under observation before September of 1977 exact causes of such shifts are difficult to determine). Visual inspection of the plots shows that performance is affected by factors other than heating requirements, since there is little agreement in performance trends for the schools over the years. This suggests that use and operation of individual buildings plays a major role in shaping annual fluctuations in performance.

Building electricity consumption rates have been fairly consistently stratified over the years, and have exhibited a very wide range of values (from 1.0 to 9.6 W/m^2 in 1977). The spread in natural gas consumption rates (corrected for variations in annual heating requirements) has been more limited (between 7.0 and 11.6 mW/m^2 per degree-day, with most buildings consuming between 7.0 and 8.5 mW/m^2 per degree-day in 1977). Some buildings have undergone large changes in natural gas consumption rates over the years, even becoming more or less efficient than other buildings.

Table 7.4 compares rankings of the school buildings when ordered according to installed electric capacity (electric billing demand) and annual electricity consumption rates. Although the ranking correspondence is not one to one, it is very close. The major ranking discrepan-

Table 7.4. Electric capacity and electricity consumption rates for Grande Prairie School District No. 2357 buildings (based on utility company records).

Building	1977 Electricity Consumption Rate (W/m^2)	Building	1977-01 Billing Demand for Electricity (peak kW)	(peak W/m^2)
Composite	10.4	Parkside	88	35
Parkside	9.7	Swanavon	70	30
Swanavon	8.5	Composite	400	25
Hillside	7.5	Hillside	88	25
Avondale	5.8	New Montrose	118	21
New Montrose	4.1	Avondale	48	17
Old Montrose	3.5	Old Montrose	56	14
Central Park	1.0	Central Park	12	14

cy occurs in the case of the Composite High School. The higher consumption relative to capacity is attributable to more extensive use of the high school facilities for evening and weekend activities.

Figures 7.6 and 7.7 show the distribution of 1977 school system demand for electricity and natural gas on a monthly basis. Electricity consumption was fairly consistent over the school year - spring, fall and winter average consumption rates varied by less than 5 percent.

During July and August (when Grande Prairie public schools are not in use) electricity consumption amounted to 10 percent of the annual total. Natural gas consumption rates exhibited a much greater seasonal variation, in accordance with monthly heating requirements; almost 60

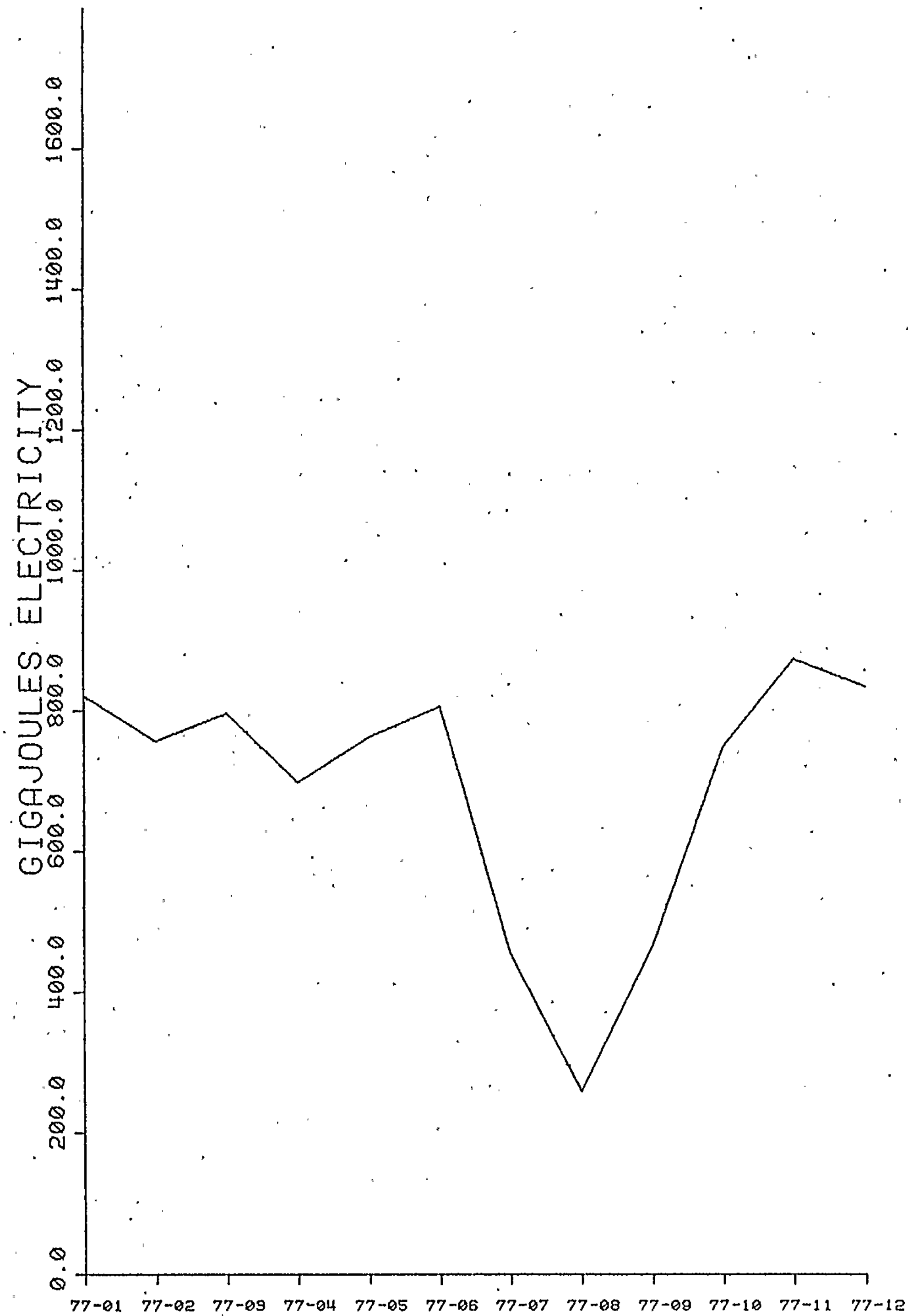


Figure 7.6 1977 monthly electricity consumption in Grande Prairie School District No. 2357 (based on utility company records).

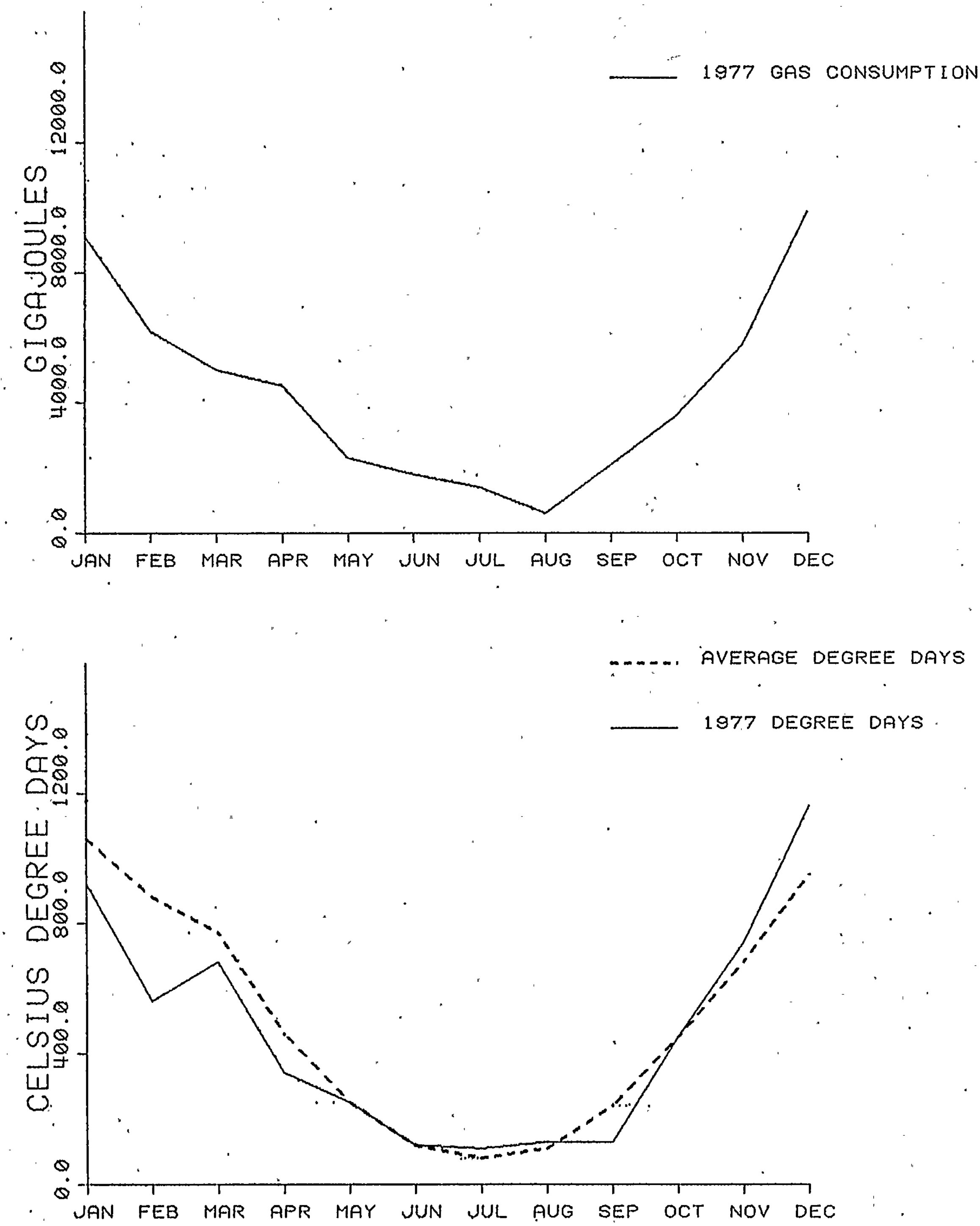


Figure 7.7 1977 monthly natural gas consumption in Grande Prairie School District No. 2357 compared with monthly heating requirements (based on utility company records and meteorolgical data).

percent of annual consumption occurred in the mid-November to mid-March period. Only 4 percent of annual consumption occurs in the July-August period, and only 11 percent in the mid May to mid September

7.4 Conclusions

The following conclusions were reached based on the analysis of archival data:

(i) Grande Prairie Public School District is typical of Alberta school systems with similar enrolments in its building energy requirements.

(ii) Examination of individual buildings in the system revealed subtantial variations in performance between buildings and over time which suggested that better regulation might be possible.

(iii) Analysis revealed a potential for energy savings during the summer months.

(iv) It is evident that in determining overall system performance, the high school plays a major role.

8. TECHNICAL ASPECTS OF ENERGY MANAGEMENT IN GRANDE PRAIRIE SCHOOL DISTRICT

The preceding chapter examined patterns of energy utilization in Grande Prairie School District facilities; this chapter examines some of the determinants of building energy consumption levels and types of measures used to reduce these levels.

8.1 Technical Analysis: Human Comfort

The primary function of buildings is to provide spaces where people can engage in various activities with an economic minimum of disturbance by the natural environment. Extensive research has been invested in the definition of conditions for human physiological and psychological comfort. By utilizing scientifically developed criteria the building designer can propose enclosure systems and environmental control systems with some degree of confidence that they will meet human requirements. The same criteria can be used to assess whether performance of an existing building is adequate. The criteria are based on averages of human reactions to environmental conditions staged in laboratories; in practice, each individual is the best judge of his own comfort.

Most notable in the successful propagation of standards have been the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE, 1977) and the Illuminating Engineering Society (IES, 1972). Standards exist for thermal comfort, illumination levels, ventilation rates, humidity and noise. The first three receive greatest attention in design of Alberta schools since they are most obviously of concern in the Canadian environment.

Comfort conditions are functions of activity, attire, and age, as well as of the physiological and psychological characteristics of the individual. Typically accepted schoolroom standards specify 0.019 m^3/sec/person ventilation (ASHRAE Standard 62-73), 22 degrees Celsius to 25 degrees Celsius room temperature (ASHRAE Standard 55-66), and 300 to 1100 lux (30 to 110 footcandles) of illumination (IES, 1972); these examples provide some indication of the types of measures used to specify criteria.

A much more detailed knowledge of principles and guidelines is required for competent design. In ensuring adequate ventilation, it is also necessary to avoid subjecting occupants to excessive drafts. In ensuring thermal comfort not only air temperature, but also temperatures of wall surfaces must be considered (to avoid excessive radiant heat loss to exterior walls in winter, for instance). In ensuring a comfortable luminous environment not only the level of lighting, but also glare and shadow must be considered.

Thermal regime, illumination levels, and air quality affect both energy consumption and human comfort (McNall, 1976). Excess levels of service provided over several hundred hours per year can be a needless energy expenditure. Remedying insufficient levels of service can increase human health and productivity. Many Canadian buildings do not meet recognized standards, either through excess or deficiency. Matching of performance to standards has been extensively documented (Dubin, 1976).

A more controversial aspect of guidelines is their validity. Illumination guidelines are the most intensely disputed standards for environmental control. Proponents of higher lighting levels argue that they increase human productivity, while proponents of lower lighting levels maintain that increments in productivity dwindle rapidly above 200 lux. With the marginal cost of providing increasing levels of illumination rising sharply and the marginal benefit of more illumination tapering off at higher levels, critical re-examination of standards is tending to favour a less resource consumptive tradeoff. For spaces which are mechanically cooled the resource cost is compounded by the thermal inefficiency of lighting systems. Richard Stein (Stein, 1976) presents many of the arguments against the high levels of illumination specified in IES lighting standards. Research funded by the General Services Administration in the United States has also contradicted IES sponsored findings. Although some school districts have moved to even lower levels (Thomas, 1976), standards recommended by the GSA (Wotton, 1976) were adopted as minimum average levels for Grande Prairie schools:

(i) Workplace - 540 lux (50 footcandles) (planar)

(ii) Background - 320 lux (30 footcandles) (planar)

(iii) Corridors - 110 lux (10 footcandles) (planar)

Many factors enter into high quality illumination apart from lighting levels; one must consider shadow, glare, and light distribution. These are discussed by Stein, Wotton, and other authors. Care was taken to ensure that they were considered when making modifications in Grande Prairie.

The thermal regime maintained in a building is also a major determinant of energy consumption levels, and manipulation of this regime is also being examined as a source of energy savings. ASHRAE Standard 55-74 maintains that "normally clothed adults engaged in office activity" are comfortable between 23 and 26 degrees Celsius at low relative humidity. Other sources show comfort for Canadians occuring at 21 degrees Celsius (Olgyay, 1963). The British comfort zone ranges from 15 to 21 degrees Celsius (Brooks, 1956)! Scientific experiments have demonstrated that sedentary job performance and comfort are actually improved when the ambient temperature is reduced from higher to lower temperatures (25.6 to 20.0 degrees Celsius - Reddy, 1976). Again, the standards vary, and the literature must be consulted for more detailed analysis of the causes. The temperature at which most people will be comfortable can be shifted higher in summer and lower in winter (to reduce respective cooling and heating loads) by removing or adding clothing. For a man dressed in a warm suit the comfort zone boundary may lie around 18 degrees Celsius; for a man dressed in a light suit the comfort zone boundary may lie around 26 degrees Celsius (McNall, 1976).

Standards are necessary for protecting health, for guiding plant operation when control is not decentralized, and for general purposes of specification. The best guide to human comfort will be the acceptance of conditions by users. This may be as much a psychological as a physiological acceptance.

8.2 Technical Analysis: Physical Plant

8.2.1 Conservation Measures

Technical measures for improving energy efficiency may be grouped in three categories.

8.2.1.1 Period of Operation

Reducing the time for which any active system must operate will generally tend to reduce annual energy requirements.

Instructional days in schools number less than 200; at 9 hours of use per day this amounts to less than 25 percent of the 8760 hours in a year. For two summer months each year only custodial and maintenance staff may have access to the buildings. During the winter school space may lie unoccupied for 12 to 24 hours per day; at times these spaces are unoccupied for up to a week. Of course, community uses and other functions add to the number of hours when conditions for human comfort must be sustained.

During off hours tolerances for interior conditions can be relaxed permitting energy savings (ventilation is not required, warmer or cooler temperatures are acceptable). Adjustment of conditions will still require recognition of considerations other than human comfort and energy conservation. Some heating during the winter, for instance, is still necessary to ensure durability of building systems and components. Within the limits of these physical constraints, substantial energy savings are theoretically realizable through off hour reductions without affecting primary activities.

This is not meant to imply that community uses of schools should be discouraged. The reverse is true from a community planning standpoint. Increasing the "load factor" for public buildings can be a very significant means of conserving both energy and capital. The incremental costs of additional use may actually be quite small, as will be demonstrated in chapter 13.

During "business" hours conditions for human comfort must be satisfied. Because switches and thermostats are highly decentralized control mechanisms, demands on building systems will largely be determined by individual users. If users become more conservative in their demands building performance can be improved.

8.2.2 Level of Operation

The rate of doing work (power) multiplied by the time over which the work is performed determines the energy consumption. Reducing the level of operation at which any active system must operate will generally tend to reduce annual energy requirements. It can also reduce the peak demand factor on which some utility charges are based. Such reductions may be possible if a building system is over-performing or if demand on the system can be reduced.

8.2.2.1 Efficiency of Operation

The less energy a system requires to perform a given task, the more efficient it is. Proper maintenance of equipment (lubrication, adjustment, etc.) is one aspect of ensuring the application of full energy potential. Buildings are frequently operated by individuals lacking an understanding of the systems, resulting in excessive consumption (Saunders, 1976). The same problem was found with some consistency in this study.

8.2.3 Building Systems

The building systems to which measures may be applied are as follows:

- (i) enclosure systems (walls, windows, and roofs)
- (ii) space heating systems
- (iii) lighting systems
- (iv) domestic water heating systems
- (v) circulating systems (ventilation air, domestic water)
- (vi) auxiliary systems (shop, office, audiovisual)
- (vii) space cooling systems
- (viii) humidification systems
- (ix) control systems

Enclosure systems and control systems consume the least energy, but are the most important systems in reducing energy consumption. By reducing heat loss/heat gain, the enclosure system significantly reduces utility consumption. It must be maintained in good repair to minimize air infiltration and heat conduction. Control systems are the mechanical intelligence which govern environmental control system operation, or which allow humans to govern operation. It is important that they be accessible, functional, and calibrated as accurately as possible.

It is not possible to review all the features of building systems and their impact on building energy requirements in this report. Detailed discussions of relevant topics may be found in the literature (Dubin, 1976).

8.3 Conclusions

Rationalization of energy consumption levels exhibited by a building is subject to constraints not only of utility costs, but also of human comfort and material durability of building components. However, by satisfying these constraints with economy of energy expenditure, both energy and financial resources can be conserved.

9. FINANCIAL ASPECTS OF CONSERVATION IN GRANDE PRAIRIE SCHOOL DISTRICT

The federal government has a stated objective of energy self-reliance for Canada. Nine major policy elements have been proposed in support of this objective. The first policy element is "appropriate energy pricing": "Domestic prices must continue to increase, to reinforce efficiency and restraint in energy use". The second policy element is "energy conservation": "The federal government's energy conservation programme is designed to encourage efficiencies in energy use and, more generally, to reduce the rate at which Canadian energy requirements will grow in the future" (EMR, 1976). Provincial governments are similarly encouraging restraint in energy consumption.

Increasing prices are intended as a signal to consumers that efficiency of energy use must be increased; the interest in conservation expressed by Grande Prairie School District shows that this economic message has been received and correctly interpreted. To clarify the specific local implications of increasing energy prices, an analysis of school district budgeting and of retail energy pricing in Grande Prairie is undertaken in the following sections.

9.1 Utility Expenditures and School District Budgeting

As a fraction of the total school district budget, Grande Prairie School District utility expenditures amount to only 3.9 percent (based on the 1977 budget - see Figure 9.1). As a fraction of non salary expenditures they amount to 13.0 percent. At international prices for energy, the value of utility services purchased would have amounted to ap-

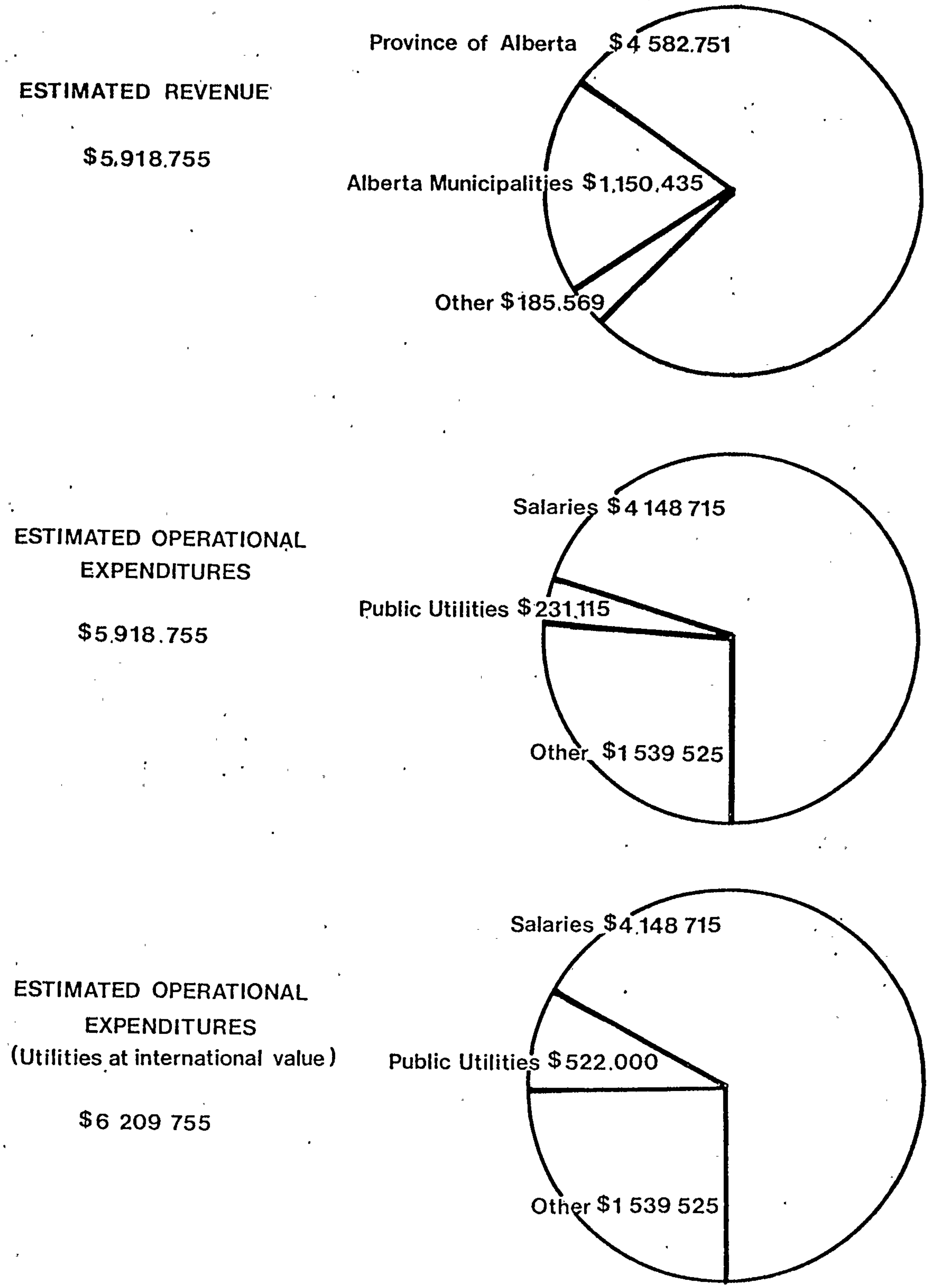


Figure 9.1 1977 Sources of revenue and allocation of funds in Grande Prairie School District No.2357. A hypothetical set of expenditures with utility prices at international rates is shown.

proximately 8.0 percent of the total budget, and approximately 25.0 percent of non salary expenditures, over the same period. The increase in total school district funding required to cover such an increase in utility expenditures would have been 4.9 percent, had it been necessary. From this perspective present shifts in fossil fuel prices pose a significant but not a catastrophic financial threat to the school district.

At international energy prices, the physical work a man can perform daily is valued at less than five cents (Leaney, 1977). This illustrates the present monetary cheapness of mechanical energy used in the western world (and the importance of conserving reserves which provide this energy). Where energy costs do begin to appear expensive in the short run is in the opportunity costs of inefficient energy use. Ten percent of the 1977 utilities budget could have purchased the services of a highly qualified teacher or almost half the new textbooks required annually by the district.

Average annual utility expenditure increases of about 15 percent have been the recent trend in Grande Prairie School District. Alberta Power Limited has advised the Grande Prairie School Board that increases in electric service tariffs of 20 percent annually may be expected over the next few years. At such a rate of increase the cost of electric service will double in less than four years. It is not unlikely, given stated government policy, that natural gas prices will also double over the same period. This means that inefficient operation will pose rapidly increasing opportunity costs over the next few years.

In the long run energy prices are difficult to estimate with both accuracy and confidence; questions of resource availability and international economics enter uncertainty into the energy situation. Given the cost of further resource development, future energy costs (in 1978 dollars) at double today's figures will probably be a minimum constraint in future financial planning.

9.2 Utility Tariffs and Dollar Conservation

Fiscal success of energy conservation must be reckoned in monetary terms. However, reductions in consumption cannot be directly translated into dollars; utility service tariff structures must be consulted to determine the dollar resultant of conservation efforts.

Table 9.1. Northwestern Utilities Limited Natural Gas Service Tariff effective 1977-08-01.

Billing Schedule:

1 Fixed Service Charge = $4.20

2 Energy Charge = .11/therm ($1.05/GJ)

3 Add 8.7% franchise tax to the total of 1 and 2

4 Subtract 3.5% provincial discount from the net of 1,2 and 3 combined

Formula: Effective Monthly Charge= $4.39 + $0.12 * Consumption in Therms

Table 9.2. Alberta Power Limited Electric Service Tariffs effective 1977-08-01.

from Rate Schedule 21 (General Service)

For the first 40 kWh per month per kilowatt of billing demand
$0.097 per kWh ($26.90/GJ)
For the next 160 kWh per month per kilowatt of billing demand
$0.058 per kWh ($16.10/GJ)
For all use in excess of 200 kWh per month of billing demand
$0.0321 per kWh ($8.90/GJ)

Billing Demand: The maximum electric demand (kW) experienced during either the previous 11 months or the current month.

Provincial Discount: A 3% reduction is applicable to the total charge for electric service.

Formula: Monthly Charge = 6.54 * Billing Demand + 0.0312 * Electric Consumption

from Rate Schedule 32 (Large General Service)

Demand Charge: For the first 300 kW or less $2607.45
For the next 200 kW $8.23 per kW

Energy Charge: For the first 400 kWh per kilowatt of billing demand
$0.0185 per kWh ($5.10/GJ)
For energy in excess of 400 kWh per kilowatt of billing demand
$0.0103 per kWh ($2.90/GJ)

Provincial Discount: A 3% reduction is applicable to the total charge for service.

Formula: Monthly Charge = $134.30 + 7.98 * Billing Demand + 0.0179 * Electric Consumption

(only if consumption is less than 400 times the billing demand)

Despite minor complications introduced by taxes and discounts, natural gas tariffs applied to Grande Prairie schools are relatively straightforward (see Table 9.1). A 10 percent reduction in gas consumption will immediately produce a reduction in billing very near to 10 percent.

Electric service tariffs often distort the translation of energy savings into dollar savings (see Table 9.2). The distortion is a reflection of infrastructure capitalization costs, operating costs, and politically determined pricing policies. Two electric rate schedules apply in Grande Prairie School District: Rate Schedule 32 only to the Composite High School, Rate Schedule 21 to all other buildings. Rate Schedule 32 offers a lower average unit cost to large consumers. In 1977, $11.90/GJ (4.3 cents/kWh) was paid for electricity at the larger school, while the average unit costs for all the other buildings combined was $14.40/GJ (5.2 cents/kWh). Customers of Alberta Power Limited are (according to company policy to be) billed according to the least expensive service tariff applicable.

Reduction of expenditures for natural gas can only be achieved through reduction of consumption. Reduction of cost for electricity can be achieved either through reduction of peak demand or reduction of consumption (see Table 9.3). A 10 percent saving in electricity consumption alone will not produce a 10 percent dollar saving, nor will a 10 percent reduction in billing demand alone produce a 10 percent dollar saving. Joint reduction of billing demand and consumption will produce the highest dollar return. This makes permanent reduction of base load the most attractive source of dollar savings; reduction of consumption over

Table 9.3. A study of hypothetical conservation efforts examining discrepancies between energy and dollar savings according to different scenarios.

Building	Billing Demand (kW)	Monthly Electricity Consumption (kWh)	Monthly Utility Change
A	360	100 000	$4957.25
B	80	20 000	$1181.20

Conservation Measure	Building	Reduction	Reduction in Monthly Utility Charge	
1. 2000 kWh reduction in consumption	A	2000 kWh	$37.00	0.7%
	B	2000 kWh	$64.20	5.4%
2. 2 kW reduction in peak demand	A	2 kW	$16.46	0.3%
	B	2 kW	$13.48	1.1%
3. 10% reduction in consumption	A	10 000 kWh	$185.00	3.7%
	B	2000 kWh	$64.20	5.4%
4. 10% reduction in peak demand	A	36 kW	$296.28	6.0%
	B	8 kW	$53.22	4.5%
5. 10% reduction in peak demand and consumption	A	(see above figures)	$481.28	9.7%
	B		$117.42	9.9%

shorter periods will produce disproportionately less significant monetary benefits (reducing disproportionately high billing demand by evening out peak loads may still be an important step in rationalizing expenditures).

Scrutiny of the electric service tariffs indicates that dollar savings achieved through a sustained reduction of peak electric demand would not accrue until 12 months after reduction was achieved. A very short relapse from good management practices (re-establishment of a higher peak) can greatly reduce monetary benefits of conservation for an extended period. Kilowatt-hour for kilowatt-hour, reductions in consumption at the smaller buildings produce almost a twofold larger dollar saving.

let D be the billing demand in kW
C be the monthly consumption in kWh
MCH be the monthly charge
ACH be the annual charge

from Table 9.2

Rate Schedule 21: MCH=6.54D + 0.0312C
Rate Schedule 32: MCH=7.98D + 0.0179C + 134.30 (D>=300)

Assuming 10 months operation annually and C to be the average monthly consumption during these months:

Rate Schedule 21: ACH = 65.4D + 0.312C

Rate Schedule 32: ACH = 95.8D + 0.179C + 1612. (D>=300)

By solution of simultaneous equations, the point at which equal charges are incurred is defined as:

D = 0.00437C - 53 (D>=300)
or C = 228.6D + 12 200 (D>=300)

At the 1978-05 billing demand of 360 kW average monthly consumption exceeding 94 400 kWh (340 GJ) makes Rate Schedule 32 more attractive. 1977 consumption averaged over 10 months was 124 000 kWh (446 GJ).

Figure 9.2. An examination of the transfer point for electric service tariffs applicable to the Composite High School.

The two electric rate schedules were analyzed to determine the point at which transfer from one schedule to another would occur (see Figure 9.2). This transfer point is a function of the relationship between billing demand and electricity consumption. Rate Schedule 32 favours consumers with a higher ratio of consumption to demand, and with demand not much less than 300 kW.

Rate Schedule 32 exacts a large charge for demand even when consumption is very low (as in July and August). Determination of the transfer point between schedules from monthly charge formulas would erroneously favour Rate Schedule 32 over a broader range than is actually economical, since it would not take into account the summer billing charges.

1977 performance of the Composite High School resulted in Rate Schedule 32 being substantially more favourable to the school district from a financial perspective. If conservation efforts could shift the advantage to Rate Schedule 21, this would be be significant because the immediately realizable benefits of further reductions in consumption would be increased by 75 percent due to the higher marginal cost of electricity under Rate Schedule 21 ($8.90/GJ (3.21 cents/kWh) versus $5.10/GJ (1.85 cents/kWh) under Rate Schedule 32).

Electric energy is far more costly than that obtained from natural gas. Average 1977 unit costs paid by the school district were $13.90/GJ (5.0 cents/kWh) for electricity and $1.14/GJ (12.1 cents/ therm) for natural gas. A 10 percent reduction in 1977 electricity consumption and peak demand at all schools would have saved the school district approximately $6000 per annum immediately and $12,000 per annum after 1978 (disregarding rate increases and assuming no relapses from conservation). A 10 percent reduction in 1977 gas consumption would have saved the school district $7000 per annum. The high cost of electricity, the relative ease of evaluating its end use efficiency, and the time delay preceeding the realization of full savings for reductions made it a first priority in rationalization of utility expenditures.

As was mentioned in 9.1, retail prices for energy can be expected to continue increasing at an escalation rate of 10 percent to 30 percent over the next few years. Potential energy savings are limited by constraints such as human comfort, equipment efficiencies, and building component durability. It cannot be expected, therefore, that energy management will reduce school district utility expenditures for more than a short period, if at all; from 1976 to 1977 alone the average unit price paid for electricity by Grande Prairie School District rose by 11 percent, and that paid for natural gas by 25 percent (see Table 9.4).

Table 9.4. 1976 and 1977 average unit prices paid for electricity and natural gas by Grande Prairie School District No. 2359.

	Average unit cost		
Utility	1976	1977	Increase
Electric	12.50 $/GJ (0.045 $/kWh)	13.90 $/GJ (0.05 $/kWh)	11%
Natural Gas	0.92 $/GJ (0.0097 $/Therm)	1.14 $/GJ (0.0121 $/Therm)	25%

However, failure to rationalize energy use will bear an increasingly heavy penalty. As unit prices continue to rise, more extensive investments of time, effort and capital in improved energy efficiency will be warranted. The real and significant benefit from energy conservation will lie in the forgone costs of continued excessive consumption.

10. INVENTORY

Early in the project an inventory of physical plant was conducted. Table 10.1 outlines the building systems which were studied and the kinds of information which were gathered. Tables 10.2 through 10.4 list some general characteristics of the buildings.

Table 10.1. Matrix showing types of data collected for various buildings in Grande Prairie School District No. 2357.

Information Gathered	Equipment Type	Equipment Model	Capacity	Layout	Zoning	Condition	Setting
Environmental Control System							
Space Heating	●	●	●	●	●	●	
Lighting	●		●	●	●	●	●
Domestic Hot Water	●	●	●	●	●	●	●
Circulating	●	●	●	●	●		
Space Cooling	●	●	●	●	●		
Control	●	●					●
Auxiliary	●			●			
Enclosure	●			●		●	

Table 10.2. Basic information on Grande Prairie School District No. 2357 buildings.

Building	Year of Construction	Gross Floor Area (m^2)	Levels	Heating System Type	Air-conditioning
Avondale	1956	2 781	1	forced air	no
Hillside	1959	3 506	1	forced air	no
Parkside	1973	2 511	1	forced air	partial
Swanavon	1957	2 334	1	forced air	no
Old Montrose	1950	4 083	2	hot water	no
New Montrose	1961	5 617	1	forced air	no
Composite	1962	14 694	1	forced air	partial
Central Park	1929	874	2	hot water	no
Administration	1969	1 158	1	forced air	partial

Grande Prairie School District has an inventory of 145 main heating units in eight school buildings. These were supplied by a dozen different manufacturers, and include two dozen model types and sizes. This small sample gives some indication of the rather staggering amount of information describing physical plant.

The information was largely organized by coding it on school floor plans - particularly lighting layout and capacity (power), illumination levels, equipment location, and data on thermostats (location, setting, and condition).

Table 10.3. Information on electrical systems in Grande Prairie School District No. 2357 buildings.

School	Installed Electric Capacity (W/m^2) Total	Lighting	Other	% Other	Classroom Illumination (planar lux)
Avondale	17	14	3	17.6	430 to 860
Hillside	25	22	3	12.0	1080 to 2040
Parkside	35	24	11	31.4	800 to 900
Swanavon	30	24	6	20.0	250 to 1800
Old Montrose	14	8	6	42.8	540 to 760
New Montrose	21	11	10	47.6	300 to 760
Composite	27	18	9	33.3	550 to 1080

Table 10.4. Information on forced air heating systems in Grande Prairie School District No. 2357 buildings.

School	Heating System Input Capacity (W/m^2)	1977 Natural Gas Consumption (W/m^2)	Number of Gas Burning Units	Number of Thermostats
Avondale	277	41	17	14
Hillside	273	42	27	22
Parkside	230	42	15	9
Swanavon	293	44	26	17
New Montrose	246	45	47	40
Composite	230	48	58	70

The eight schools are similar in some of the basic buildings systems used to construct them (structural materials, heating units, etc.), but differ markedly in the particular organization of these components on each site.

The two oldest buildings, Central Park and Old Montrose, differ most from the other buildings. They are both two story structures and employ hot water heating systems with a single central boiler. These buildings exhibited the highest natural gas and lowest electricity consumption rates (Central Park is omitted from tables of data on electricity use because its consumption rate is so small that it is not even demand metered). High rates of heat loss may be attributed to infiltration around the extensive glazing and to the single glazing itself. The boilers are very old and decrepit, and the heating systems do not respond consistently to controls.

The newer buildings are virtually all single level concrete block construction, and all have forced air heating systems. All of the newer buildings have been modified in some fashion since construction. Even the newest school, Parkside, which was originally constructed with "open plan" classrooms, has been partitioned into smaller spaces.

Because of the detail which would be required to provide descriptions of every building, basic sample inventories of just two buildings (Parkside Elementary School and the Composite High School) will be presented.

Supplementary details concerning other buildings will be presented later.

10.1 Parkside Elementary School

Because of its relatively small size (see Figure 10.1) it is possible to present a relatively comprehensive set of information on Parkside School. The building also provides a more satisfactory model for study than some of the other schools because it has not been extensively modified since construction.

The building is in superior structural condition compared with other Grande Prairie schools - differential settlement has not yet become a problem.

Commonly used exits have vestibules, although fire exits from the gym and open areas do not have vestibules. Doors do exhibit substantial cracks between the door and frame (up to 10 mm).

Heat is supplied via a forced air system (see Tables 10.5 through 10.7). The heating system capacity and consumption are comparable to those of the other newer schools (see Table 10.4). The interior classrooms and the resource centre are served by a roof-mounted multi-zone air conditioning unit with a 40kW (132.5 kBtu/h) cooling capacity.

Records show that Parkside School exhibited the highest per unit electric demand in 1976 and had the second highest electricity consumption rate (Table 5.4). Table 10.3 shows that both lighting and non-lighting electric capacity were higher at Parkside School than at any other school. Actual illumination levels were above IES standards, but were exceeded at some other schools (in spite of their lower lighting power) because interior surface finishes at Parkside were more highly textured and of a relatively dark colour. The high non-lighting load is largely attributable to the excessive power of the heating and ventilat-

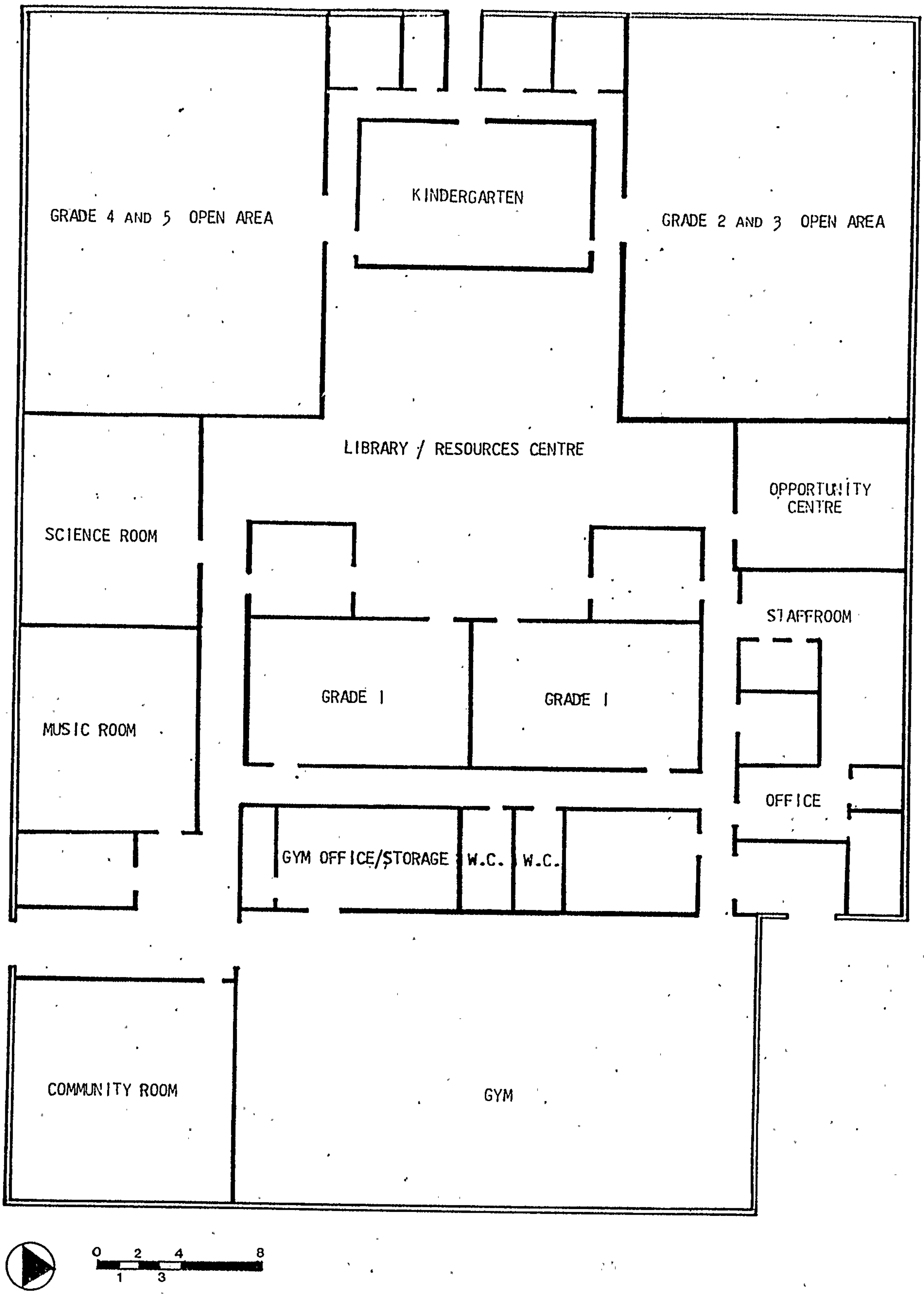


Figure 10.1 Plan of Parkside Elementary School.

Table 10.5. Information on heating units installed at Parkside Elementary School (broken down by unit capacity).

Number of Units	Unit Input Capacity (kBtu/h)	Unit Input Capacity (kW)	Total Input Capacity (kW)
4	82	24	96
4	137	40	160
2	110	32	64
4	165	48	192
1	220	64	64

Table 10.6. Information on fan motors installed at Parkside Elementary School (broken down by unit capacity).

Number of Units	Unit Motor Specified by Manufacturer (hp)	Unit Motor Installed by Contractor (hp)	Unit Motor Installed by Contractor (W)	Total Output Capacity (W)
4	0.25	0.33	246	984
4	0.33	0.75	560	2240
2	0.25	0.33	245	490
4	0.33	0.75	560	2240
1	2.00	2.00	1492	1492

ing system. The total air supply volume was found to be 10.7 m^3/sec (Table 10.7). At Sir Robert Borden High School in Ontario this parameter is only 23 m^3/sec for a building seven times as large (Graham, 1976). 10.7 m^3/sec amounts to 0.0305 m^3/sec per person at school utilization capacity; ASHRAE standards only call for 0.0023 in offices and

Table 10.7. Information on ventilation rates at Parkside Elementary School (broken down by unit capacity).

Number of Units	Unit Air Volume (cfm)	Unit Air Volume (m^3/sec)	Total Air Volume (m^3/sec)
4	800	0.368	1.47
4	1500	0.690	2.76
2	1000	0.460	0.92
4	1800	0.828	3.31
1	4800	2.208	2.21

0.0092 in gymnasia. The extra air intake represents a severely increased heating burden in winter.

10.2 The Composite High School

The Composite High School (see Figure 10.2) was constructed in three phases:

(i) 1962 - 7 244 m^2 (77,900 sqft)

(ii) 1969 - 5 989 m^2 (64,400 sqft)

(iii) 1974 - 1 739 m^2 (18,700 sqft)

The latest addition, the west wing (organized around the resource centre) is served by four roof mounted space multizone conditioning units. The classrooms were intended to be easily remodelled with "temporary" wall partitions. These have frequently been shifted to create

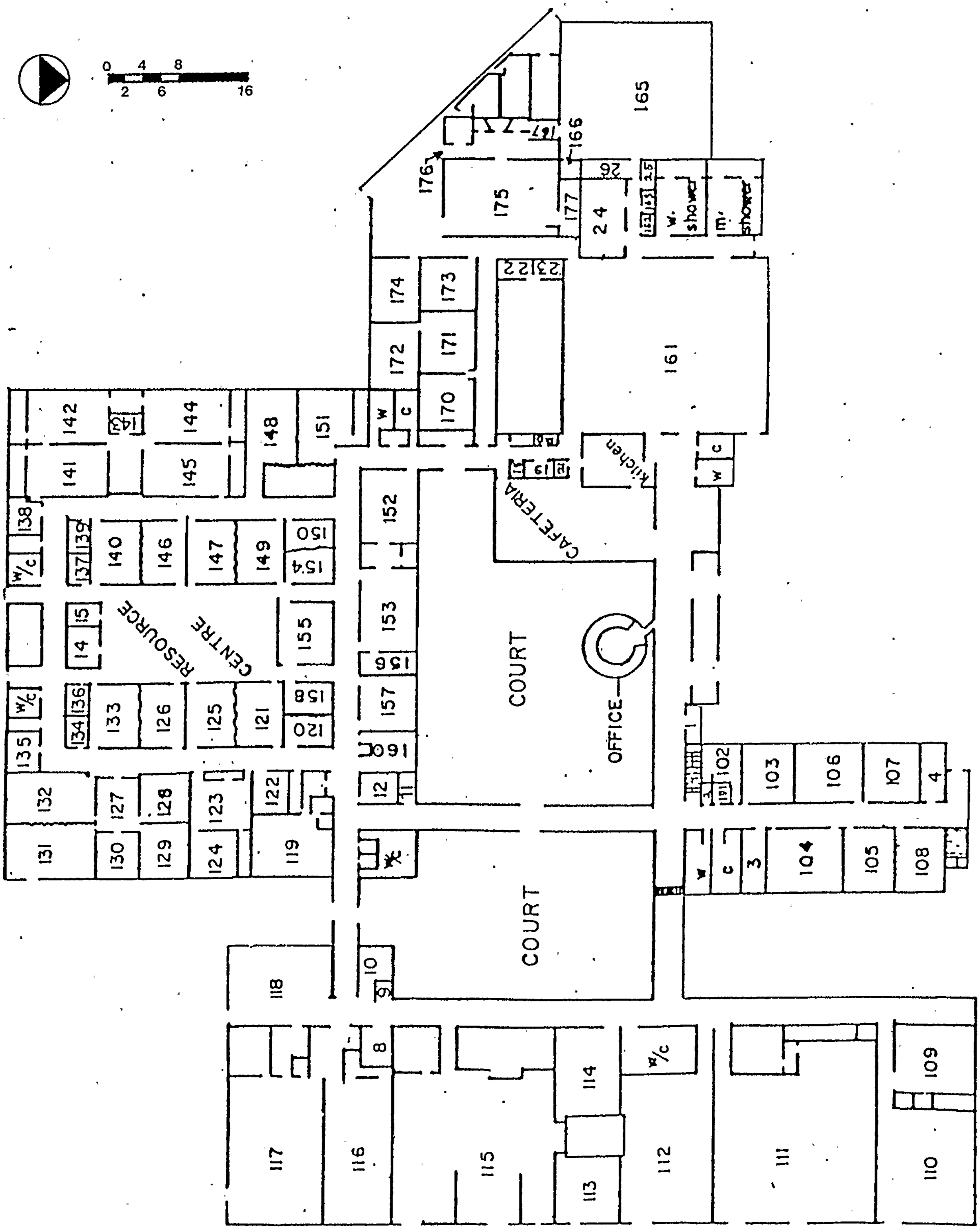


Figure 10.2 Plan of Grande Prairie Composite High School.

new spaces. However the ducting for the space conditioning system and the control systems have never been adapted to these new configurations. When the control systems for the space conditioning units were initially installed, coded wire was not used consistently. Therefore the maintenance staff has very little idea of how the controls are connected.

The other sections of the school are served by an assortment of forced air heating units including through wall unit heaters, small forced air furnaces, and ceiling suspended unit heaters. Some of these are located in very inaccessible locations, impeding maintenance and inspection.

Domestic hot water is provided by four heaters at different points in the building. The hot water distribution systems have been expanded in an ad hoc manner as the building has grown. Single systems heat very diverse functions and in some cases incorporate exceptionally long runs of piping.

Lighting levels varied from 500 lux in older classrooms to over 1080 lux in some vocational areas. The main entrance lobby was found to be illuminated with 1700 lux of artificial lighting, even though large amounts of daylighting are available.

Skylights in the gym had been blacked out to accomodate use of audiovisual equipment

Many entrance ways (particularly those providing access to the courtyards) have no vestibules. Cracks of up to 10 mm width were found between doors and frames.

More than a dozen thermostats were encased in protective metal enclosures; several others were encased in locked plastic boxes. Some thermostats were badly damaged.

The design organization of the building (original structure, additions, and modifications) is very inefficient from both maintenance and energy conservation viewpoints.

10.3 Common Building Characteristics Affecting Energy Performance

Some characteristics of buildings affecting regulation of energy utilization were recurrent.

10.3.1 Enclosure Systems

10.3.1.1 Differential Settlement of Foundations

Foundation instability has impaired the structural quality of all the newer schools in Grande Prairie, except for Parkside. Differential settlement of floor slabs and foundation footings is so bad that it is easily detected by visual inspection. In some cases, it exceeds 100 mm over intervals of 500 mm. This has led to rupture of the enclosure (both roof membrane and walls) and to unintended infiltration.

10.3.1.2 Seasonal Heaving of foundations

In many cases the differential settlement mentioned above varies from season to season. This complicates sealing of the envelope. For instance, doors which fit properly in one season may have large gaps in other seasons.

10.3.1.3 Vestibules

Entrances are major sources of air infiltration, and hence of heat loss in the winter. Yet many entrances in Grande Prairie schools lacked such elementary thermal buffers as vestibules.

Sometimes vestibules had been constructed but interior doors were removed. This precaution had usually been taken for safety reasons where vestibule doors had been designed so that the door swing could injure unsuspecting bystanders.

Observation of vestibules in use indicated that present design approaches do not commonly take into account actual functional requirements. Specifically, T-shaped entrances would serve to deflect wind and to better accomodate the use of vestibules as mud rooms. The matter would bear more detailed investigation to verify this observation.

10.3.1.4 Solar shading

The same rooms which could not be kept warm in winter could sometimes not be kept from overheating in other seasons due to lack of solar shading. In one school which was not utilized at 100 percent capacity, three south facing rooms were commonly not employed due to excessive heat gain in warmer months.

10.3.2 Space Heating Systems

10.3.2.1 Zoning and Control layout

In some classroom areas three rooms were served by a single thermostat and furnace. This usually meant that rooms varied in temperature according to the distance from the furnace and the relative position of the room in the building (one or two exterior walls). The variation was severe enough that when the thermostat was adjusted to keep a room with two exterior walls warm (in winter), windows had to be opened to keep rooms with only one exterior wall and on the same system from gaining excessive heat.

10.3.2.2 Mechanical Rooms

Mechanical rooms were frequently found to be cramped and to allow access to equipment only with difficulty. In at least one case, it is necessary to dissassemble some units when extensive servicing of their neighbours is required.

10.3.2.3 Tandem Units

Some larger spaces are heated by furnaces working in tandem. In virtually every case these had been connected so that separate operation was not possible. This means that modular operation cannot be employed to conserve energy in warmer months.

10.3.2.4 Shop Areas

Some shop areas require high rates of air exhaust to prevent the build up of fumes. Because these spaces were heated by forced air systems (as opposed to radiant heat systems), it was impossible to maintain these spaces at temperatures above 16 to 18 degrees Celsius for several winter weeks even with all heating units operating at full capacity. Air supplied by the heating units was simply evacuated by the exhaust units.

10.3.3 Lighting Systems

10.3.3.1 Blacked-out skylights

Skylights can reduce the requirement for artificial illumination. However because teachers did not have a convenient means of shutting out this light when using audiovisuals, the skylights in classrooms were almost always blacked out with cardboard. This meant that the penalty of the relatively poor thermal performance of the skylight was being paid without the benefit of the additional light.

10.3.3.2 Excessive Lighting

Illumination levels were found to be highly variable in the schools, as can be seen from Table 10.2. In some rooms the range of light intensity on student's desks was found to range from 200 lux (near room corners) to 2000 lux (near windows).

10.3.3.3 Mercury Lighting Systems

Lighting in several gymnasia had been upgraded from incandescent to mercury vapour type lamps. These provide only 51 lumens of light per watt, compared with 75 lumens per watt for flourescent type lamps. 50 percent more power is therefor required to obtain the same amount of light with a mercury system. Further, the mercury lamps require roughly 15 minutes to warm up before full illumination is provided by the mercury system. This means that users are reluctant to switch off these light during the day even when they are not in use.

10.3.4 Control Systems

10.3.4.1 Switches

In numerous instances, equipment could not be switched from reasonable locations. In one case the switch for an exhaust fan was located in the motor housing on the roof of the building. Unit heaters commonly have control switches mounted inside the housing; these can only be accessed by removing screwed on panels. In other cases equipment could only be switched by using circuit breaking equipment which is not designed for such use.

10.3.4.2 Thermostats

In the four High School and Junior High School buildings, many thermostats were damaged, inoperable or inaccessible (for their own protection in the last case). This impedes the adjustment of operating levels to current conditions.

10.3.5 Domestic Hot Water Systems

10.3.5.1 Aquastat Settings

Domestic hot water at all schools was between 50 and 60 degrees Celsius at the faucet (for most purposes 45 degrees is adequate).

10.4 <u>Equipment Operation Schedules</u>

Lighting was typically operated from between 07:00 and 08:00 until between 18:00 and 22:00 depending on the activity patterns within the schools.

The only timed regulation of building space conditioning equipment before the project was initiated was performed by a clock on the exhaust fans at Parkside School. These are set to operate from 08:30 to 16:30 Monday to Friday.

Although the large multizone units at the Composite High School are equipped with similar clocks to permit automatic night setback of interior temperatures, the timing tabs had been removed by the maintenance staff so that the equipment operated continuously at full capacity. The explanation offered was that winter power blackouts caused problems with the timing. However, when the frequency of such blackouts was verified with a representative of Alberta Power Ltd., the researchers were informed that such occurrences were extremely rare.

Again, the maintenance staff claimed that equipment was regularly shut down during the summer months. However information obtained from utility records refuted this assertion, at least in part.

10.5 Plant Maintenance Schedules

Checklists were found to exist for each school for the following activities:

(i) lubrication of motors and fans at three month intervals.

(ii) cleaning of filters at one month intervals

These tasks are performed by custodial staff in each school, and verified by the supervisor of maintenance through random checks. Some heating units, particularly in the Composite High School, can be reached only by erecting a scaffold. It is doubtful whether these units are frequently serviced.

One maintenance man (according to the maintenance supervisor) dismantles and services heating units in the summertime. However, with 145 units to attend to, the frequency of treatment is necessarily limited.

10.6 Facility Use Schedules

The Composite High School and the other schools are used with quite different intensities.

The High School is staffed by at least one custodian 24 hours a day, 6 days per week. Activities run throughout the building from 08:30 to 22:00 during weekdays, although utilization is lower in the evening. Night courses are taught in both vocational and academic areas, while sporting facilities are in frequent use for training and competition. Sporting facilities are the only spaces used with regularity on weekends.

The other schools are used from 08:00 to 17:00 for academics, and from 19:00 to 22:00 for community activities (during the week). Custodial staff open and inspect schools around 07:00, and close them between 18:00 and 22:00 depending on the daily schedule. Evening use of these schools is almost always restricted to the gymnasia and public areas.

Activities at all schools are scheduled by individual administrators at each school, and use of facilities is usually supervised by regular custodial staff.

Cleaning is scheduled to occur between 16:00 and 18:30 at the elementary schools, and between 16:00 and 22:00 at the high schools.

Apart from these regular functions, other activities, such as socials and open houses, occur at more random intervals.

10.7 Summary

Observations made during the inventorying process revealed repeated examples of inefficient functional planning in terms of both maintainability and energy utilization. The more common and serious instances have been enumerated above, and some implications of these conditions have been mentioned.

The particular systems installed in the Grande Prairie schools restricted the range of conservation measures which could be employed. Since heating and ventilating systems are not differentiated at most of the schools, curtailment of hours of operation does not offer the potential for savings it does in many buildings. These systems had to be kept operating continuously in colder weather to ensure durability of building components. Features of buildings also restrict the use of intermittent operation as a conservation technique, even in warmer months. Problems with switches, as described above, impede the effective control of building equipment by building operators.

Other conditions, such as the unstable foundation conditions complicate the implementation of more permanent changes to improve performance, such as sealing of the building envelope. These problems are discussed in more detail in the following chapter.

It was evident from the inventory that there is a need for improved functional planning, design, and construction of school buildings.

11. IMPLEMENTATION

11.1 User Involvement

At the onset of the project, three sets of seminars were organized. They had the same basic themes but were varied to emphasize the interests of the particular user group to which they were addressed - administrators, teachers, and custodial/maintenance staff.

The seminars for teachers were presented once in each school to an assembled grouping. The seminars for administrators (mainly principals) and custodial/maintenance staff were held once for an assembly of each group. The seminars dealt with the nature of the project and its purpose, the reasons for conserving energy, the work to be undertaken, and possible contributions by each user group. It was particularly emphasized that conservation measures were to be applied in a reasonable manner, that they were intended not to be disruptive, and that implementation of the programme should be carried out cooperatively. Users were encouraged to voice their concerns at the seminars and were assured that the research team would listen to any future comments from users.

Questionnaires were subsequently distributed to teachers soliciting their opinions on a number of items, both to provide information and to reinforce their belief that the research team was sincerely interested in listening to their views. Administrators, head custodians, and maintenance staff were interviewed frequently (about 12 contacts per individual) during the first year of the project. Principals and custodians, being in daily contact with teachers and students, were able to provide information on the reactions of these individuals as the project progressed. Numerous random contacts were also made with teachers as they were encountered in the schools.

With the assistance of Mr. K. Wagner, the Deputy Superintendent responsible for science curriculum development experiments were conducted with carrying the concept of conservation into the classroom. A closer liaison was maintained with teachers at the grade six level who were interested in the venture. Grade six science classes monitored their schools energy consumption and experimented with basic measures to reduce consumption. The research project coordinator also participated in two high school social studies classes looking at energy and society. Several hundred copies of "100 Ways to Save Energy and Money in the Home" were distributed to students.

11.2 Monitoring

Once basic information had been gathered on the characteristics and energy utilization of the Grande Prairie school buildings, it was necessary to begin testing of conservation measures.

The limitations of utility invoices as records of building performance have already been mentioned. The lack of existing high quality data posed a problem in evaluating measures, since a precise record was required to thoroughly evaluate the benefits of conservation measures. A programme of daily meter readings (excepting weekends and holidays) was instituted in October. Custodial staff in each building recorded meter readings on forms specially designed by the research team. By the middle of October learning problems had been overcome and a four week control period was initiated to obtain a baseline measure of building performance. During this period building users were specifically asked not to change their behaviour. As a further control the users of the three junior high school buildings (the Old Montrose, New Montrose, and Central Park Schools) were requested to continue habitual practices for the remainder of the year. Implementation of the first electricity conservation measures was initiated after the first week, and implementation of the first gas conservation measures was initiated after the seventh week of the daily meter reading programme.

More detailed monitoring of energy consumption was undertaken at two sites: Parkside Elementary School and the Composite High School. Parkside School was the least complicated building to study, facilitating the interpretation of results. The Composite High School plays a key role in overall district performance.

Northwestern Utilities Limited (the natural gas supplier) and Alberta Power Limited were requested in October to install continuous recording devices on gas and power entries at the two schools. By February instruments had been installed in all the desired locations.

It turned out that the natural gas consumption recorders could not record fine enough intervals and quantities to satisfy the research team's information requirements. As a substitute, a limited amount of time lapse photography of meter dials was undertaken by the research team.

Computer listings of data generated by the electrical survey units (which record on magnetic tape) were received in May. These enabled the researchers to undertake a detailed study of electricity consumption patterns.

To obtain a better understanding of subsystem energy demands, domestic type natural gas meters were borrowed from Northwestern and installed on two hot water heaters at the Composite High School and one at Parkside.

Results obtained through monitoring are discussed in Chapter 12.

11.3 Conservation Measures

Measures were implemented with the cooperation of administrators, custodial staff, and teachers.

11.3.1 Electricity Conservation Measures

11.3.1.1 Lighting

From the inventory it was evident that lighting and motors constituted the major electrical loads, with lighting being the most amenable to incremental change.

Parkside School, because of its relatively high electricity consumption rate, was selected as the initial test case for conservation. It had an installed electric capacity of 35 W/sqm of which 24 W/sqm was lighting. Two windowless classrooms were reduced to a minimum of 540 lux (50 footcandles) of illumination (the GSA recommended standard) by removing 50 percent of the flourescent tubes. Teachers complained that although there was no problem with "visibility", the rooms "felt dim" at this lighting level. Fixtures were restored until teachers were satisfied. This occurred at about 650 lux (60 footcandles) and 16.8 W/sqm. The perceived dimness probably was an effect of the room finish - relatively dark rough-textured panels and the lack of an exterior view.

The remainder of Parkside School was adapted to lighting levels equivalent to those in the test rooms. After a couple of weeks teachers commented that although they noticed the change, it did not cause any problems.

At this point other elementary schools were adapted to the 540 lux level of installed lighting. These schools were generally painted lighter colours with a higher reflectivity (such as yellow). Under such conditions, even in windowless classrooms, teachers had no complaints about dimness at the reduced lighting levels.

Corridors were also reduced to lower lighting levels. Corridor lighting has a greater influence on weekly electricity consumption than its installed capacity might suggest. Some of this lighting is active 24 hours a day, 7 days a week for security purposes. Corridor lighting of any type is usually in operation for more hours than any other lighting in a school building. Frequently this lighting had been installed to provide the same illumination levels as classroom lighting.

Some corridor lighting at the Composite High School was found to be even higher than classroom lighting levels. 13 kW of the 400 kW recorded maximum demand was eliminated by removing the excess.

The second step in cutting electrical consumption was to reduce the time over which lighting was used. Custodial staff in elementary schools were accustomed to operating all lighting from 07:00 to 18:30. This routine was changed so that teachers switched on lights as they arrived in their class, and shut them off as they left. Teaching staff were encouraged to minimize the use of lighting (at recess, lunch, etc.).

11.3.1.2 Circulating Systems

Additional major electrical loads were furnace motors and similar electrical equipment. These could not be shut down since the ventilation and space heating systems were one and the same.

The Old Montrose School is the only building with an independent ventilating system. Apart from being a control building, the maintenance staff had found from experience that the ventilation system drive units (mounted in roof housings) freeze up in colder weather if left idle overnight during the colder months. Another problem was that some equipment could only be switched from locations on the roof, while other motors could only be switched with circuit breaking equipment.

11.3.2 Natural Gas Conservation Measures

11.3.2.1 Aquastat Setback

Reduction of aquastat setting was a simple matter except at the Composite High School. Here each hot water system served a diverse group of functions (cafeteria, shower rooms, beauty culture, shop areas), some of which required higher temperature hot water. Others were so far removed from the heater that lower temperature water leaving the heating unit arrived at its destination at too low a temperature.

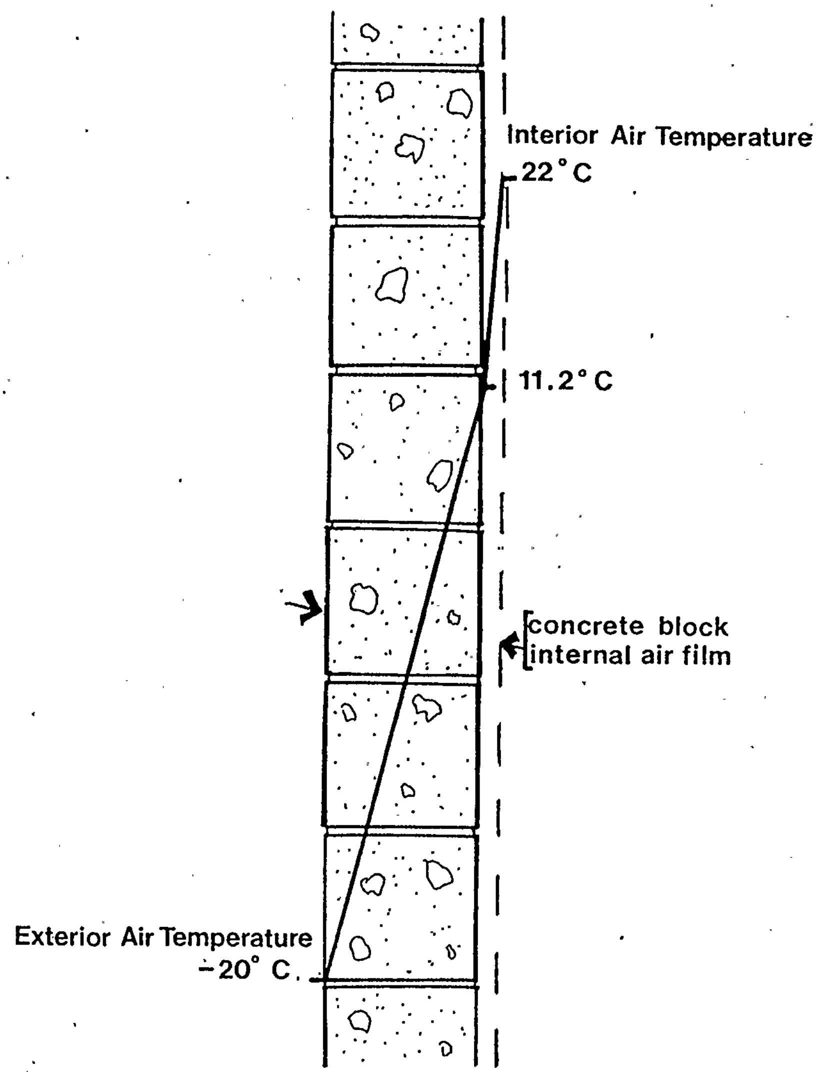
11.3.2.2 Permanent Thermostat Setback

Thermostat setback can take two modes - permanent and short term (overnight, weekend, etc.). Permanent setback produces the greatest savings. However it is something of a problem under conditions found in Grande Prairie. In the discussion of human comfort (Section 8.1) radiant heat loss to surrounding surfaces was mentioned as a possible cause of discomfort.

Figure 11.1 shows a calculation of interior wall temperature under typical winter conditions in Grande Prairie. Even with the room air temperature at 22.0 degrees Celsius, theoretical calculations show the wall surface temperature would attain only 11.2 degrees Celsius. In fact, at exterior temperatures below -20.0 degrees Celsius, patches of frost were observed to persist on interior wall surfaces at some schools, indicating a surface temperature near 0 degrees Celsius (average weekly temperatures were at or below -20 degrees Celsius for 6 weeks during the 1977-78 winter).

Just as sitting before a hot fire in cold air can provide adequate warmth, sitting near a cold wall in warm air can lead to discomfort. Figure 11.2 quantifies the effect of mean radiant temperature for two locations in a square classroom with only one exterior wall. It is evident that thermal conditions experienced by the occupants of a classroom will not meet comfort criteria even at "room temperature".

Apart from deficiencies in mean radiant temperatures, excessive air infiltration was observed to cause discomfort in some classrooms; these drafts become increasingly aggravating as temperatures drop further below freezing.



RESISTANCE TO HEAT FLOW :

FOR STILL AIR = 0.7

FOR CONCRETE BLOCK = 2.0

1. THE TOTAL TEMPERATURE DIFFERENCE = 42.0 C

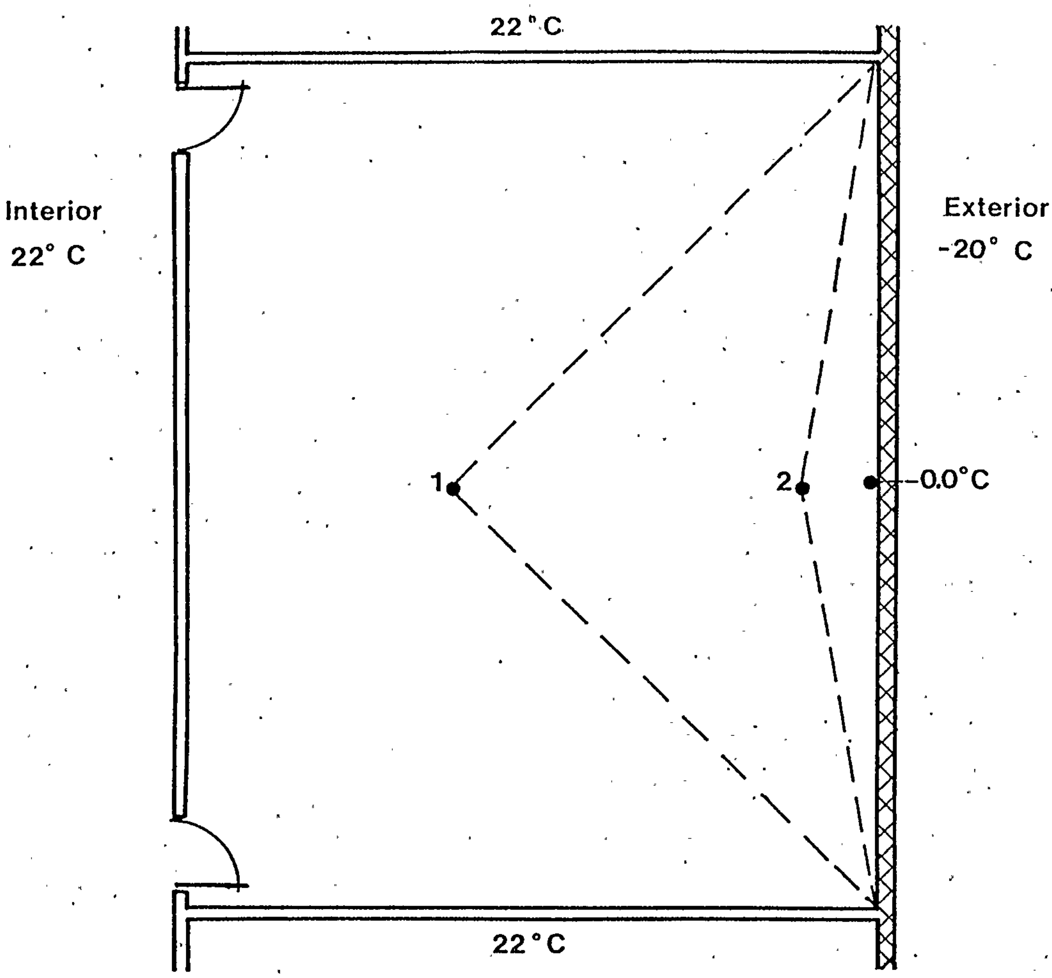
2. THE TOTAL RESISTANCE TO HEAT FLOW = 2.7

THEREFORE :

THE INTERIOR WALL TEMPERATURE =

$$22.0 - \frac{0.7}{2.7} \times 42.0 = 22.0 - 10.8 = 11.2 \text{ C}$$

Figure 11.1 Thermal gradient showing the interior surface temperature of a masonry wall under winter conditions in Grande Prairie.



CASE 1: $\text{MRT} = \dfrac{90°(0.0°C) + 270°(22.0°C)}{360°} = 16.5°C$

CASE 2: $\text{MRT} = \dfrac{160°(0.0°C) + 210°(22.0°C)}{360°} = 12.2°C$

Figure 11.2 Diagram showing the effects of mean radiant temperature in a classroom under winter conditions in Grande Prairie.

In one classroom, an air temperature difference of 4 degrees Celsius was observed to obtain across the width of the room.

These reasons have collectively led the research team to the conclusion that no permanent thermostat was possible within the constraint of maintaining conditions for human comfort. Therefore none was attempted.

11.3.2.3 Intermittent Thermostat Setback

Setting back thermostats at night and during other periods when the schools are vacant was another possibility. Due to the construction of the buildings in Grande Prairie and the severe climate intermittent setback presented something of a problem. Burst plumbing caused by freezing is not an uncommon occurrence in the school buildings during the winter (pipes are frequently routed along uninsulated exterior walls), and lowered internal temperatures increase the probability of such occurrences. The unit heaters and fan motors are exposed directly to air temperatures of -30 degrees Celsius on many winter nights. If thermostats are reduced and furnace idle time increased, components run a greater risk of being frozen. This occurs from time to time even without thermostat setback, leading to burnt out motors and damaged heating units.

Nevertheless, at Hillside School (where the custodian was particularly interested in improving performance) an aggressive setback programme (reductions to 16 degrees Celsius) was pursued after the fourth week of the control period until the end of the school year, and without mishap. Less aggressive thermostat setback programmes (reductions to 18 degrees Celsius) were experimented with at the other "conservation" schools. However in a couple of instances pipes froze during cold periods even when thermostats had not been set back. In general, custodial staff were reluctant (and with good reason) to experiment with such measures.

While thermostat setback at the smaller schools could be managed easily by the custodial staff, the High School was not so amenable to manual control. With 70 thermostats to attend to, the custodial staff could not possibly reset temperatures in time to anticipate the first classes.

11.4 Conclusions

The range of conservation measures which could be applied was limited by the types of mechanical systems installed in the Grande Prairie schools and by the thermal properties of their enclosure systems. Further, these enclosure systems are in many cases inadequate both to ensure conditions for human comfort and to protect building components from weather effects. Working with the custodial, maintenance, and administrative staff revealed that very specific guidance is required in the implementation of conservation measures. Once routines are understood, they are usually followed with regularity as long as some evaluation of performance and feedback occurs.

Changes in patterns of energy consumption resulting from implementation of these measures are presented in chapter 12 and are also discussed in Chapter 13.

12. RESULTS FROM THE MONITORING PROGRAMME

The uses of information on building energy utilization were enumerated in section 3.2. Such information is a cornerstone of both developmental and routine aspects of energy management. The researchers particularly needed data to determine

(i) where, when and how energy is expended in the buildings under study.

(ii) what type of data and what kinds of indicators are necessary to audit building performance

(iii) the most effective techniques for evaluating the results of implementing energy conservation measures.

Through an intensive programme of monitoring building energy consumption, data were collected to fulfill these requirements.

Although records of daily natural gas and electricity meter readings were maintained by custodial staff, weekly intervals were selected as the basic time period for evaluating performance in all schools. Weekly calculations of consumption rates benefit from the high degree of redundancy obtained by basing them on daily or near daily readings (limitations of manually obtained daily readings are outlined in Table 2.1). Precise monthly records can also be obtained from the same data base of daily readings.

In spite of the limitations of the daily readings, they were useful (in some circumstances) for analyzing building performance over periods of less than a week.

Automatic recording equipment, available on a limited basis, provided more precise short term records. These were needed to identify relationships between user activities and variations in energy requirements, and to obtain a better understanding of energy demands by individual building systems.

This chapter reviews the results obtained through evaluating electricity and natural gas use over different time intervals, by different building systems, against different factors, and with different measurement techniques. Analysis of electricity consumption is dealt with first, followed by analysis of natural gas consumption. In both cases, the discussion focusses first on longer measurement time periods (weeks and months) and then on shorter time periods (hours and days). Results of the conservation effort are evident from the data collected in the course of the monitoring programme.

12.1 Analysis of Electricity Consumption

12.1.1 Weekly and Monthly Electricity Consumption Patterns

Figures 12.1 through 12.5 illustrate building requirements for electricity over time. The conspicuous troughs in consumption rates (Figures 12.1 through 12.3) at weeks 11 and 24 are attributable to Christmas and Easter vacation periods. Note that the troughs bottom at very close to the same level, in spite of a twofold difference in heating requirements between the two periods.

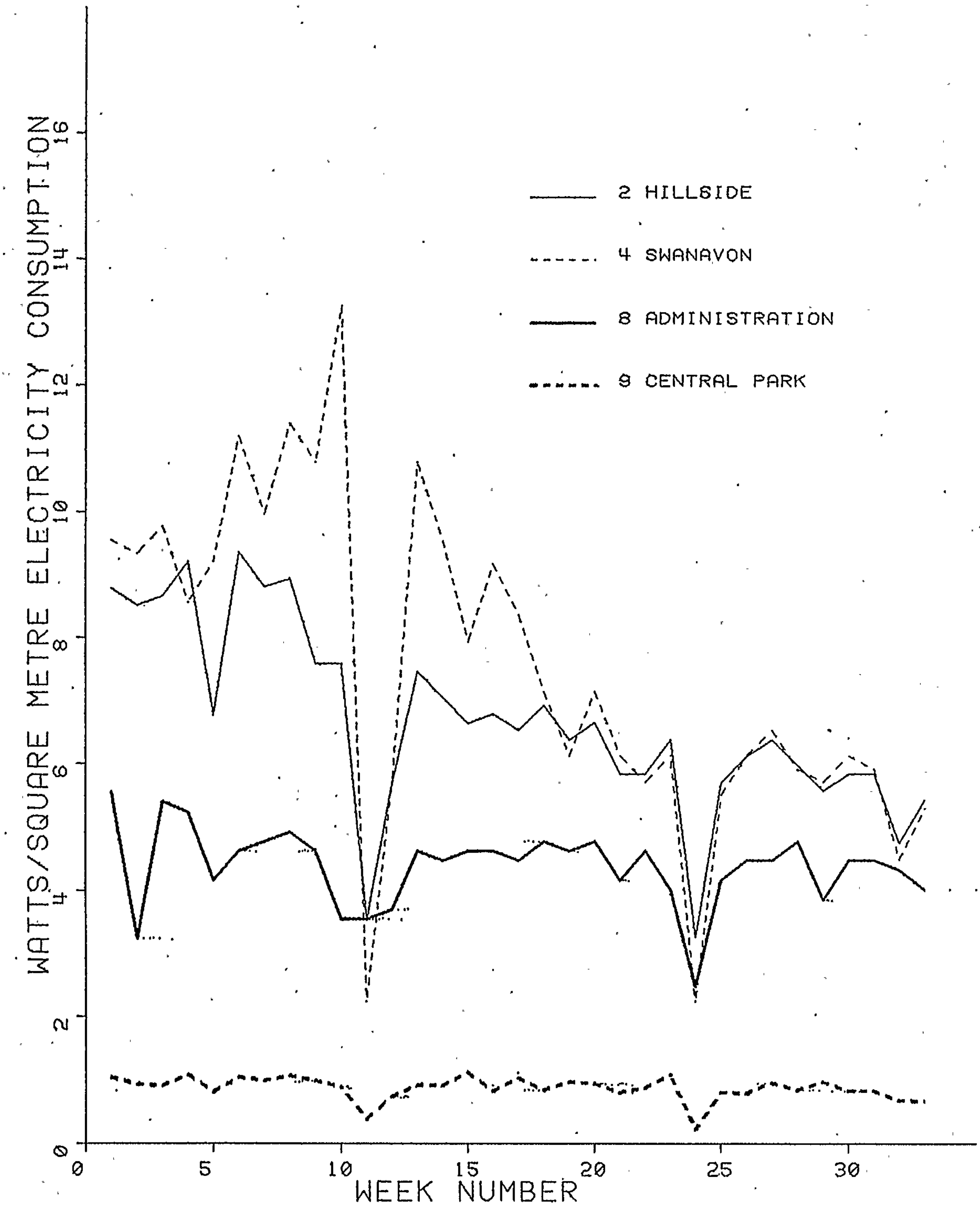


Figure 12.1 Weekly electricity consumption rates at the Hillside, Swanavon, and Central Park Schools during the research study (rates for the Administration building are also plotted).

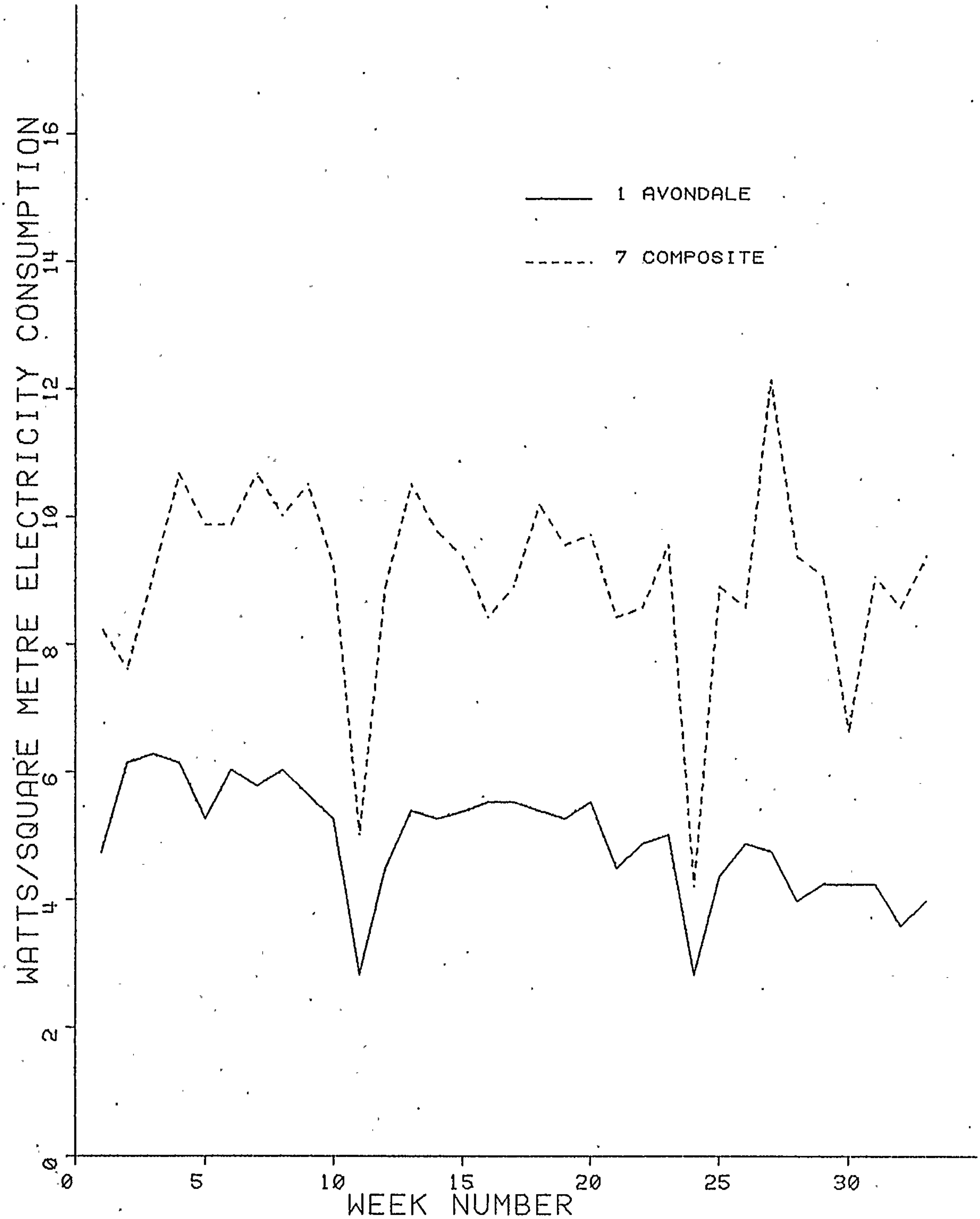


Figure 12.2 Weekly electricity consumption rates at Avondale School and the Composite High School during the research study.

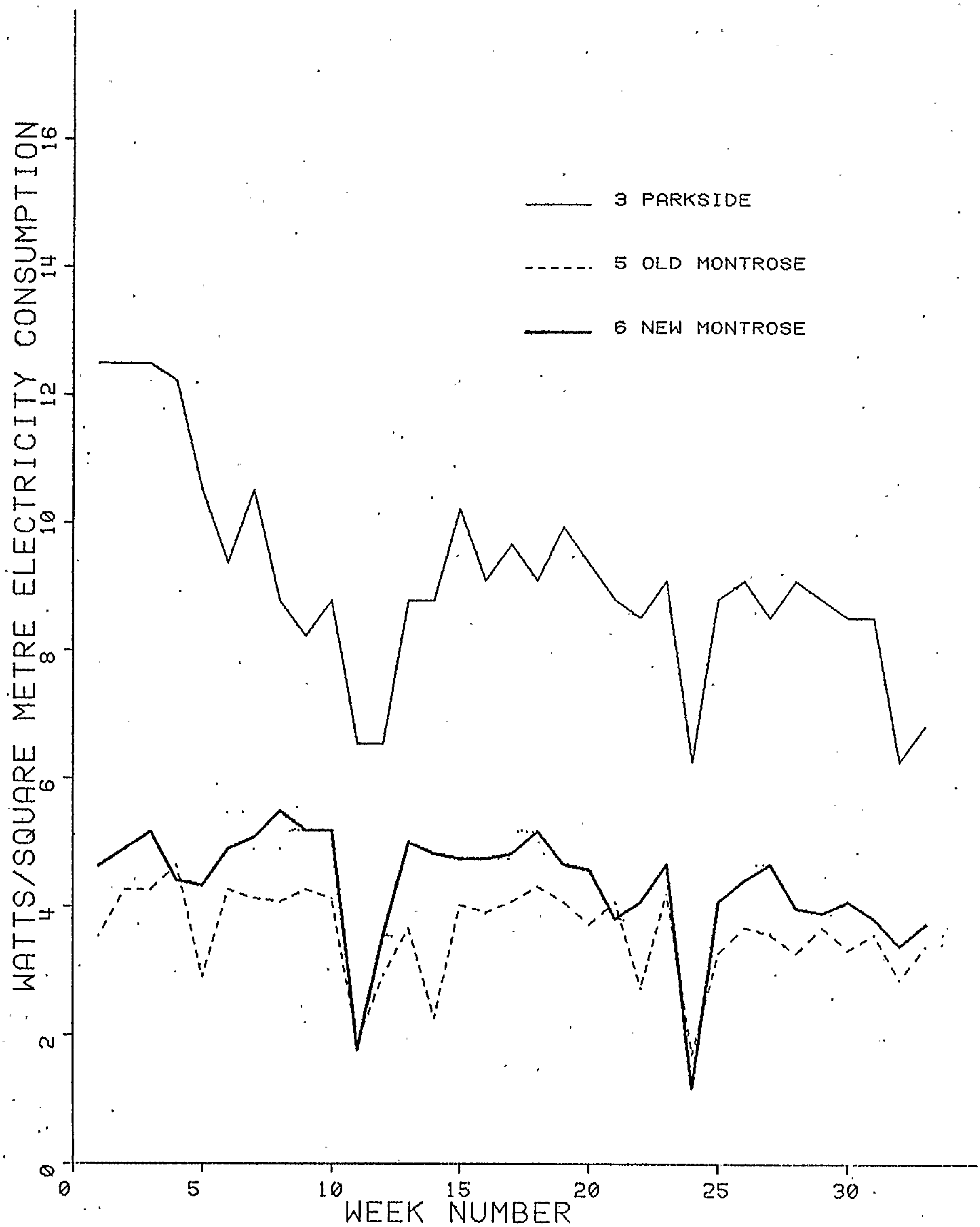


Figure 12.3 Weekly electricity consumption rates at Parkside Elementary, and the Old and New Montrose Junior High Schools during the research study.

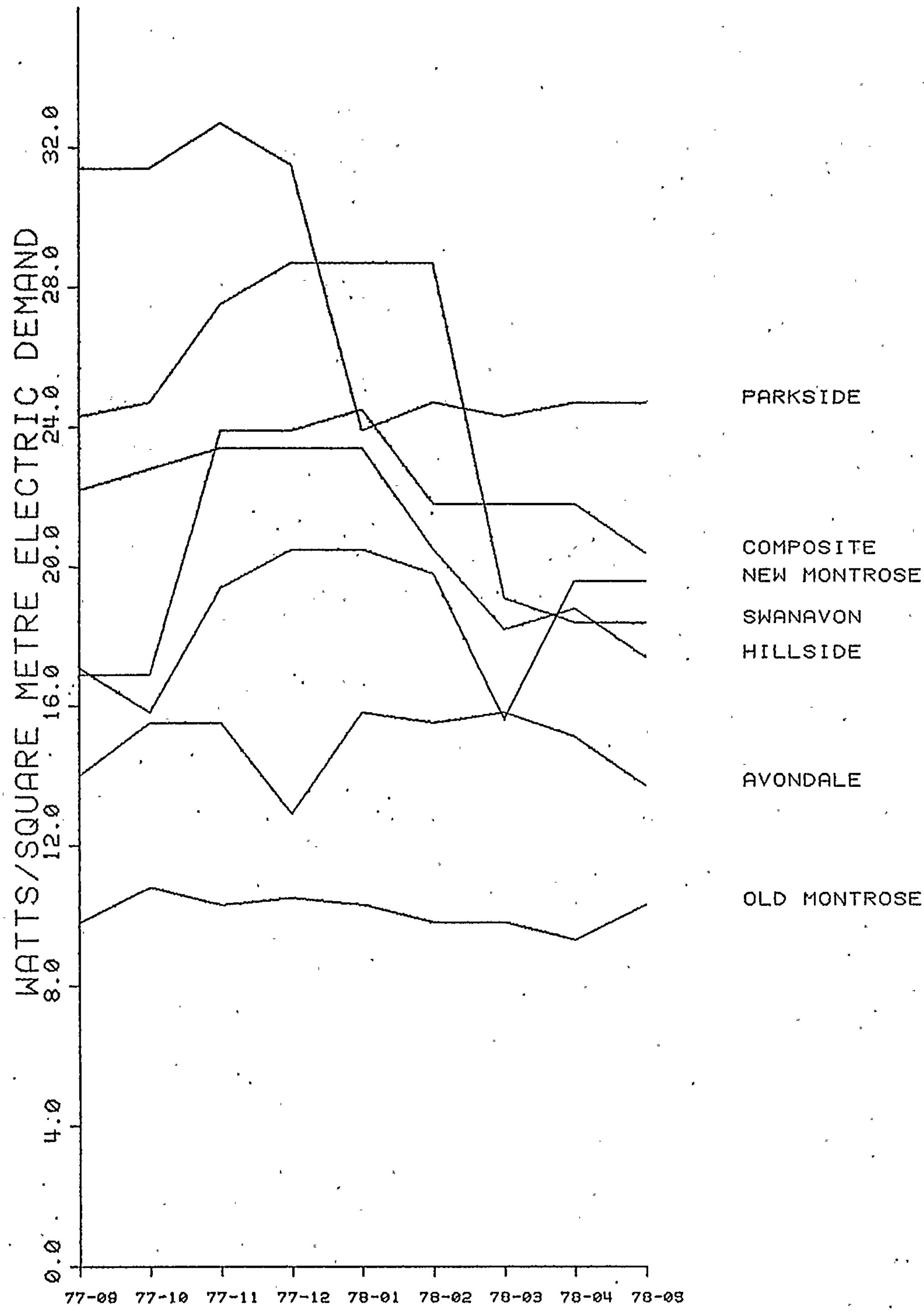


Figure 12.4 Monthly electric demand peaks in Grande Prairie Public School District buildings during the research study.

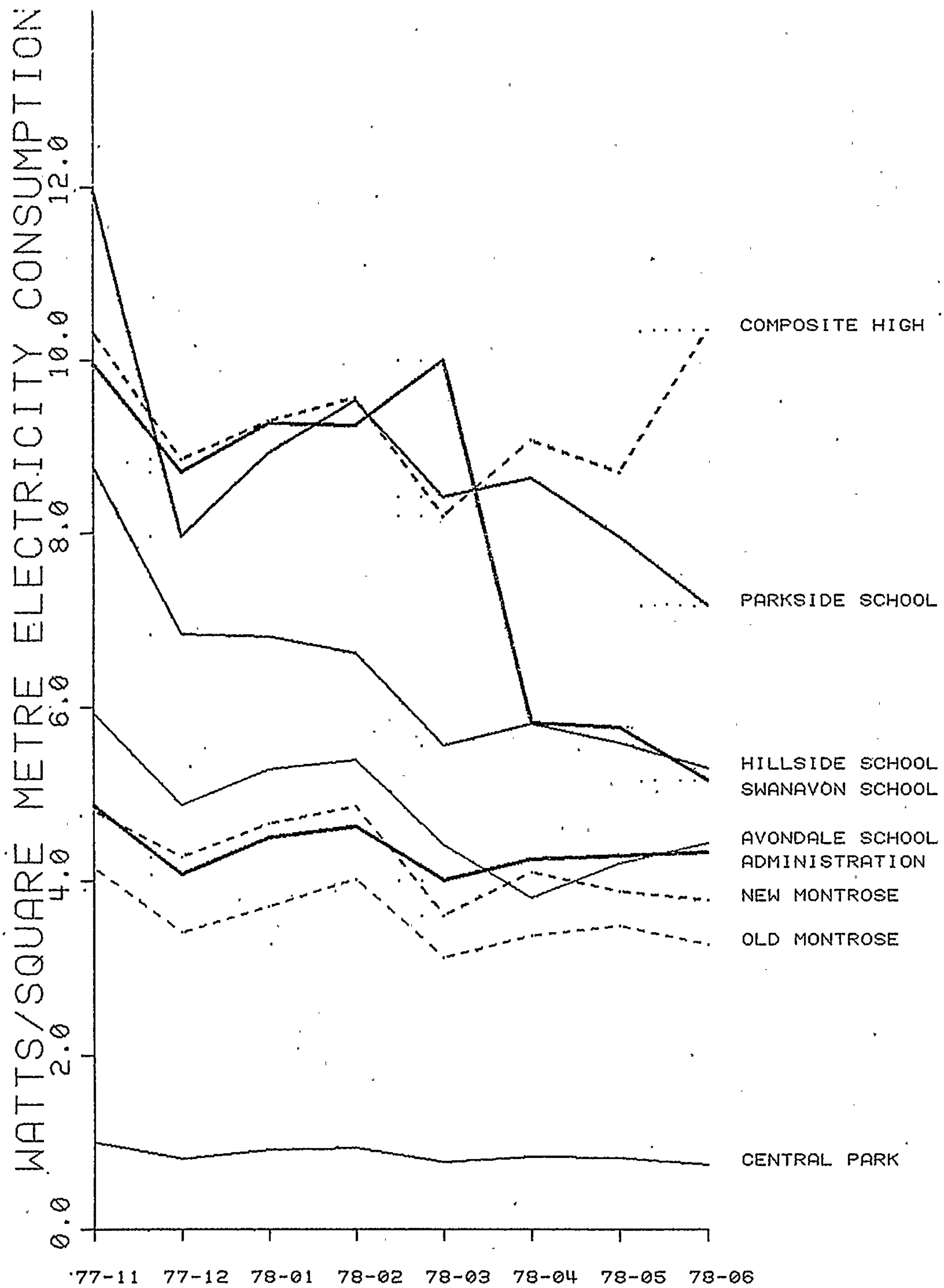


Figure 12.5 Monthly electricity consumption rates in Grande Prairie School District No. 2357 buildings during the research study.

Peak demand appears to be more dependent on weather than are consumption rates, although the dependency varies from school to school (see Figure 12.4).

Table 12.1. Comparison of electric demand levels before and after implementation of conservation measures in Grande Prairie School District No.2357.

School	Registered Demand 1977-02 (kW)	(W/m^2)	Peak Demand 1978-02 (kW)	(W/m^2)	% Change
Avondale (*)	43	15	44	16	+2.3
Hillside (*)	88	25	64	18	-27.2
Parkside (*)	79	31	61	24	-22.2
Swanavon (*)	62	27	48	21	-22.6
Old Montrose	48	12	42	10	-12.5 (** -8.3)
New Montrose	109	19	88	16	-19.3
Composite (*)	352	24	320	22	-9.1
Administration (*)	22	16	14	10	-36.4

(* denotes conservation buildings)

(** 4.2% of the decline was due to a minor adjustment of the lighting system)

Decreased requirements for electricity were exhibited by both "conservation" and "control" buildings between the pre- and post-conservation periods on which Tables 12.1 and 12.2 were based. Electric demand dropped 19.2 percent in the conservation buildings and 13.8 percent in the control group (on average), while consumption dropped 24.1 percent and 12.8 percent respectively. Decreases in demand and consump-

Table 12.2. Comparison of electricity consumption rates before and after implementation of conservation measures in Grande Prairie School District No. 2357.

	Electricity Consumption (W/m^2)		
School	1977-10-21 to 1977-11-11	1978-03-14 to 1978-04-14	% Change
Avondale (*)	5.8	4.5	-22.4
Hillside (*)	8.8	6.0	-31.8
Parkside (*)	12.4	8.9	-28.2
Swanavon (*)	9.3	6.0	-35.5
Old Montrose	4.2	3.4	-19.0 (** -13.0)
New Montrose	4.8	4.3	-10.4
Composite (*)	12.2	10.0	-18.3
Administration (*)	4.9	4.5	- 8.2
Central Park	1.0	0.85	-15.0

(* denoted conservation buildings)

(** 6.0% of the decline at OM was due to a minor adjustment of the lighting system)

tion are also evident in the monthly data (Figures 12.4 and 12.5). For both conservation and control buildings, consumption rates can be seen to decline.

Comparison of monthly and weekly plots of electricity consumption rates show that increasing the measurement period can obscure significant fluctuations in performance.

12.1.2 Hourly and Daily Electricity Consumption Patterns

Electrical survey units, capable of recording requirements for electricity over 15 minute intervals, were used to obtain very precise information on patterns of consumption at the Parkside and Composite Schools.

A typical daily record for Parkside School is plotted in Figure 12.6. The base load represents 50 percent of daily consumption; on a weekly basis the base load represents 60 percent of consumption.

Just as monthly averaging of consumption rates conceals some very sharp variations in requirements, plots of hour by hour consumption rates conceal shorter interval variations (see Figure 12.7). As the time interval becomes shorter, the activity pattern in the building is more precisely reflected in the electricity consumption rates.

Two daily plots for the Composite High School are shown in Figure 12.8. The lower overnight demand for power on Sundays was a recurrent pattern. The difference of 20 to 30 kW between the curves is about half the peak demand at an elementary school. This represents a potential for significant savings, since the high school is inactive during the hours when this higher consumption rate obtains.

A succession of daily electricity consumption totals are plotted in Figure 12.9. Over the period shown, a consistency of daily consumption rates is evident. The base load (about 2000 kWh/day) represents about 60 percent of weekly consumption.

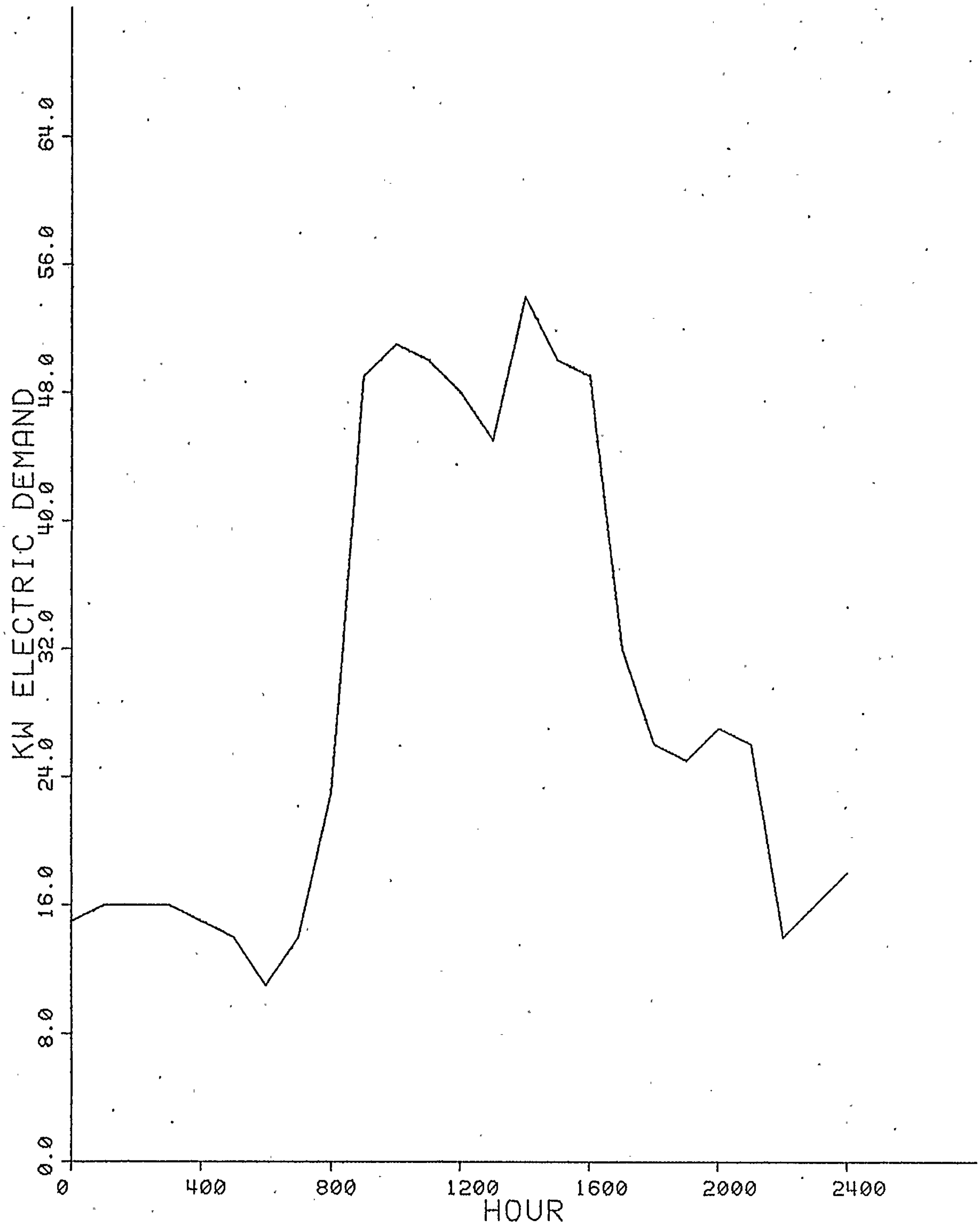


Figure 12.6 A plot of typical hourly electric demand over a 24 hour period at Parkside School.

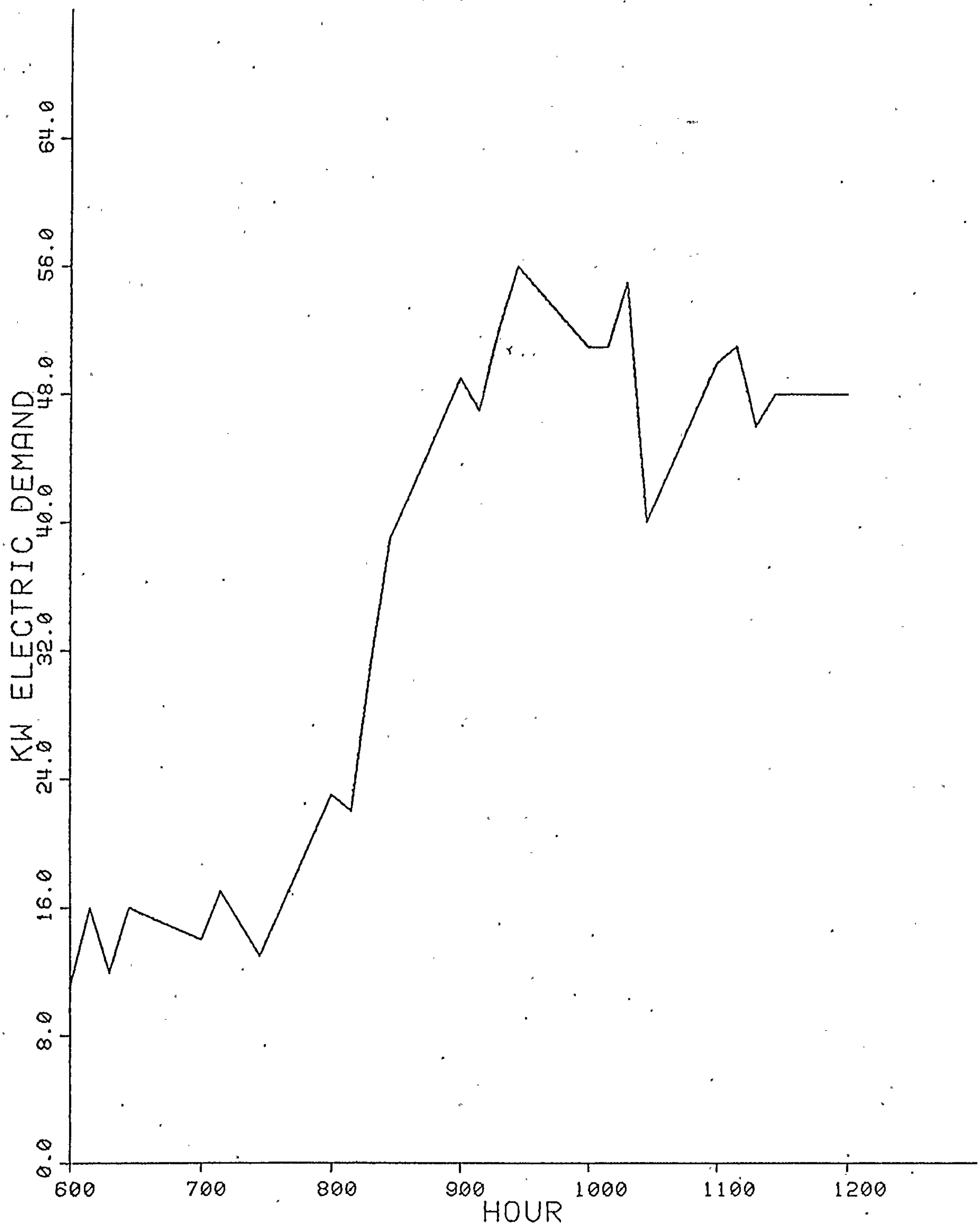


Figure 12.7 A plot of typical 15 minute electric demand levels at Parkside School over a 6 hour period.

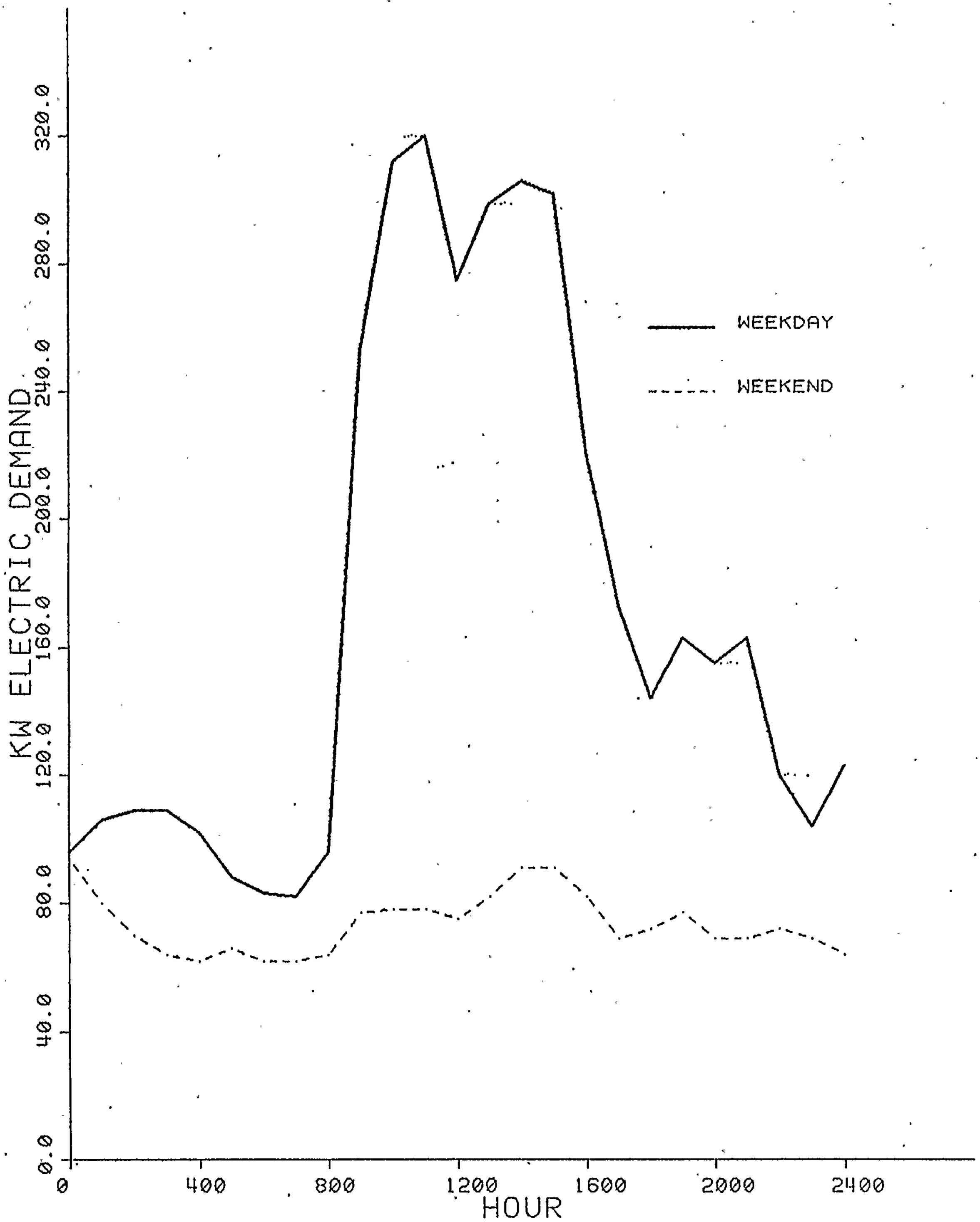


Figure 12.8 Plots of typical weekday and weekend hourly electric demand levels at the Composite High School over a 24 hour period.

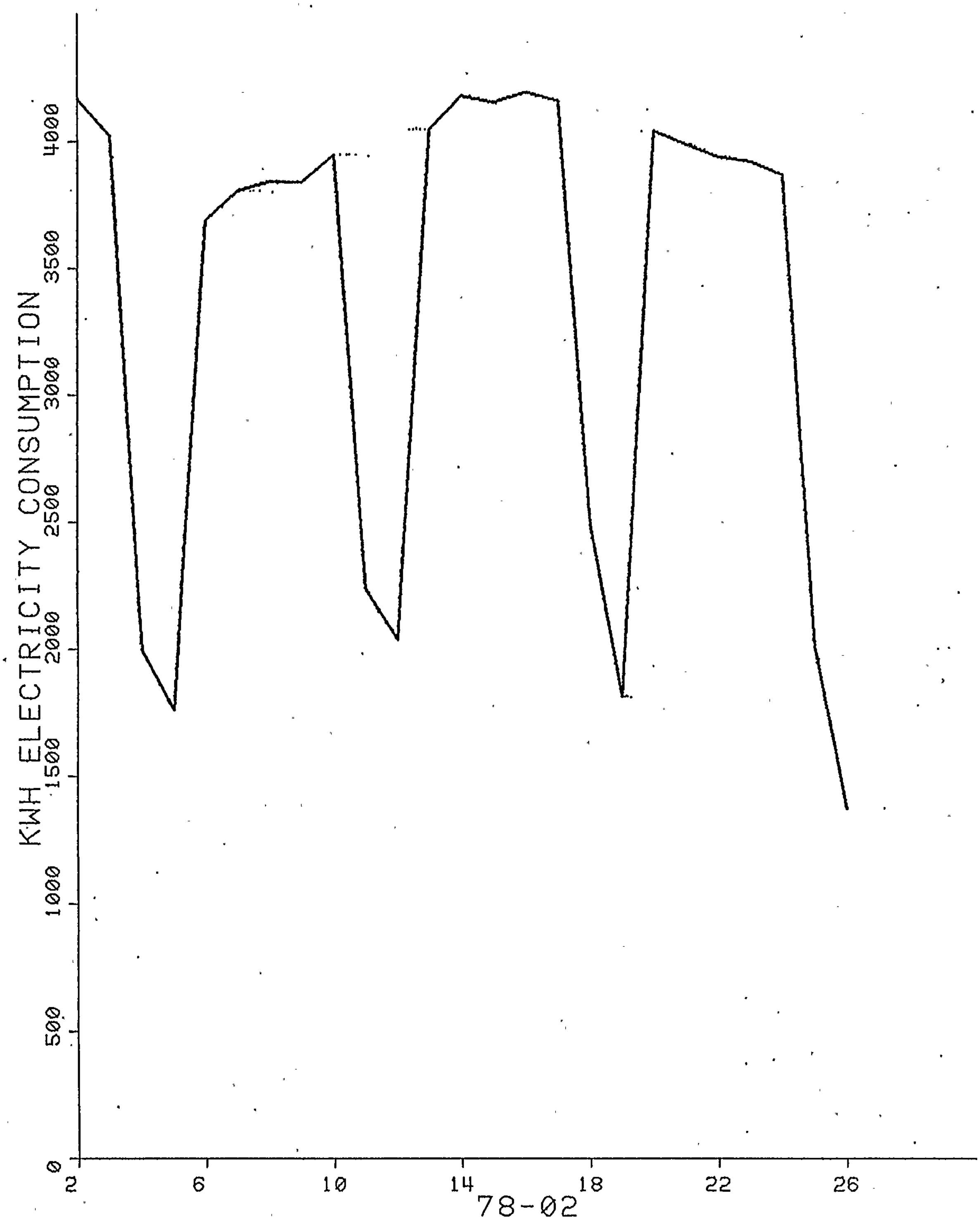


Figure 12.9 Plots of typical daily electricity consumption at the Composite High School over a 24 day period.

Average Sunday electricity consumption rate at Parkside School was found to be 5.9 W/m^2 as measured by the survey unit. This compares with 6.6 W/m^2 and 6.2 W/m^2 weekly averages calculated for the Christmas and Easter holiday periods on the basis of readings by custodians. Average Sunday rate at the Composite High was found to be 4.8 W/m^2 compared with the 5.0 W/m^2 and 4.2 W/m^2 over the same holiday periods. Thus, weekly consumption records can be used to obtain some good estimates of base loads when electrical survey units are not available. However more detailed information is needed to isolate items such as the higher week-night electric demand at the Composite High School.

12.2 Natural Gas Consumption

Techniques for estimating heating requirements of buildings must increase in sophistication as the complexity of the building increases. As stated in the ASHRAE Systems Handbook (1976) "a simple procedure may use only one measure, such as annual degree days, and will be appropriate only for simple systems and applications". The school buildings in Grande Prairie are relatively simple buildings, and the dominance of heating requirements in determining overall demand for natural gas renders them amenable to less sophisticated techniques of analysis. The Systems Handbook also states "records of past operating experience of the building in question, when these are available, provide the most reliable and usually the most accurate basis for the prediction of future requirements". Data on gas consumption were collected and analyzed to determine how effectively such estimating of energy requirements could be performed.

12.2.1 Weekly and Monthly Natural Gas Consumption Patterns

Average weekly temperatures during the research study are plotted in Figure 12.10. Although buildings exhibited very similar consumption patterns (see Figures 12.11 and 12.12), correlation of building performance with temperature left 7.1 percent of the variation in performance unaccounted for on average. Regression lines were plotted for each school - data on the Parkside and Composite Schools are presented in Figures 12.13 and 12.14 respectively.

From the results of the regression analysis, Table 12.3 was compiled. The reference temperature is that above which supplementary use of natural gas for space heating will not be required; the magnitude of the slope of the regression line ("lossiness") is the increase in the rate at which heat must be supplied to the building per degree decline in temperature.

The reference temperature assumed for calculation of standard degree-days is 18.0 degrees Celsius. It is evident that this reference temperature does not match any of those obtained through regression analysis. This implies that degree days of heating will not provide a very satisfactory correction for the effects of exterior temperature on thermal performance.

Table 12.3. Results of regression analysis of data on weekly natural gas consumption rates in Grande Prairie School District Buildings during the research study.

Building	Reference Temperature (degrees Celsius)	Lossiness (W/m^2 per degree Celsius)	Consumption Rate at 22 degrees Celsius (W/m^2)
Avondale	22.0	2.07	0.0
Hillside	21.2	2.36	0.0
Parkside	25.7	2.02	7.5
Swanavon	16.6	2.81	0.0
Old Montrose	31.4	1.97	18.5
New Montrose	19.4	2.72	0.0
Composite	22.8	2.35	1.9
Administration	22.6	2.35	1.4
Central Park	28.2	3.42	21.2
AVERAGE	26.0	2.72	5.6

(the reference temperature and the lossiness correspond to the intercept and slope of the regression line)

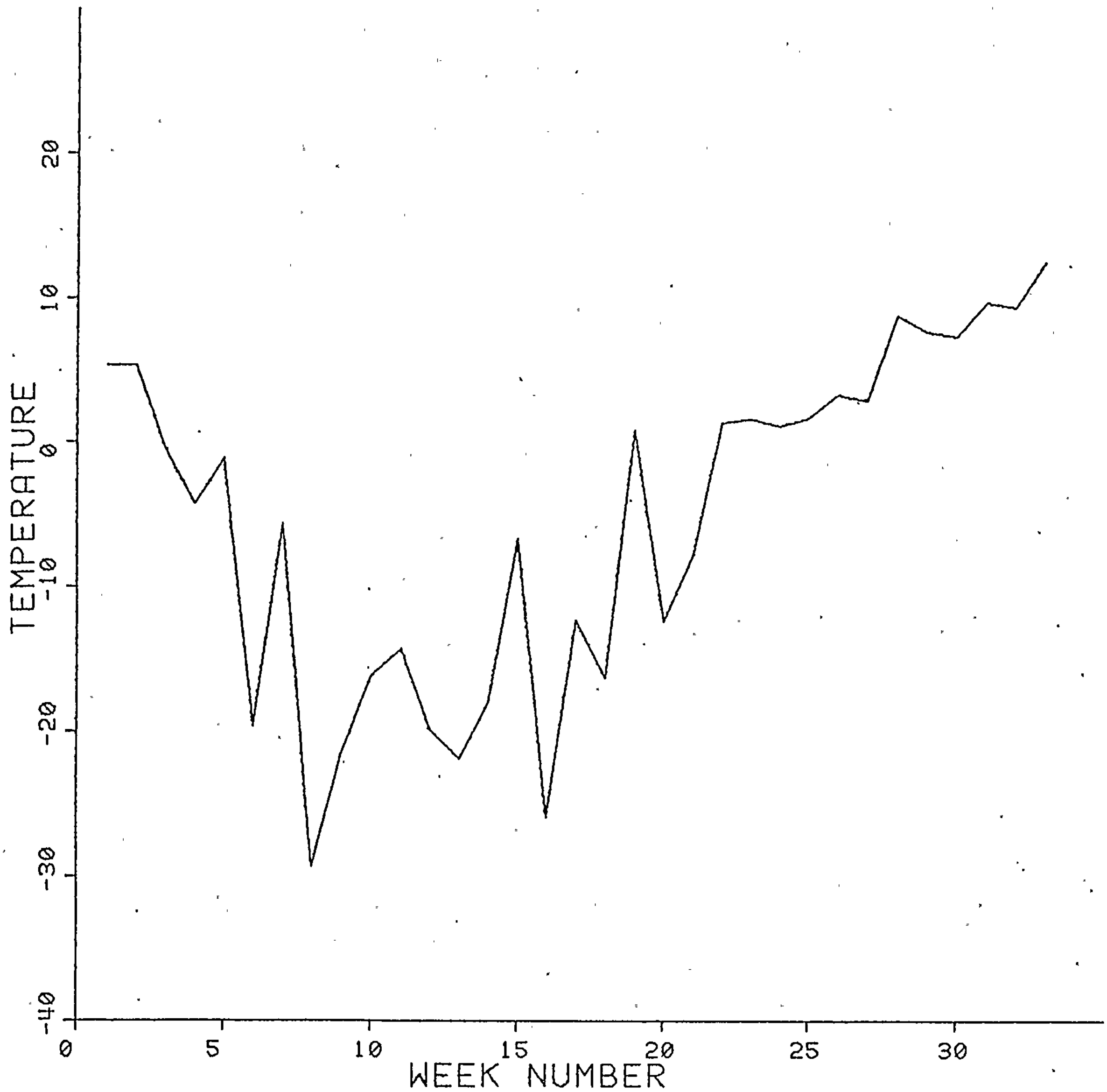


Figure 12.10 Average weekly temperature in Grande Prairie during the research study.

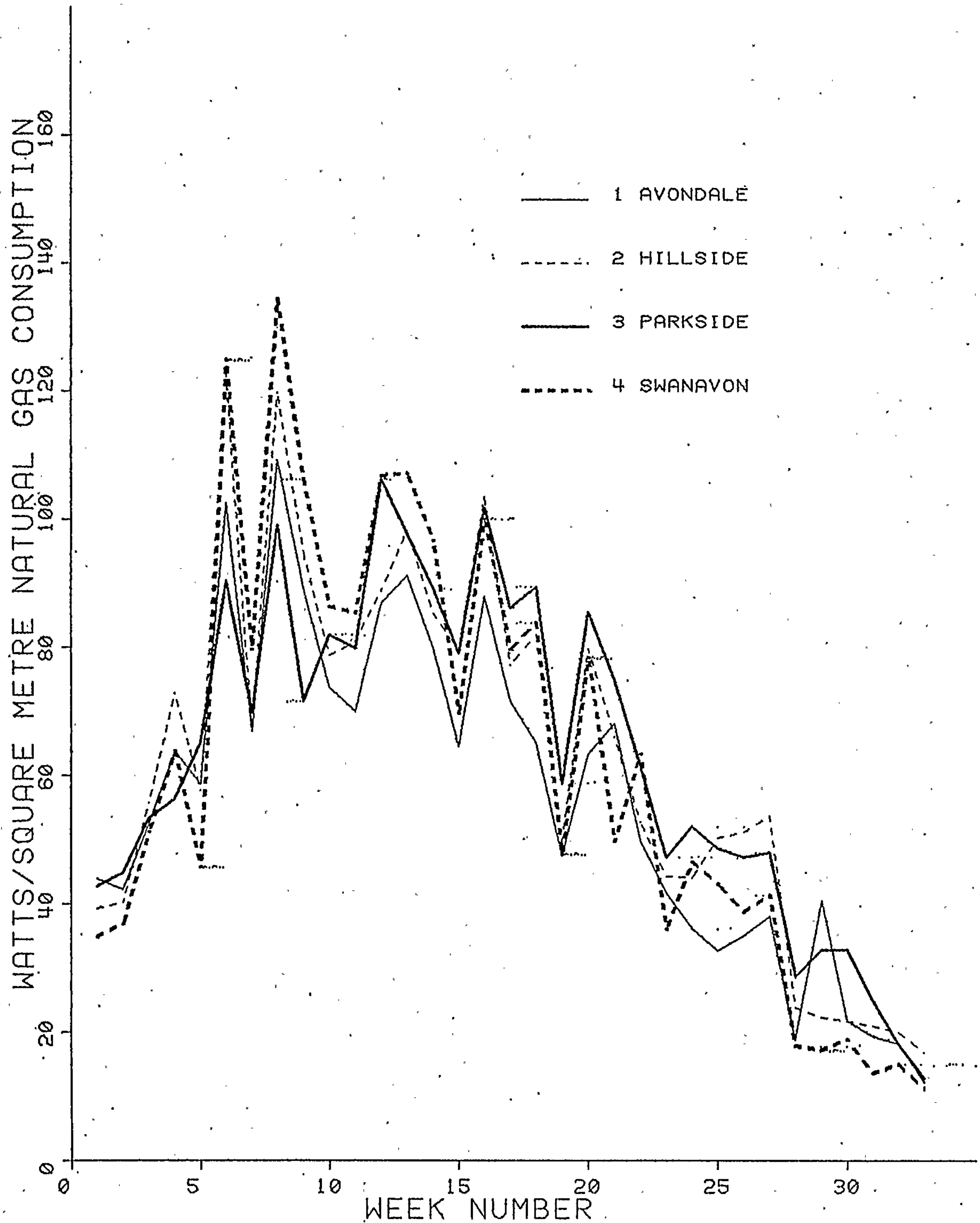


Figure 12.11 Weekly natural gas consumption rates at the four Grande Prairie elementary schools during the research study.

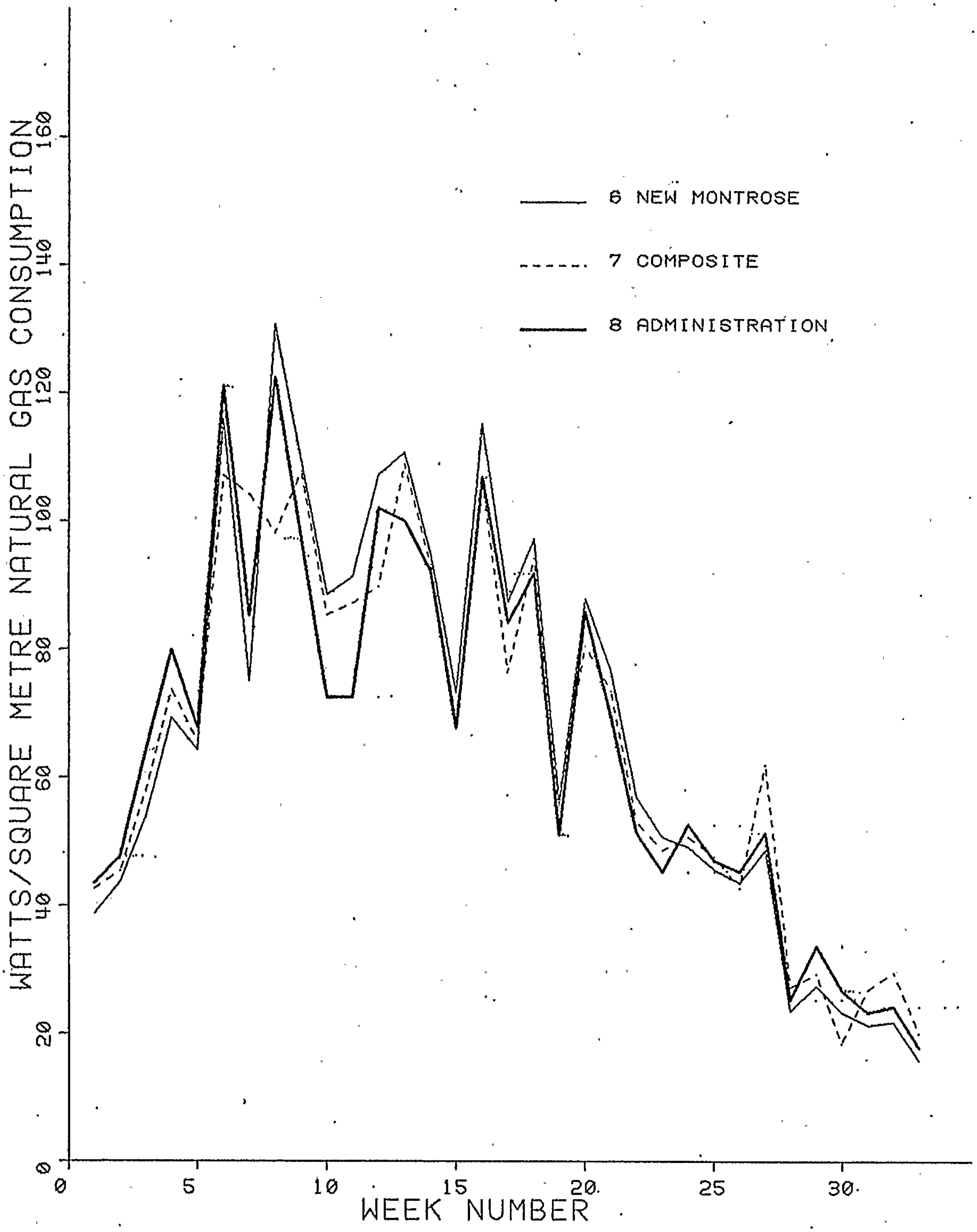


Figure 12.12 Weekly natural gas consumption rates at the New Montrose and Composite Schools during the research study (consumption rates for the Administration building are also plotted.

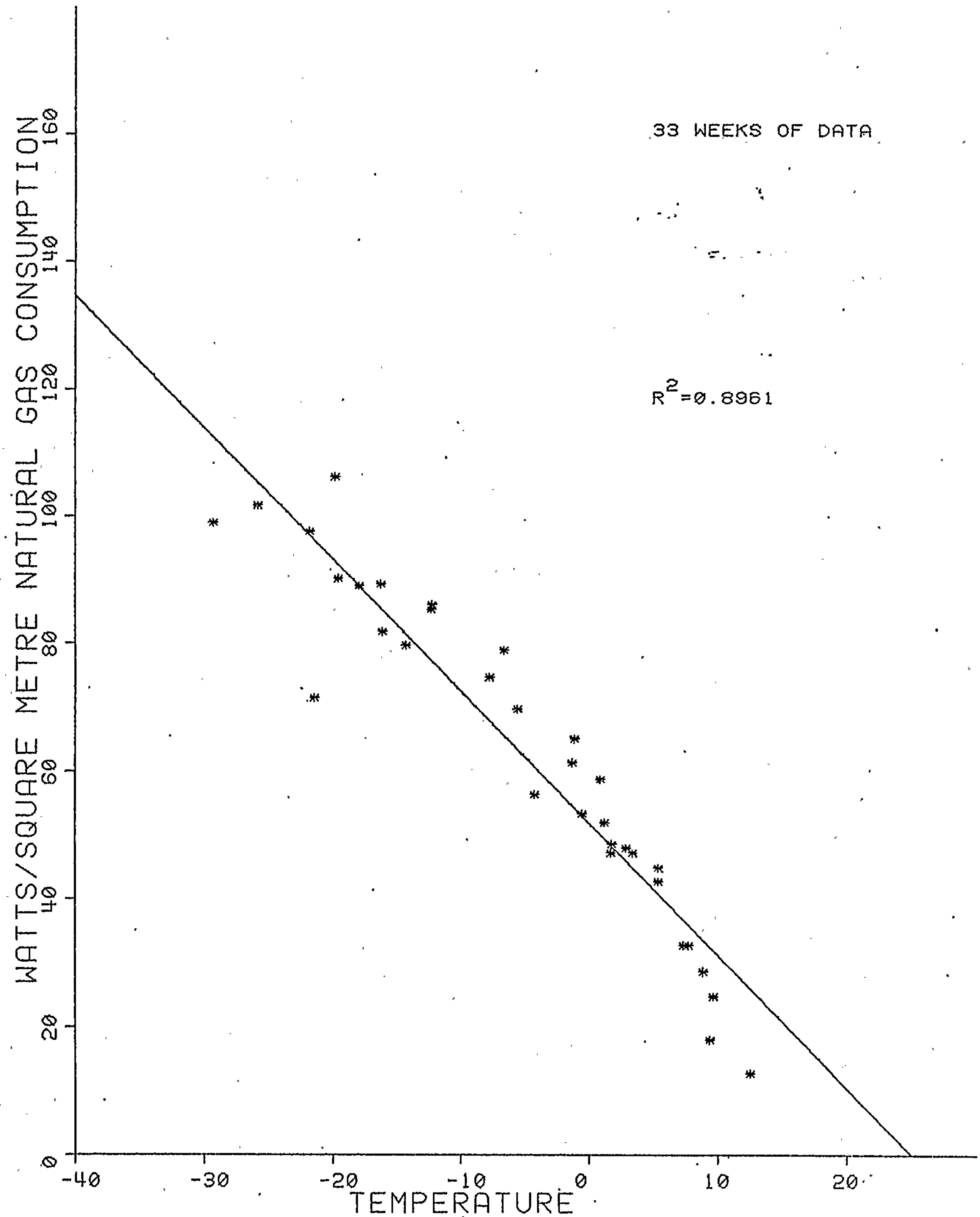


Figure 12.13 Regression plot based on weekly natural gas consumption rates at Parkside School.

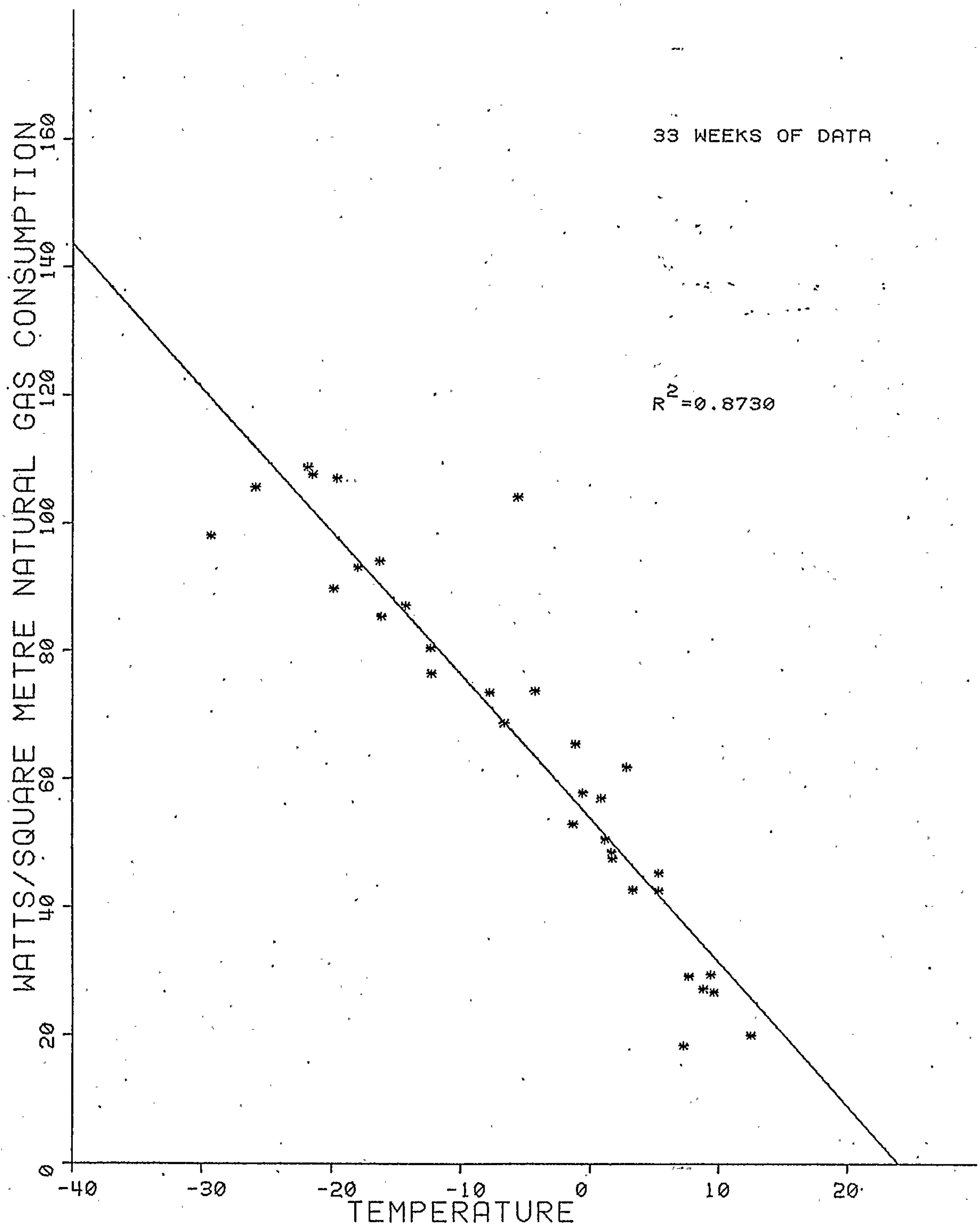


Figure 12.14 Regression plot based on weekly natural gas consumption rates at the Composite High School.

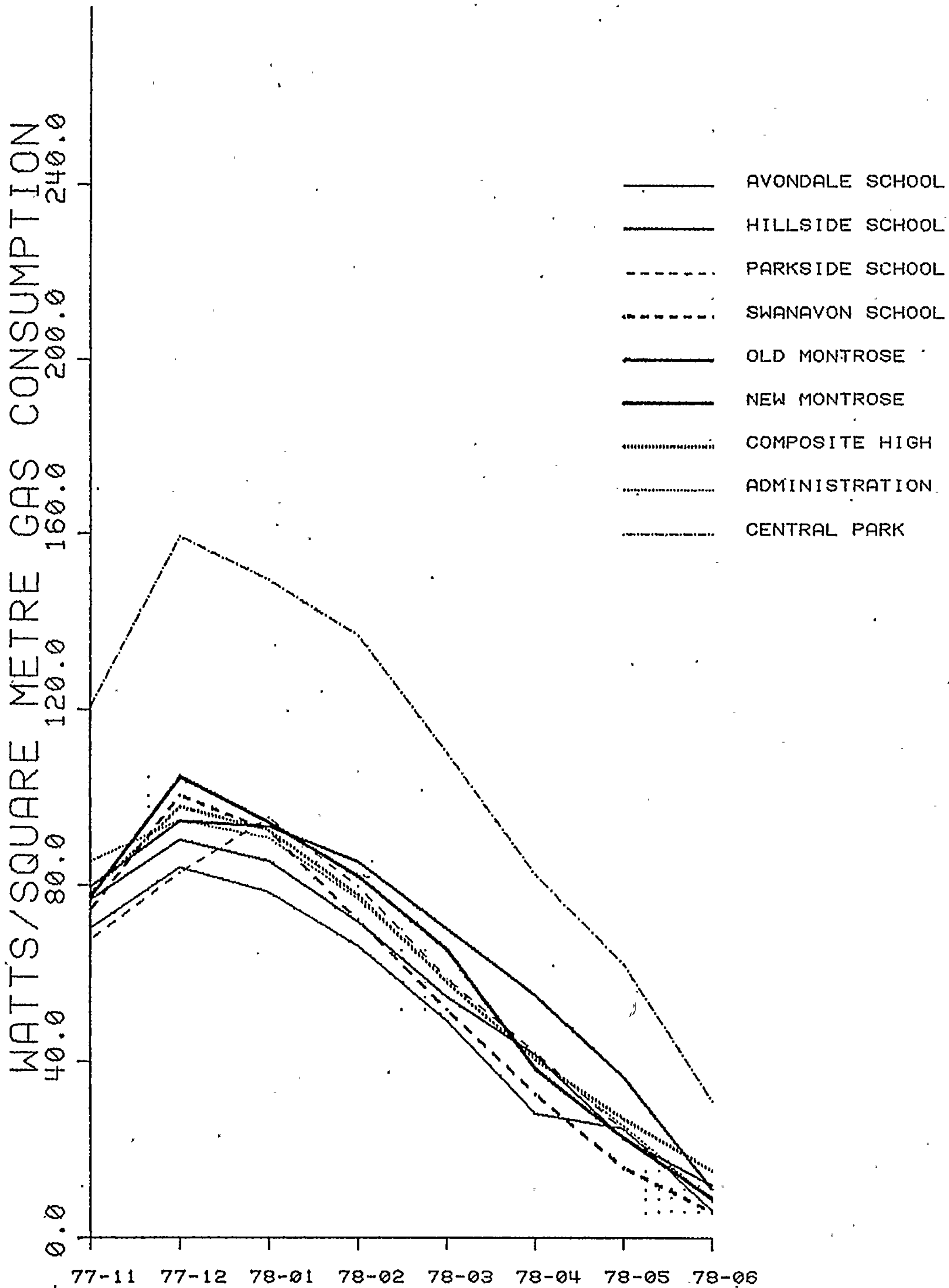


Figure 12.15 Monthly natural gas consumption rates in Grande Prairie School District No. 2357 buildings during the research study.

The intercepts were obtained by extrapolation; it is not likely that schools will consume 0.0 W/m^2 of gas at 22 degrees Celsius since hot water heating must still be accomodated. It is also evident, from the regression line for Parkside, that the consumption rate at this school appears to be dwindling rapidly as the average weekly temperature approaches 22 degrees. Two schools appear to have extraordinarily high reference temperatures. Additional data will be required (and is being obtained) to determine true consumption rates at warmer temperatures.

Lossiness also varies substantially from building to building.

Factors primarily affecting the lossiness of a building are:

(i) thermal conductivity of the building envelope

(ii) air tightness of the building envelope

(iii) massing and site factors

These characteristics of a building are relatively stable over periods of at least a year or two.

Factors which could affect both the reference temperature and the lossiness of a building are:

(i) thermostat settings

(ii) domestic hot water heating

(iii) insolation

(iv) wind

(v) heat gain from internal sources (people and lights)

(vi) space cooling

(vii) human demands (use of doors and windows, for example)

(viii) heating system performance

Average effects of these factors will determine the reference temperature, while variations in these effects will cause scattering of performance around the "lossiness line" for a building.

Various investigations, discussed in the following subsections, were conducted to gain a better understanding of the effects of these factors on building energy requirements. Because reductions in consumption were being sought of the same order of magnitude as fluctuations caused by these factors, it was essential to be able to correct for them.

12.2.1.1 Domestic Hot Water Demand

The only major uses of natural gas during the heating season are space heating and domestic hot water heating.

At Parkside School, the sole domestic water heater was metered. Maximum weekly consumption amounted to 1.25 W/m^2 for the building. Total gas consumption at Parkside was over 40 W/m^2 every week except during the late spring. Daily readings of the meter on the hot water heater revealed that the typical weekday consumption rate was 1.45 W/m^2 and that the typical weekend rate was 0.96 W/m^2. This compares with total standing pilot consumption, calculated to amount to 1.30 W/m^2 for the school (furnaces plus hot water heating units - Macriss, 1977).

At the Composite High School, the two hot water systems serving the highest demand areas (cafeteria, beauty culture, and showers) were metered. Joint consumption never exceeded 1.25 W/m^2. Doubling this figure provides a high estimate of domestic hot water system demand for gas at 2.50 W/m^2. Total standing pilot consumption amounted to 0.80

W/m^2 (furnaces plus hot water heating units). Total natural gas consumption at the Composite High School also exceeded 40 W/m^2 during the winter months.

Given the magnitude and regularity of natural gas use for domestic hot water heating, this factor does not appear to make great enough an impact on overall performance to have caused the large week to week variations in lossiness or the high reference temperatures which were observed at some schools.

12.2.1.2 Climatic Effects

Evaluating effects of heat gain from the sun was a rather difficult proposition. No data on local insolation are collected by the Grande Prairie weather office. The nearest recording station is located at Fort St. John, British Columbia, some 100 km northwest of Grande Prairie. It was therefore necessary to employ solar data from this station in correlating natural gas requirements with heat gain from the sun. Local records were available to check wind effects.

Correlation of building natural gas consumption with average weekly temperature (discussed above) produced an average r-squared of 0.938 (with 33 weeks of data); when multiple correlation of natural gas consumption with average weekly temperature, wind speed, hours of insolation, and days of school use was undertaken, the average r-squared was found to be 0.929 (with 20 weeks of data) (see Table 12.4). Of this, 0.905 was attributable to temperature. Given the complexity of wind effects and the remoteness of the location at which the solar data were collected, it is possible that these climatic comparisons are slightly

Table 12.4. R-squared values obtained from analysis of factors affecting variability of natural gas consumption rates in Grande Prairie School District buildings (step wise multiple regression was performed on 24 weeks of data to obtain these figures).

	Variable Explained				
Building	Temperature	Wind	Hours of Sun	Days School Opened	TOTAL
Avondale	0.874	0.016	0.010	0.015	0.915
Hillside	0.889	0.008	0.001	0.003	0.901
Parkside	0.853	0.034	0.017	0.011	0.915
Swanavon	0.884	0.000	0.002	0.000	0.943
Old Montrose	0.921	0.001	0.002	0.000	0.923
New Montrose	0.975	0.007	0.000	0.001	0.976
Composite	0.945	0.002	0.003	0.001	0.952
Administration	0.849	0.002	0.004	0.007	0.880

inaccurate.

To probe the weather question further, cross-correlations of building performance were run (see Table 12.5). Cross-correlation of building natural gas consumption produced an average r-squared of 0.92 This suggests that weather effects to which all buildings were exposed (such as insolation) were not responsible for the remaining variation.

Cross-correlation of gas consumption by the four buildings located beside each other at the centre of town yielded an average r-squared of 0.94. This suggests that microclimatic variations between school sites were not responsible for the variations in gas consumption which are not

Table 12.5. R-squared values obtained from cross-correlations of natural gas consumption rate variations in Grande Prairie School District No. 2357 buildings.

Building	01	02	03	04	05	06	07	08	09
01 Avondale	1.00	0.93	0.86	0.93	0.89	0.95	0.88	0.94	0.90
02 Hillside		1.00	0.87	0.98	0.92	0.96	0.89	0.95	0.93
03 Parkside			1.00	0.86	0.90	0.92	0.83	0.87	0.92
04 Swanavon				1.00	0.90	0.96	0.89	0.94	0.92
05 Old Montrose					1.00	0.94	0.89	0.92	0.94
06 New Montrose						1.00	0.92	0.96	0.97
07 Composite							1.00	0.91	0.89
08 Administration								1.00	0.91
09 Central Park									1.00

AVERAGE = 0.92

explained by climatic variables.

12.2.1.3 Heat Gain and Heat Loss from Internal Sources

Typical weekly heat gain from lights at Parkside School was calculated to be 3.0 GJ/m^2. Heat gain from users was estimated at 2.8 GJ/m^2. This amounts to 5.8 GJ/m^2, or between 8 percent and 48 percent of the thermal value of natural gas supplied weekly to the school during the research study. For most of the heating season, the figure represents less than 24 percent of the gas supply.

Correlations of weekly gas consumption rates with the number of days per week of school use showed a minimal connection between the two (see Table 12.4). As with solar data, this correlation result cannot be accepted at face value; the effects of human users on building energy consumption are more complicated than effects such as temperature. People contribute body heat to interior spaces, but they also cool buildings by admitting outside air through doors and other openings. Such infiltration is very difficult to estimate with precision. While their use of lights will always warm rooms, the results of people's use of thermostats can be quite unpredictable, as the following example illustrates.

Figure 12.16 shows natural gas use at Hillside School plotted against average weekly temperature. One point, noticeably removed from the vicinity of the regression line is marked. This point corresponds to the first week of very cold weather in November. While an average temperature of -1.2 degrees Celsius was experienced in the preceeding week, during the week in question a figure of -19.6 degrees was recorded. Consumption of natural gas during this week was greater than at much colder temperatures experienced later in the winter, as can be observed from the plotted data. Three other schools exhibited the same phenomenon. When "predicted" consumption rates (based on the regression plots) were substituted for the actual rates recorded during the week, the r-squared obtained by correlating with temperature rose by an average of 0.015 for these four buildings. The variation in gas consumption not accounted for by climatic factors was less than 0.100. Given the apparent impact of human users on building performance over a single

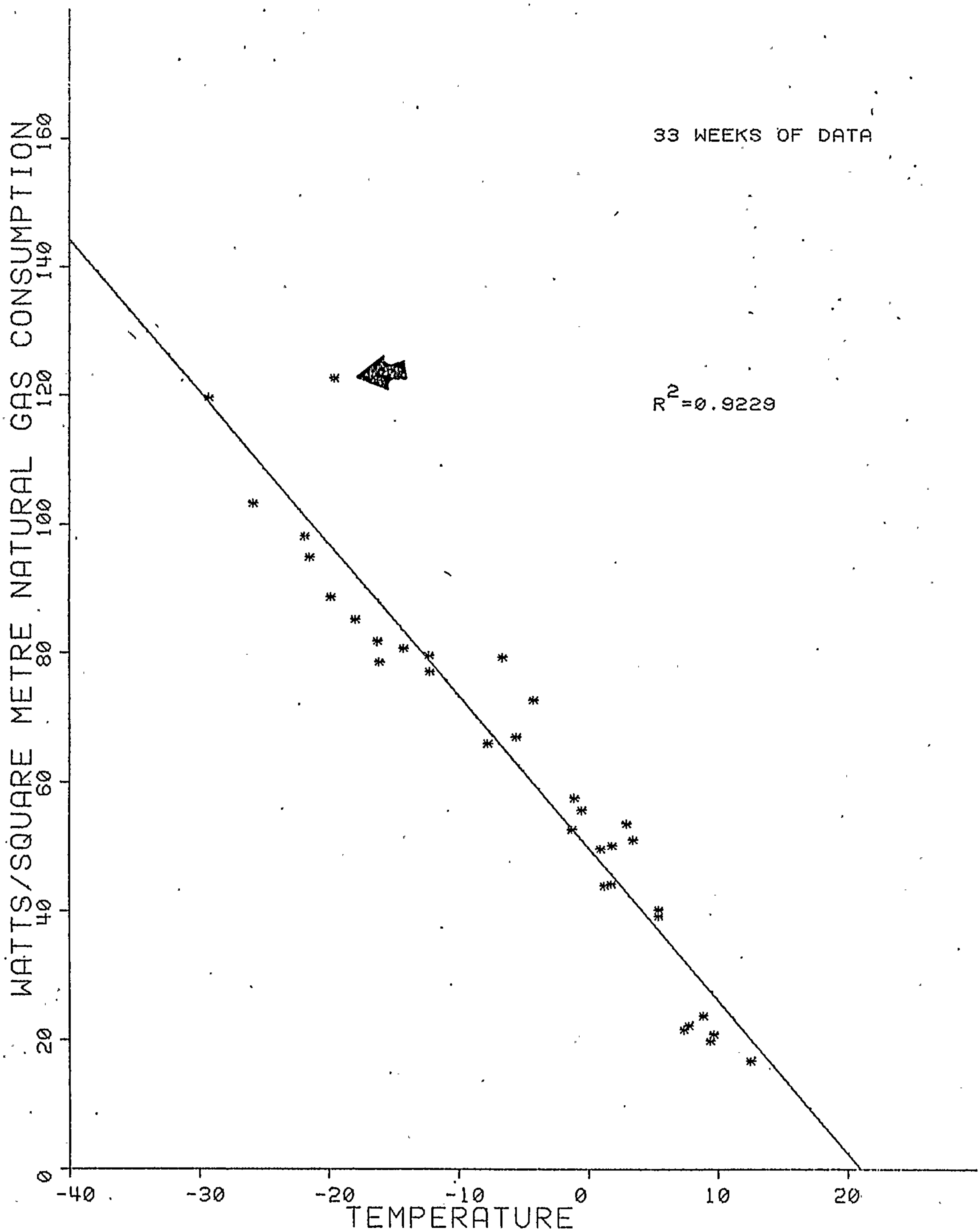


Figure 12.16 Regression plot based on weekly natural gas consumption rates at Hillside School.

week, it is probable that the majority of the 0.100 residual variation is attributable to variations in demands placed on environmental control equipment by building occupants.

12.2.1.4 Space Cooling

Space cooling could affect the reference temperature by raising it for schools equipped with such systems. However schools without space cooling equipment were found to have high reference temperatures.

12.2.1.5 Heating System Performance

The two schools with very high reference temperatures both have old hot water heating systems; the high reference temperature is possibly a manifestation of inefficiencies in these heating systems.

12.2.1.6 Summary

It appears that exterior temperature is the only major determinant of requirements for natural gas. Of the secondary factors causing variations in heating requirements from what would be expected as a result of simple physical heat loss by buildings to the exterior environment, human demands appear to be substantially more influential than any other such factors. Additional collection and analysis of data will be required to further probe some of the peculiarities of performance which have been noted above. However, it appears that a statistically based characterization of building response to temperature can be used to evaluate performance.

12.2.2 Hourly and Daily Natural Gas Consumption Patterns

To develop a better understanding of the factors affecting building requirements for natural gas, an attempt was made to measure natural gas usage over very short periods, as was done for electricity. Unfortunately the automatic gas survey units were not capable of providing as detailed information as the electrical survey units. Time lapse photography of meter dials was undertaken at the Parkside School from 1978.02.07 (Tuesday) to 1978.02.12 (Sunday) to more precisely monitor short term natural gas demands of the building. While a longer measurement interval would have been desirable, it was not feasible given the nature of the attention required by the equipment. The object was to examine the links between patterns of activity in the building and natural gas consumption rates. Parkside was selected again because of its relative lack of complexity.

Figure 12.17 shows plots of hourly consumption rates for active and inactive days at Parkside School. No distinct variations linked to hours of use could be found in the data. However, the absence of a distinct variation during the weekday is in itself conspicuous, since one would expect a more substantial decline in gas supply during the day, considering the heat gain from occupants, lights, and increased outdoor temperature. It may be that heat loss via infiltration just balances heat gain from these other sources. It should be noted that averages over any period less than a day can be somewhat misleading in that "instantaneous" consumption rates fluctuate between observed maximum and minimum rates throughout the day. Such rapid fluctuations are attributable to the intermittent and independent operation of 15 gas burners in

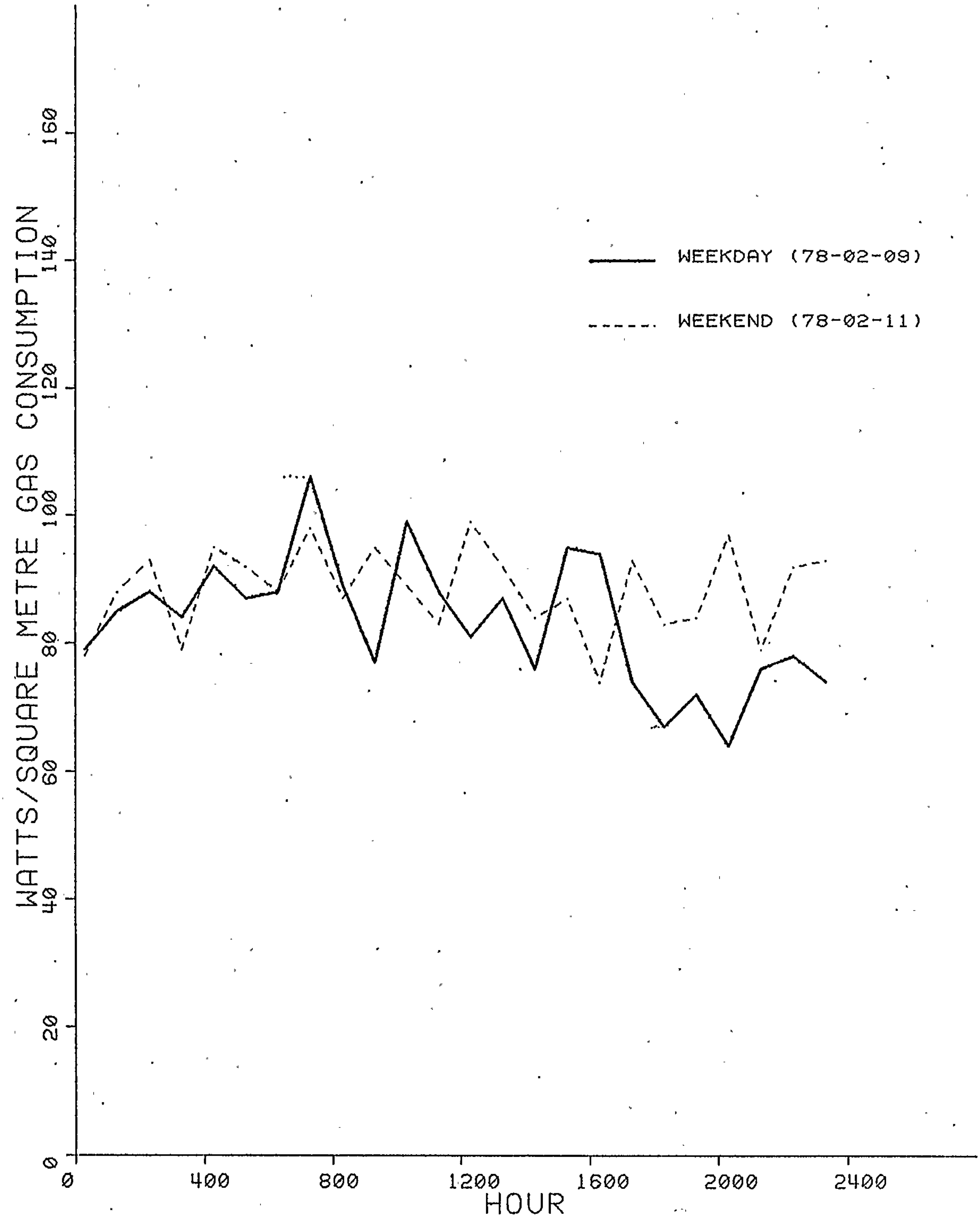


Figure 12.17 Plots of weekday and weekend hourly natural gas consumption rates at the Composite High School over a 24 hour period.

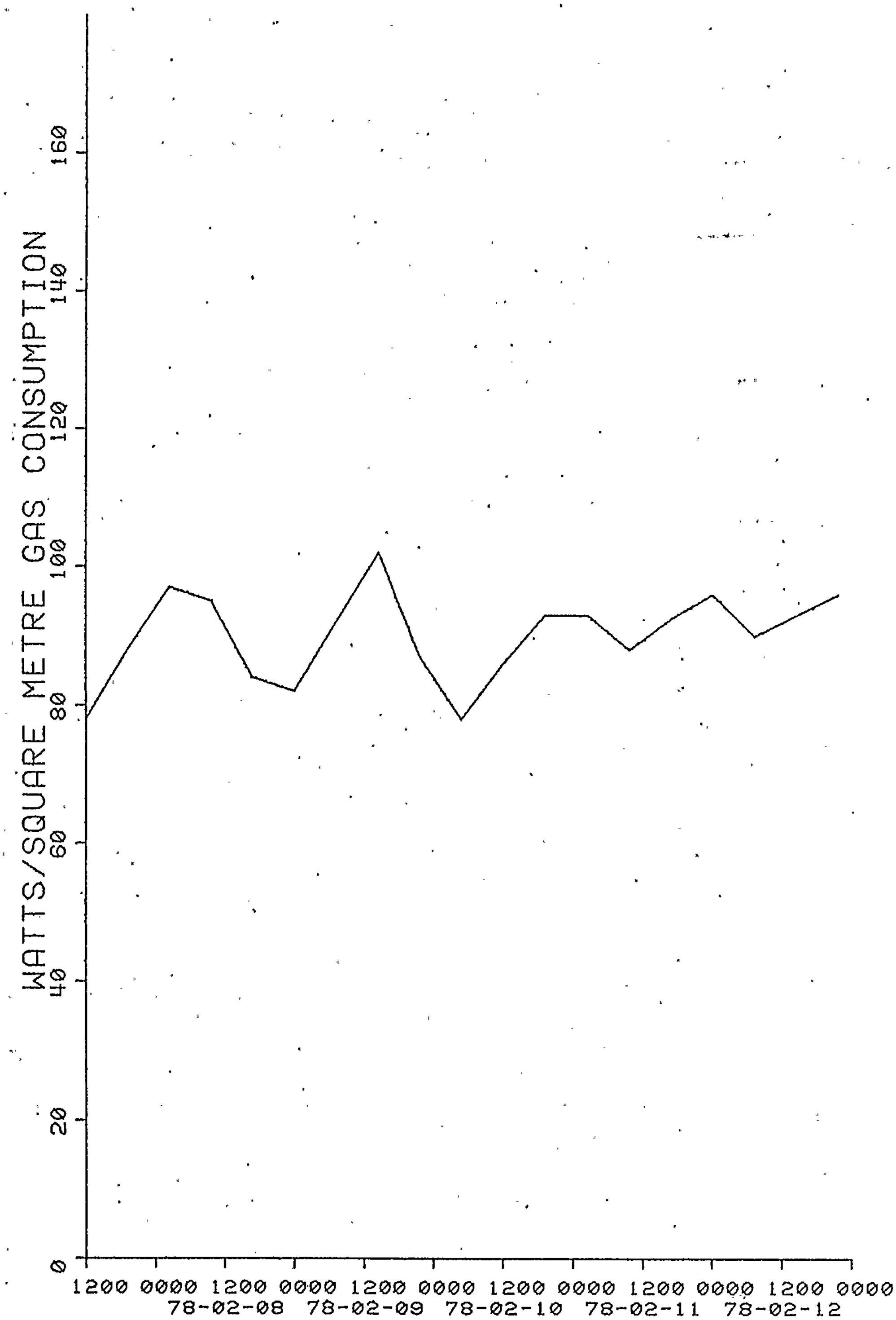


Figure 12.18 Plots of 6 hour natural gas consumption rates at the Parkside Elementary School.

the school, regulating temperatures in different sections of the building. The magnitude of the fluctuations never exceeded 15 percent of the mean daily consumption rates. Direct links between events such as morning arrivals and evening departures, and "instantaneous consumption rates" could not be found. Further data collection and analysis would be required to pursue this enquiry.

Consumption rates were calculated for each of the four six hour periods in a day, and plotted in Figure 12.18. Peak consumption rates occur in the early morning hours, while the minimum consumption rate occurs during the afternoon, as might be expected from daily temperature and insolation profiles.

12.2.3 Evaluation of Natural Gas Performance

Evaluating reductions in consumption was more complicated for natural gas than for electricity, due to the magnitude of the reductions possible and the magnitude of variations caused by weather.

Since a control period had been instituted before conservation measures were implemented, and since control buildings were employed after implementation, it was possible to develop Table 12.6. Four sets of weekly data are presented for each of the control and conservation groups. The first set corresponds to the period after which conservation schools were requested to implement gas conservation measures. The second set corresponds to the same period, but excludes one week due to the abnormally high gas consumption rates experienced at four schools (all in the conservation group). The third set covers the "post-

Table 12.6. Information obtained from monitoring for evaluation of natural gas conservation measures.

Data Set	R-squared (Average Weekly Temperature)	Reference Temperature (degrees Celsius)	Lossiness (W/m^2 per degree Celsius)
Control Group			
I Weeks 1-7	0.949	23.9	3.08
II Weeks 1-5,7	0.894	20.8	3.01
III Weeks 8-33	0.959	26.4	2.68
IV Weeks 17-33	0.921	22.9	3.11
Conservation Group			
I Weeks 1-7	0.969	21.2	2.81
II Weeks 1-5,7	0.937	20.5	2.89
III Weeks 8-33	0.946	20.9	1.98
IV Weeks 17-33	0.922	19.6	2.48

control" period. The fourth set covers "postcontrol" weeks, but excludes midwinter weeks in which temperatures much colder than those recorded in the control period were experienced.

From period II to period IV, control buildings exhibited a 2.1 degree increase in reference temperature and a 3.3 percent increase in lossiness. Over the same intervals, conservation buildings exhibited a 0.9 degree decrease in reference temperature and a 14.1 percent decline in lossiness. The drop in reference temperature is noteworthy, since it was achieved in spite of a reduction in heat gain from lighting in the conservation period (one would normally expect the reference temperature to rise if supplementary heat gain from interior loads was reduced, since a greater burden would be placed on the building heating systems). A consistently maintained improvement in performance of this magnitude by the conservation buildings would represent an overall reduction in natural gas requirements of between 15 and 20 percent.

12.3 Conclusions

Major savings in electricity consumption are to be achieved through reducing excessive lighting, excessive use of lighting, and excessive base load requirements. Because of building system features and climatic conditions, large scale reductions of base load on a year round basis is not possible.

While savings in natural gas from conservation measures for the hot water system can be easily achieved, this use of gas is a relatively small fraction of overall consumption. Space heating represents the single major load. However, again because of building system features and climatic conditions, major reductions through thermostat setback are not possible.

It is possible, through use of a statistically developed measure to evaluate building performance in terms of natural gas requirements over weekly intervals. One week intervals appear to be the most satisfactory time framework for monitoring requirements for both natural gas and electricity since they span the shortest consistently recurring activity cycle within the school system. However a data base of daily readings is necessary to ensure the accuracy of weekly calculations.

13. OBSERVATIONS AND CONCLUSIONS

13.1 Assessment of the Conservation Effort in Grande Prairie

The objective during the first year was primarily to evaluate techniques for monitoring and regulating energy utilization rather than to secure the greatest possible savings. Nonetheless, reductions in electricity and natural gas consumption, and in electric demand levels, have been achieved which are equivalent to a saving of more than $20 000 of the annual $180 000 utility expenditure (in 1978). With full implementation of conservation measures, this saving should be substantially increased.

Secondary benefits have been realized both directly and indirectly by the school district. A $2000 saving in expenditures for flourescent tubes was a direct benefit of the conservation programme. The 60 to 100 kW reduction in peak electric demand by the public school district represents a long run saving in infrastructure costs to the utility, which will benefit consumers in general. A specific manifestation of this benefit is the power supply for the new elementary school being constructed by the separate school district in 1978. The reduction in demand from conservation will allow this school to be connected without any increase in the electric utility system capacity.

The following items represent a potential for future savings:

13.1.1 Electricity

13.1.1.1 Summer Operation

It appears that a 5 to 10 percent reduction in electricity consumption could be achieved by cutting electricity use in July and August, when the schools are inactive. Measures are being taken to ensure that this load is disconnected over this summer vacation period (1978).

13.1.1.2 Lighting

Reductions of lighting levels have still to be implemented in some areas, while disconnection of idle ballasts should reduce overall district electric demand by a further 10 kW, with a corresponding reduction in consumption (this work was not undertaken during the 1977-78 winter since the district was in the process of hiring an electrician).

At some schools, users could still make significant reductions in their demads on systems.

13.1.1.3 The Composite High School

Reductions of excessive overnight electricity use at the Composite High School represent a potential for a 5 percent annual saving in that building.

13.1.1.4 Fall/Spring Operation

While reductions in operating times are not possible from November through March, weather during the months of September, October, April, May and June, is moderate enough to allow motors of heating/ventilating units to be switched off during inactive periods. If such motors are operated only 50 hours per week, this would amount to a 70 percent reduction in weekly base load. Maintained over 5 months, this would be equivalent to approximately a 20 percent reduction in annual district electricity consumption. One obstacle to this measure is the inaccessible location of controls for many units.

13.1.2 Natural Gas

13.1.2.1 Summer Operation

A small saving (about 2 percent) in natural gas consumption appears to be possible through reduction of summer consumption.

13.1.2.2 Fall/Spring Operation

The electricity saving achieved through reduced operation of heating/ventilating units in warmer months would be parallelled by a saving in natural gas. However, since 60 percent of natural gas consumption occurs in the November to March period, the potential annual savings in natural gas would be about 5 percent.

13.2 Selective Retrofit

Justifications for use of retrofit on a selective basis were discussed in Chapter 6. Experience with conservation efforts in Grande Prairie has revealed another important reason for selective application of retrofit: physical modification of buildings may be necessary to facilitate the implementation of operational measures for reducing energy consumption. Specific examples of problems requiring a physical solution are:

(i) The relocation and installation of switches to allow custodial staff greater control over building operation.

(ii) The rewiring of car plugs at the Composite High School onto a separate meter to reduce winter peak demand for the building. This would also make it possible to regulate the usage of car plugs.

(iii) The addition of insulation to walls of schools. This would extend the seasonal period over which heating/ventilating units could be shut down.

Addition of insulation has additional direct benefits of reducing heat flow through the building envelope and of improving the conditions for human comfort within the buildings. It would also allow lower permanent thermostat settings, since the "cold wall" effect would be remedied. This measure would also protect plumbing, allowing for a more aggressive programme of thermostat setback during inactive periods. Apart from savings in utility expenditures, there would also be a reduction in manpower and material costs of repairing weather damaged building components.

13.3 Categorization of Schools

As determined from the analysis of utility records, the Composite High School consumes over half the electricity purchased by the school district and forty percent of the natural gas. It also has the highest specific electricity need in the district. No other single building comes close to having the same impact on overall district performance.

Size is an immediately distinguishing characteristic of the High School; it encompasses nearly three times the gross floor area of the next largest building in the district. The scale and simplicity of plan of the other buildings allows a tour of inspection to be completed in a few minutes; the "Comp" requires a much longer time, not only because of its size, but also because of a greater complexity of plan. The greater size is complemented by a greater diversity of function; the school includes not only classrooms, but a fully equipped wing for instruction in industrial vocations, several laboratories, a cafeteria and kitchen, and other specialized activity areas.

Being a large building with diverse functions, the Comp also has a proportionately more extensive teaching, administrative, and custodial staff than any of the other schools. The range of employment roles is diverse,. both among the teaching staff and among the administrative and custodial staff. The Comp is the only school with a full time professional business manager. The size of the building also merits the presence of custodial staff on a 24 hour basis.

These three characteristics - impact on overall consumption, complexity of function, and staffing - necessitate a different approach to regulation of energy utilization at the High School. This approach will be enlarged on in later discussions.

13.4 Impact of User Groups on Consumption

A fundamental question was the relative impact of different user groups on energy consumption. The answer is important in determining where efforts should be directed to realize the maximum energy savings in day to day operations for the effort expended.

13.4.1 Electricity Consumption

Roughly 50 percent of average weekly electricity consumption in a school is attributable to the base load which is mostly comprised of electric motors. These are not under the control of teachers and students. Building users have more control over consumption by lighting systems which are responsible for the other 50 percent of weekly electricity use. This control is limited to duration of use: installed lighting power is again beyond the control of the immediate user.

Reductions in lighting at selected schools produced corresponding reductions of up to 27 percent in registered electric demand and up to 36 percent reductions in consumption. Determining exactly how much of reduced electricity consumption was attributable to reduced electric system capacity and how much to more careful use was not possible at the conservation buildings, since the users (even when requested not to) became more conservative in their energy use. Even at the New Montrose School, a reduction of 10 percent occurred, although this was a "control building". Similarly, at the Old Montrose School, a decline of 19 percent in consumption was noted, although 30 percent of this decline was attributable to removal of 30 flourescent tubes in corridors. The change not attributable to physical modifications at the control schools was probably a result of the "Hawthorne effect", which argues that performance improvements can sometimes be the result simply of the increased attention paid to the group being studied (Seligman, 1978).

This demonstrates that people using a building can have a significant effect on levels of electricity consumption, but leaves unanswered the question of what effect each user group has. It was evident from observation that students generally have the least influence on consumption levels, since teachers and other staff supervise and have authority in most areas within a school.

Between 08:30 and 16:30, when teachers are occupying buildings, lighting must be on in many areas within a school. In windowless classrooms, lighting is always required when the spaces are in use. Because rooms with windows are often poorly designed for illumination by daylighting, artificial lighting is frequently needed to counteract exterior glare and to balance interior illumination levels. In the Grande Prairie schools, spaces are often in use throughout the day. During the winter, classrooms are in use as lunchrooms at noon for most of the student body in elementary schools; at other times of the year, bussed students will still be around at noon. Within the 8 hour school day these types of circumstances will limit the amount of lighting which can be switched off.

Custodial staff, on the other hand, occupy school buildings from 07:00 to 08:00 and from 16:30 to 18:30 (or later), times when most of the rooms are empty. This represents a minimum of 25 percent of daily use time. If these people are careless about use of lights they can easily negate conservation efforts by teachers. If they are conservative in their use they can make a large difference in requirements. It was likely these people who were responsible for the majority of the energy savings in the control buildings. They, like other custodians, were recording their buildings' energy consumption on a daily basis. This certainly engendered an increased awareness of energy use in the custodians at the conservation schools. Added to this was the knowledge that these readings were being evaluated by the research team.

An equally significant conservation role for custodians lies in the operation of building equipment - custodial staff could reduce requirements created by the base load. During the warmer months (September, October, April, May and June), substantial electricity savings could be achieved by switching off heating/ventilating systems at night. If such systems are operated from 07:00 to 17:00 Monday to Friday only, this would represent a 70 percent reduction in the weekly base load.

13.4.2 Natural Gas Consumption

The savings in electrical energy obtained by switching off heating/ventilating units would be complemented by a saving in natural gas. Again it must be emphasized that classrooms are only occupied 50 of the 168 hours in a week, so that this saving could be very significant.

Such extreme measures cannot be applied during colder months. However in a classroom, even in midwinter, lighting and human body heat contribute about 75 percent of the space heating supply (3 kW versus 1 kW from a unit heater). If thermostats are raised above 20 degrees Celsius between 08:30 and 16:30, the net penalty in natural gas consumption requirements is therefore not as great as it might seem. The real penalty is incurred if thermostats are left at settings higher than 20 degrees Celsius for the 120 hours per week that classrooms are unoccupied (greater energy savings accrue as the interior temperature is further reduced, but this potential is limited by other constraints such as durability of building components). Custodial staff can again play a major role by ensuring that thermostats are set to reasonable limits at 16:30.

Where teachers and students will have a major effect is in air infiltration. By using vestibules (where they exist) as thermal buffers and by leaving exterior doors open for a minimum amount of time, the load on heating equipment can be significantly reduced. In residential construction, air infiltration accounts for about 30 percent of the heating load; infiltration in the Grande Prairie schools can be estimated to be of the same order of magnitude.

13.4.3 The Composite High School

Features of the Composite High School deserve some special comments. Here, many spaces tend to be used less intensively for some periods of the day than is the case at the other schools, creating a greater potential for daytime electricity savings. Some individual staff members also control a relatively large amount of electricity and gas use.

In the vocational wings, shop areas have high lighting levels (important for safety reasons). These shops included large amounts of floor area, and so represent large individual electrical loads when all the lighting is switched on. Often only small parts of these areas are in use - significant savings could be achieved by selectively switching lighting as required. The shops are also equipped with large doors opening to the outside for moving equipment in and out of the service bays. Infiltration through these doors, when open, places a major load on building equipment. Therefore conservative use is important.

Another area where significant savings can be made during active hours is the resource centre. This area is thoroughly illuminated by skylighting. On an overcast day, levels of illumination exceed 2000 lux, even without the aid of the electric lighting system. This system is therefore seldom really needed although the practice has been to use it continually. The lighting capacity in each of the shop areas and the resource centre is about 6kW, or about 2 percent of the total school electrical demand, so these are large unit loads.

Overnight demand at the Comp was found to be about 25 kW higher on days other than Sundays than it was on Sundays (when the building was totally unoccupied). This represents about 5 percent of annual consumption at the Comp, an amount equal to about one third of the total consumption of any of the other schools. Yet there is only one individual in the building at the times that this consumption occurs.

13.4.4 Community Use

Community use of an elementary school gymnasium 3 hours per day 5 days per week over 40 weeks would account for between 2 and 5 percent of annual electricity consumption, or about $100 dollars worth of electricity in 1978 dollars. The impact on gas consumption would be equivalent, barring extremely wasteful practices (such as leaving doors open in midwinter). With buildings under custodial supervision, however, waste should be limited. It can be concluded that community uses of schools do not represent an exorbitant energy burden to the school district.

13.4.5 Maintenance Staff

The influence and potential influence of custodial staff on energy consumption has been noted. This influence stems from the custodian's intimate relationship with operations in his building.

However, maintenance staff also have an important role to play. The operating efficiency of the building and its component systems will be significantly affected by the quality of servicing which is given physical plant. Particularly important is maintaining the air-tightness of the building envelope through regular inspection and repair (some of the physical obstacles to maintaining air tightness have been discussed in Chapter 10).

13.5 Organizational Problems in Energy Management

In the course of the project, major obstacles to conservation have been identified and categorized. This section deals with some of the human and organizational barriers to reduced energy consumption rates.

13.5.1 Apathy, Inertia, and Ignorance

Some users were found to be unwilling to make an effort to conserve energy, small as the required effort might be. This was true of elements of all user groups. The explanation (since these individuals were frequently accosted and questioned) was sheer apathy and inertia. This may have to do with a factor called the "high effort-low payoff" factor (Seligman, 1978). People do not believe that the effort made to conserve really makes a difference.

This was reinforced by random interviews with teachers who were spotted, alone, in classrooms which were fully illuminated. In one case, for example, the lady replied that she was very conscious of energy conservation since her husband worked for Alberta Power Ltd. She simply didn't think that the lights "made that much of a difference". In another case, the gentleman replied that he was a recent university graduate, and that as a well informed person he was concerned about conservation; however, the proffered reply about lights was the same.

Combatting apathy, inertia, and ignorance will require a continuing programme of education of all users.

13.5.2 Lack of Leadership

The education of users must be carried out by the administrators, who are the senior educators in each district and who have the recognized authority to implement change.

In some cases, principals and their assistants were as guilty as any other party of energy waste. One of these individuals habitually left the lights on in his vacant home room, even after expressing concern for conservation in meetings to plan for reductions at his school. Another prime example is provided by the High School staff. The large doors in the vocational wing are commonly used as a "short cut" to the staff parking lot, especially in cold weather. This was a practice of all staff, including administrators. Again, the problem is one of not realizing that the consequences of all these actions add up.

The administrators must make a genuine commitment, expressed in deed as well as in word, to energy conservation. They must in turn follow up on their staff. This will require more attention to the use of the school building itself than has been customary in the past.

A couple of school systems in Alberta have attempted to implement energy conservation programmes, as have some school systems in other parts of Canada. Interviews and case studies provided some useful perspectives on leadership problems.

It is frequently the practice to delegate responsibility for energy management; this is usually the assigned task of the maintenance supervisor. Yet, this individual, while he can sometimes reduce energy requirements (particularly if he is competent and self motivated), cannot effectively assume responsibility for the whole district. The personnel chart (Figure 3.1) shows that the strongest lines of authority flow from the superintendent via the principals to local school staff. In many cases the maintenance supervisor is considered a subordinate figure to principals and even to teachers; they will not recognize his authority to insist on changes in the use of schools. The situation will be even worse if the maintenance supervisor is not motivated.

Another problem is that the maintenance supervisor is not necessarily trained to develop conservation measures or to assess energy utilization. His scope of responsibility often emphasizes more of a "caretaker function", than one of finding new ways to improve building performance.

One of the real problems for a district superintendent is evaluating energy utilization and the effectiveness of conservation measures relative to their potential. This individual does not usually have a technical background, yet it is essential that he be involved in the operation of the programme.

13.5.3 Loss of Enthusiasm Over Time

Energy conservation programmes are frequently initiated with much publicity and little substance. Users are exhorted to be more conservative, but in time interest tends to wane. Over time conservation may also be displaced by other concerns.

A rigorous management approach is required to ensure that the programme maintains its effectiveness. The information/auditing system is essential in providing an indisputable, quantitative, and continuing check on performance.

13.5.4 Discontinuity of Personnel

With contemporary levels of mobility, roles are filled by different people for only short intervals of time. The goals, techniques, and records of the energy management programme must be well documented so that continuity of performance can be maintained. Again, the auditing function should quickly indicate any problems in performance.

13.5.5 Resistance to Administrative Change

Many school system administrators are already very busy people. They may resent the time demands posed by energy management. However, if the substantial benefits of a thorough conservation effort are to be realized, this resistance must be overcome.

13.5.6 Lack of Communication

Administrators must be aware of what is happening in their schools as far as energy mangement is concerned. A simple example is provided by the plight of an elementary school custodian. A teacher tended to leave lights on after Saturday work sessions in his classroom. The custodian, because of relative status, could not reprimand the teacher. Instead, the reminder about conservation was transmitted via the principal.

13.6 The Energy Auditing System

Results obtained by the research team show that it is possible to perform weekly evaluation of energy use with reasonable accuracy and economy of effort.

One of the considerations in implementing a consumption monitoring programme is where responsibility should be placed for keeping track of performance. Reading of meters on a daily basis is necessarily a decentralized task. Calculation of consumption could occur either at the local school or the central office. However, if centralized, this would represent a couple of hours of work per week for a single individual, even in a small school system.

Principals in Grande Prairie agreed to keep records for their schools; this did not seem to create any problems although it did require the acquisition of some new skills. One advantage of performing this task locally is that it puts each administration in more immediate contact with the evidence of its performance.

One factor which could complicate the evaluation of user performance is the physical upgrading of facilities which will necessarily occur as utility rates continue to climb. These modifications will lead to reductions in energy requirements which should not be confused with conservation efforts by users.

13.7 Consultative Assistance

There are several reasons why consultative assistance is necessary for a school system's energy management programme:

(i) System superintendents, who are not technical experts, need unbiased information on the condition and performance of their physical plant.

(ii) Local staff are not usually equipped to evaluate energy utilization or to plan comprehensive management programmes.

(iii) In implementing energy management programmes in general and conservation measures in particular, administrative, custodial, and maintenance staff require very specific guidance.

The need for consultative assistance has been identified by other practicing professionals (Moses, 1977). In the estimation of this research team, it also will be a necessary service for Alberta school systems, and one which would repay its cost many times over.

13.8 Summary

These observations and conclusions led to the formulation of the recommendations listed in Chapter 14.

14. RECOMMENDATIONS

The first year of investigation yielded much valuable intelligence on the implementation of energy management. This intelligence was gathered through experimentation and exploration. The second year of the project will involve the implementation of energy management as a routine function of the School District. It is recommended that implementation of energy management incorporate the following elements.

14.1 Energy Auditing

The importance of good information on consumption rates has been discussed at length. Weekly evaluation of performance offers the most economic and satisfactory approach to control. To minimize error, the programme of daily meter readings, on which the weekly evaluations are based, should become a continuing part of the custodian's duties. The weekly evaluation should be performed by the school administration.

Schools will be evaluated against their own past performance. Because of seasonal fluctuations in gas and electricity consumption, actual weekly consumption is not a useful indicator of performance. The indicator of performance will be based on a "par" value established for each school on the basis of results from the 1977-78 monitoring programme.

14.2 Conservation Measures

Conservation measures are outlined in Appendix A. It is recommended that the year be divided into three operating periods, to correspond to constraints posed by climatic and use conditions:

(i) summer

(ii) fall/spring (September, October, April, May, June)

(iii) winter (November, December, January, February, March)

Energy utilization and conservation would be geared according to the constraints posed by each period. In summer virtually all systems would be shut down. Major reductions in operating levels would occur in the fall/spring period. Only minor reductions in heating system activity levels would occur over the winter to ensure durability of building components.

14.3 Incentives

It is recommended that user commitment to conservation be primarily stimulated through the existing management structure, in the same manner that careful allocation of other school district resources is achieved. Use of the existing management structure, and the motivators of personal recognition and job satisfaction worked in the stimulation of significant efforts during the first year of the project.

Performance charts should also be posted in conspicuous locations within each school, so that occupants can monitor their progress.

The most critical personnel in ensuring the success of the programme are the administrative and custodial staff at each school, and the administrative and maintenance staff at the central office. The major energy savings are to be achieved through the efforts of these individuals.

14.4 Consultative Assistance

It is evident that continuing access to expertise will be required by the School District to point out further opportunities for conservation and to provide the District Superintendent with feedback on the technical performance of his maintenance staff and buildings. Members of the research team will continue to play this role during the second year of the project.

In the longer run, it is recommended that Alberta Education establish a technical unit to deal with energy conservation for schools. Such a unit would require a professional staff which could operate with a professional status equal to that of school administrators.

The advantage of a full time unit serving schools would be that it could attain a high level of competence in dealing with the specific problems of schools. It could also provide continuity for a province-wide conservation effort for schools.

14.5 Selective Retrofit

It is recommended that a programme of selective retrofit be undertaken to gradually upgrade the performance of the Grande Prairie School District No. 2357 buildings. This would be undertaken with in house labour and phased to occur in "slack time" for the maintenance crew. Priorities would be established based on consultation between the Superintendent, the Maintenance Supervisor, and the "outside advisor". Among the objectives would be:

(i) upgrading of controls for equipment

(ii) improvement of building enclosure air-tightness

(iii) improvement of building enclosure resistance to heat flow

14.6 Summary

While the energy management measures employed in Grande Prairie have not been capital intensive, they do pose a definite cost in time and effort. This cost is also an ongoing cost. The school system must be willing to bear this cost if it is to realize the very significant benefits of energy conservation. Functions to be carried out by school and district administrations are outlined in Appendix B. Energy management will involve a long and continuing process of education of all users in a school system. The benefits of such a programme, however, are considerable.

APPENDIX A: MEASURES FOR SAVING ENERGY

I Human Management Practices (for administrators)

1. Work cooperatively with users in the implementation of measures.

   A note of caution must precede the recommendation of the following measures. For the sake of brevity, they are stated rather tersely. These measures are maximum initiatives to be taken; their implementation must be tempered with a knowledge of circumstances in each building - user circumstances must be considered. The most effective means of dealing with such circumstances is by delegating responsibility for specific implementation of measures which will affect local users to the local school administration.

   To give some concrete examples of specific considerations which would require some thought before measures could be adopted, measures 2.1 (night time thermostat setback to 13.0 degrees Celsius) and 3.3 (morning thermostat reset to 20 degrees Celsius) will be discussed. It is evident that special provisions would have to be made for tropical fish and other temperature sensitive animals kept in schools when the former measure is implemented. The latter measure is not to be considered an absolute dicta of the daytime temperature - it is simply anticipated that users could readjust the thermostat to preferred settings upon arrival, but that this setting would place classrooms on the boundary of the air temperature comfort zone.

   To gain acceptance, measures used to conserve energy must accomodate user preferences (within reason).

2. Monitor people's efforts and give them specific feedback on their performance.

3. Assign people specific responsibility for their work spaces.

   3.1 Teachers should see that classroom lights are switched off when rooms are vacant (recess, noon, after school).

   3.2 Shop instructors should selectively switch lighting when only portions of their shops are in use. Exhaust hoods should be operated as little as possible in winter, late autumn and early spring. During cold weather, use of exterior doors should also be minimized. Equipment should be operated in an efficient manner.

3.3 The evening cleaning crew should set thermostats at night time levels at 16:00.

3.4 The day crew should set thermostats at day time levels during the morning round of classroom checks (at 07:00).

3.5 Thermostats enclosed in protective cases should be checked weekly, where possible.

3.6 Staff should attempt to be economical in setting thermostats. Wearing a sweater is frequently preferable to turning up the heat.

4. Publicize the energy conservation programme and results of energy consumption monitoring so that all groups within the schools are aware of efforts and achievements.

II Seasonal Operation Practices

1. Summer

1.1 Shut off all space heating systems.

1.2 Shut off hot water heating systems where possible.

1.3 Shut off ventilating systems for unoccupied areas.

1.4 Shut off air-conditioning for unoccupied areas.

1.5 Minimize use of electric lighting systems.

1.6 Operate air-conditioning from 10:00 to 15:00 only in occupied spaces during work days.

1.7 Set internal temperatures at 22 degrees Celsius or higher when air-conditioning is operating.

2. Fall/Spring (September-October/April-June)

2.1 Set thermostats back to 13 degrees Celsius daily at 16:00.

2.2 Set thermostats to 20 degrees Celsius at 07:00 each morning that classes are held.

2.3 In air-conditioned spaces operate the cooling system from 10:00 to 15:00 only during working days.

2.4 Maintain temperatures in cooled spaces at 22 degrees Celsius or higher.

2.5 Shut off ventilation systems daily at 16:00 (this may be delayed for gymnasia and other areas used into the evening).

2.6 Turn on ventilating systems at 08:00 each morning that classes are held.

2.7 Ensure that corridor thermostats are never set above 18 degrees Celsius.

3. Winter (November-March)

3.1 Ensure that no thermostats are set higher than 20 degrees Celsius when schools are not in use (check daily at 16:00).

3.2 Where pipe freezing, motor burnout and other hazards do not exist, set thermostats back to 16 degrees Celsius daily at 16:00.

3.3 Set thermostats to 20 degrees Celsius at 07:00 each morning that classes are held.

3.4 Shut off air cooling systems.

3.5 Ensure that corridor thermostats are never set above 20 degrees Celsius.

4. Year-round

4.1 Substitute daylighting from windows and skylights for electric lighting where feasible.

4.2 Minimize use of electric lighting systems. Lights should be turned off in all unoccupied areas at all times.

4.3 During cleaning lights should be used only in the working area.

4.4 Ensure that all windows are firmly closed (check daily at 16:00).

4.5 Ensure that both outside and vestibule doors are firmly closed (check daily at frequent intervals, especially after periods of heavy traffic).

4.6 Ensure that leaking hot water taps are repaired.

III Maintenance Practices

1. Electrical

1.1 Reduce illumination levels where acceptable, but maintain minimum standards:

- 540 lux in classrooms
- 110 lux in corridors
- 1100 lux in shop areas

Maintain an even distribution of light.

1.2 Ensure that burnt out lights are replaced immediately.

1.3 Ensure that luminaires are cleaned monthly.

1.4 Replace existing flourescent tubes with low watt tubes (but maintain minimum lighting standards)

1.5 Reduce parking lot lighting to minimum levels required for safety.

1.6 Use proper size motors.

1.7 When redecorating, use light colours to achieve higher illumination levels.

2. Mechanical

2.1 Ensure that controls are calibrated and in good condition.

2.2 Clean air filters monthly.

2.3 Lubricate motors and other rotating equipment monthly.

2.4 Adjust outdoor air dampers for tight closure.

2.5 Adjust heating and cooling equipment to ensure maximum combustion efficiency.

2.6 External door tension should be removed so that doors will not stay open.

2.7 Clean strainer screens in water circulating systems at two month intervals.

2.8 Reduce air duct leakage.

3. Structural

3.1 Caulk window and door frames. Caulk cracks in walls.

3.2 Install weather stripping around windows and doors where not subject to excessive shifting.

3.3 Repair/seal broken windows.

APPENDIX B: ENERGY MANAGEMENT PROGRAMME ORGANIZATION

District Functions

- receive and assess weekly reports on energy consumption from each school
- produce and distribute district monthly energy use reports to the Board and to each school (including cost estimates)
- ensure that energy management measures are being implemented at each school
- provide technical assistance in implementing energy conservation measures
- obtain the mean daily temperature from the weather office, calculate the weekly average, and provide this figure to the schools
- check school energy consumption (monitor meters) at month end in June, July, and August
- ensure that equipment is switched off in July and August

School Functions

- read natural gas and electricity meters every school day
- keep track of weekly energy performance
- evaluate whether performance is satisfatory based on records of energy use and the activity schedule for the building.
- implement energy conservation measures
- ensure that all staff are aware of their responsibilities vis a vis energy management
- maintain plots of weekly natural gas and electricity consumption indicators in the main entrance foyer of the school

GLOSSARY

Celsius degree-days - the difference between the mean daily temperature and 18.0 degrees Celsius when the mean daily temperature is below 18.0 degrees Celsius; used as a measure of heating requirements.

footcandle - a measure of the light falling on a square foot of surface area (replaced by lux)

insolation - the radiant energy received from the sun by a surface

lossiness - the increase in the rate of supply of supplementary heat required by a building per degree drop in temperature below the reference temperature.

lux - an SI measure of the light falling on a square metre of surface area

reference temperature - the average exterior temperature above which a building will not require supplementary heat for space conditioning.

retrofit - the physical upgrading of a building to improve its energy utilization.

specific energy need - purchased energy consumed per unit of gross floor area per annum.

LIST OF ABBREVIATIONS

ASHRAE - American Society of Heating, Refrigeration, and Air-conditioning Engineers.

Btu - British thermal unit

CEFP - Council of Educational Facility Planners

cfm - cubic feet per minute

CMHC - Central Mortgage and Housing Corporation

EMR - Energy, Mines and Resources Canada

GFA - Gross Floor Area

GJ - gigajoule

hp - horsepower

IES - Illuminating Engineering Society

J - joule

kWh - kilowatt-hour

MCF - thousand cubic feet (of natural gas)

MJ - megajoule

NRCC - National Research Council of Canada

OEC - Office of Energy Conservation (EMR)

SI - System International

sqft - square feet

W - watts

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