A MODEL FOR AN INTEGRATED DESIGN APPROACH TO SETTLEMENT PLANNING IN THE ARCTIC

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I certify that this thesis has been composed by myself and that all the work herein, without direct references, is my own original work.

Leo R. Zrudlo

ABSTRACT

This thesis proposes a design approach to settlement planning in the Arctic which integrates technical specialists and the Inuit into the planning process. This document concentrates on the climatic and cultural aspects of settlement planning within a proposed four-level planning model.

The study briefly describes the physiographic and climatic characteristics of the Arctic context as well as providing a rapid history of the Inuit culture. Examples of traditional and contemporary Inuit housing types and traditional Inuit settlements are prosented. Several contemporary Arctic settlements are analysed taking into consideration the climatic data generated for latitude 65°N as well as certain cultural traits that emerged from the Inuit cultural history and the description of traditional Inuit housing and settlements.

A comparison is made with several design methods as a means of describing the theoretical basis of the proposed four-level planning model. A detailed description is then elaborated setting out design requirements at each level with the emphasis placed on the climatic and cultural factors. The planning process at each level is then presented with the corresponding synthesis procedure between levels and for the final synthesis. It is proposed that the decomposition of the planning process into four separate levels would result in a greater clarification of the requirements by the production of a settlement plan for each level and by the synthesis process. By generating plans for each level, alternatives are increased, stimulating the production of planning solutions that normally would not be investigated, as well as making explicit the priorities of the various specialists involved. The design approach integrates the user as an active partner in the design or planning process.

A hypothetical case study is elaborated to test the viability of the planning model as well as the validity of the requirements at the four levels. The original plan which was proposed for the site is evaluated using the four-level model and its requirements.

The model attempts to bring two planning factors, climate and culture into a more prominent position in the planning process demonstrating that rather than inhibiting design solutions, the model increases the probability of a better fit between settlement, environment, and user.

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INTRODUCTION

The Problem

Settlement planning in the Canadian Arctic has been in general quite a haphazard affair. The Inuit, being a nomadic people, had no permanent villages. They changed their place of habitation according to the seasons and the availability of game. In the winter they camped in snow houses on the ice and ice floe edge; in spring and summer they camped in semi-subterranean houses and tents along the coast and rivers; during late summer they moved inland and dispersed in smaller groups in tents; and finally in autumn and early winter they lived on the edge of the sea and ice floes in tents and semi-subterranean houses (Sabo III, G. and Jacobs, J.D., 1980, pp. 495-496; Maxwell, M.S., 1980, pp. 505-514).

The first permanent settlements were usually those formed by the buildings belonging to the fur trading companies which chose places close to where the Inuit hunted, and which provided easy access for the supply ships. To this was added either a Catholic or Anglican mission a year or two later. In late 1950, infirmaries and schools were set up, followed by the construction of the first houses for the Inuit by the government (Yates, 1970, p. 45; Thomas and Thompson, 1972, p. 10; Nunaturliq, 1973, p. 72). It was at this time that the settlements began to take on the resemblance of a village.

In the early developmental stages of arctic settlements, the Hudson Bay post was the only portion of the village that could be considered as having been planned, not only because it usually formed the first group of permanent buildings, but because the Hudson Bay Company had requirements for the unloading and storing of the yearly supplies that arrived by boat. Distances between the shore and the store, or warehouse were not to be too great, with the store situated on a navigable river or on the sea edge where large ships could enter.

The white organization in each village (The Hudson's Bay Company, religious missions, R.C.M.P., Department of Transport weather stations and the Dept. of Indian Affairs), usually hired Inuit who became permanent residents of the settlement, living in wood houses built for them by the hiring organization (Williamson, 1974, p. 70-71). This was the beginning of the

sedentarisation process and the beginning of the core of the settlement. The other Inuit usually camped in their traditional houses at a distance from the core, and it was normally within the sector of the traditional house grouping that the religious missions constructed their buildings. There were therefore basically two sectors to the village - the white administrative and commercial sector, and the Inuit housing sector. In some cases (Rankin Inlet for example, where there was a mine), an intentional separation was set up as a "buffer" zone between the white village and the Inuit village to protect the Inuit from the white mine workers (Williamson, p. 102). In many villages, however, the Inuit employed by the white organizations often lived in the white sector of the village near the offices and residences of the white institutions.

As the government began to supply houses to the Inuit, the distance between the white and Inuit sectors became smaller and the two sectors eventually became one settlement. In Rankin Inlet the distance of 1/4 of a mile was gradually reduced to 600 feet or 1/2 of its original distance within a decade. When a sufficiently large number of houses were put up at one time so that a choice of location and neighbours was possible, in Rankin Inlet two of the four different Inuit dialect groups that made up the settlement chose houses closest to the white sector, that is "...the shortest distance to the store, the church, the school and the places of work" (Williamson, p. 136), but they also chose their relatives as neighbours. When houses are available in small numbers the choice of one's relatives as neighbours is not possible as houses are awarded on the basis of greatest need. Thus in a small community the traditional kinship groups can be broken up through the need to supply housing based on greatest needs. Therefore, the houses are placed one after the other in the designated expansion zone independantly of the kinship ties amongst the future neighbours. It is evident that in the minds of the government supplying the houses, the notion of providing shelter in an organized layout based on the infrastructure requirements was more important than maintaining kinship links. In the research report, Project Nunaturliq, Phase 1, 1974, (p. 222), when 23 families were asked whether they were happy with the location of their houses in the village, 16 out of 23 indicated that they were not, and that a move was desirable. Of the 16, 11 indicated that they would have preferred a position closer to the shore of the river, and of that same 11, 9 families chose sites in the older sector of the village where the

traditional houses were first built and which is also the furthest away from the administrative and commercial core of the village. The layout of the village and the location of the houses seems not to correspond to the needs and wishes of the population.

The physical layout of arctic settlements has been the result of a process of accretion which at a later date was stemmed and transformed into a rigid plan based on the ease of installing the service infrastructure. This has led to the application of southern planning principles to an arctic context, ignoring the climatic and cultural conditions. (Van Ginkel (1976, vol. 1, p. 47) suggests that the application of "southern suburban standards to northern communities" is due in part to habit and perhaps also to the notion that white "northerners" and the Inuit have always lived in individual isolated dwellings so typical of the southern suburbs.

Ralph Erskine (1968, p. 167) echoes this sentiment when he states: "At best, northern towns have become very like all others; similar in appearance, function and structure, but less pleasant and convenient due to their isolated situation and exposure to a harsh and extreme climate." The climate is an important aspect of the Arctic and must not be minimized or considered in a summary manner as has been the case in the past. Speers, (1976, p. 2) on a visit to the most remote communities north of Winnipeg points out that the contemporary built environment rarely displays any response to climate in its design and planning.

To ignore climate as a major influence on design is general and not exclusive to the Arctic. Lynch (1971, pp. 16-17) remarks: "It is unfortunately commonplace to import forms suitable for one climate into a completely different one: to plant lawns in the desert, to build North American houses in the tropics..." and the author might add temperate-type houses in the North. As Erskine notes (1964, p. 34) this is due in part to the system of educating architects using architectural types from central and southern Europe, or in the North American context, from the more temperate regions of the continent as well as Europe. Erskine (Egelius, 1977, p. 785) reinforces this notion when he remarks that: "The people whose buildings we used to imitate are rain-dwellers... Further south, the summer sun is something to be guarded against, to be avoided; with us the sun is always a friend...". Thomas and Thompson describing

government housing for the Inuit in the Canadian Arctic noted that: "House models follow southern architectural precedants (they are) built with imported construction materials (and) show little recognition of Eskimo cultural patterns and values." (1972, p. 15).

This dilemma is not limited to Europe and North America as indicated by Danishevskii (1962, p. 30) who comments concerning the Russian case in Siberia:

> "The time has come to end the practice of constructing houses, schools, and industrial enterprises on the basis of typical plans drawn up for the conditions of the temperate zone resulting... in a number of negative consequences with respect to the health of the inhabitants, a reduction in the effectiveness of the great efforts and expenditures being made in the struggle for good health."

Cooper, discussing a government planning orientation for arctic settlements which accentuated heat conservation through the use of apartment buildings and row houses regardless of cultural needs, felt that "studies aimed towards arranging buildings in compact groups to take the best advantage of winter sunlight and to afford the greatest protection in storms seem of more practical value" (Cooper, 1968, p. 153).

Given this general attitude of drawing on southern examples for the planning of northern or arctic settlements and the ignoring of cultural needs, this study is an attempt to define a new approach to the design of arctic towns or settlements. This approach proposes to bring together all the requirements, specialists and inhabitants into the planning process in the spirit of collaboration through consultation and participation. The specialists have dominated the design process in the past, paying lip service to the climatic conditions and almost completely ignoring the cultural needs of the indigeneous population.

Chapter one describes the context in relation to the physiography, climate, Inuit cultural history, arctic building history and arctic settlement history. This chapter sets out not only the physical aspects, but traces the evolution of the indigenous culture and its expression in architectural forms and layouts. It shows the development of the culture up to its critical stage where the Inuit are beginning to take their destiny into their own hands, where they must decide how much of the southern culture they will adopt and integrate or modify into their own life style. The

degree that southern influences have been assimilated is exemplified by the house plans now prevalent in the Arctic. The settlement plans also demonstrate a growing degree of sophistication and a greater dependence on southern technology.

Chapter two describes the four level model for an integrated design approach to settlement planning in the Arctic which integrates in succession four levels of planning. Level one is based on the geological and hydrological requirements; level two integrates the service infrastructure; level three brings in the climatic requirements; and finally level four includes the cultural requirements. The four levels of requirements are the basis for the plan synthesis process which proceeds from the most technical; the geological and hydrological requirements, to the most social; the cultural requirements. A case for the integration of climatic and cultural requirements is presented as well as a discussion of the climatic design strategies proposed by several authors. Various aspects of comfort are analysed and are used to formulate the climatic requirements.

Chapter three elaborates a hypothetical case study based on information gathered from a settlement relocation report. The case study uses the requirements generated in chapter two to produce plans at the four different levels. A composite plan combining the requirements of the climatic level illustrates a synthesis procedure that could be used at all levels. A discussion of the various techniques for sun, wind and snow simulation is included in the elaboration of the climatic plans. Various user participation techniques are described with their attendant advantages and disadvantages.

Chapter four presents a discussion of the case study and is an analysis of the model presenting its strong and weak points, recommending ways of correcting any faults. Applications of the model in settlement expansion plans as well as new town plans are discussed.

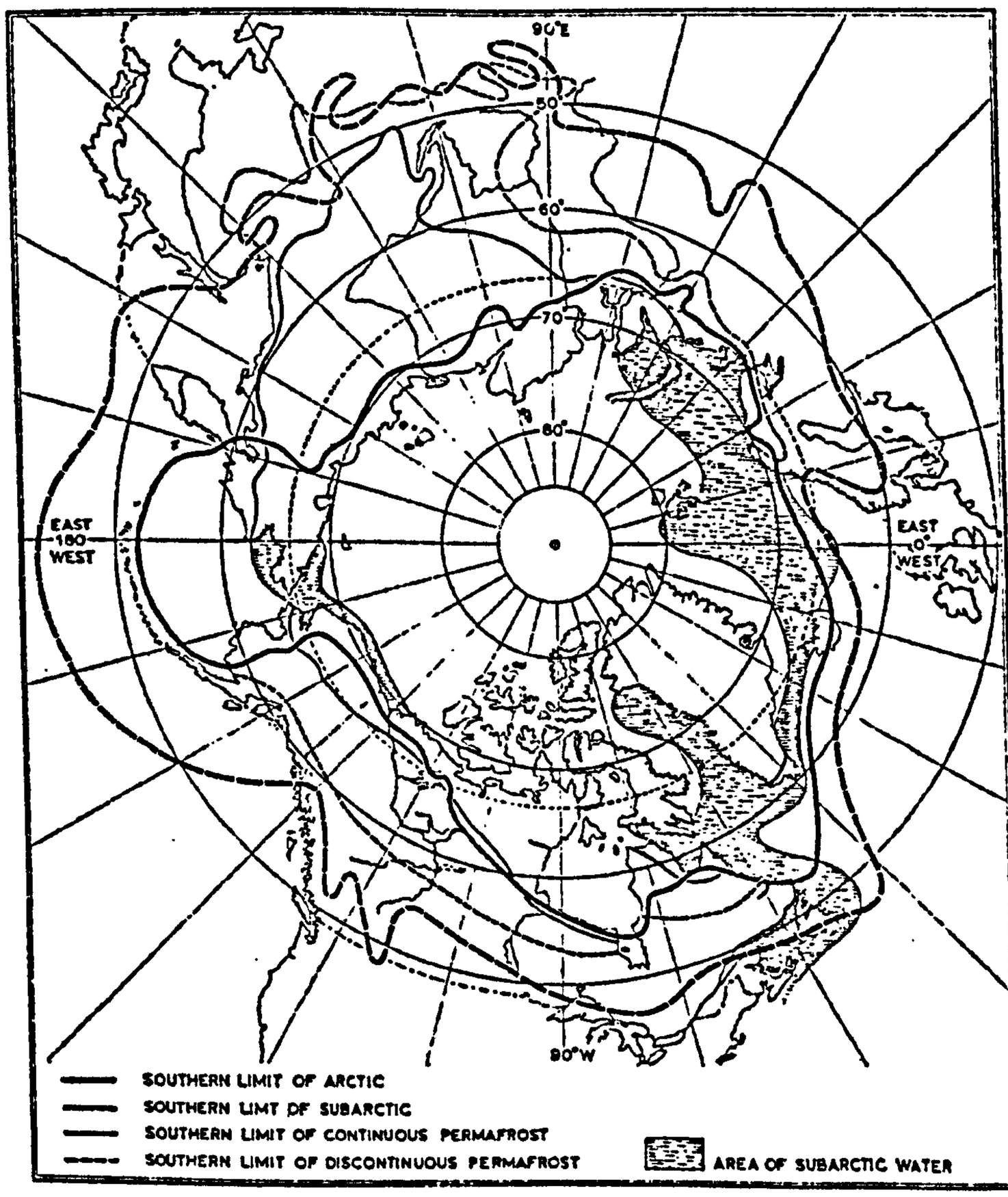
The conclusion sums up the major ideas presented and outlines the author's hopes for the work in the future.

This document proposes a model that can be used by planners for arctic settlement planning and hopefully will be used, if not in its totality, at least for the climatic and cultural requirements set out.

CHAPTER ONE

1. THE CONTEXT

This paper limits itself to the study of Canadian Arctic settlements, therefore only the Canadian Arctic will be described. Map 1 situates Canada in the overall context of the entire Arctic. The map shows the limits of the Arctic, Subarctic, continuous and discontinuous permafrost and indicates clearly that the Arctic in Russia and Scandinavia occupies a much smaller portion of the continent than it does in Canada. In Canada the Arctic limit in Québec passes well below latitude 60°N while in Russia it is generally well above latitude 65°N. The southern limits for the Arctic and Subarctic are however, the subject of much discussion and disagreement. (Dunbar, 1966, pp. 4-5).



Map 1. The Arctic and Subarctic limits of the Polar World (From Dunbar, 1966).

The arctic is a term that is difficult to define in relation to its southern limit. Sater (1963, pp. 2-5) and Baird (1964, pp. 1-10) present a survey of the various factors employed by a number of authors in their proposals for determining the southern limit of the Arctic. Sater adopts Koppen and Nordenskjold's limits which are based on the temperature of the warmest month (Nordenskjold uses 51.4°F, Koppen uses 50°F) and the temperature of the coldest month (Koppen suggests 32°F or below).

Baird defines the arctic boundary based on the following general characteristics:

1. High latitude.
2. Long winter, short cool summer.
3. Low precipitation.
4. Permafrost.
5. Frozen lakes and sea.
6. Absence of trees.

which when analyzed in detail, Baird notes, coincides very closely with the tree line. Baird rejects any mathematical climatically determined limit and opts for the tree line as the boundary of the polar region (Baird more or less equivocates Polar and Arctic), but eliminates such treeless areas as Iceland, the Aleutians, northern and western Scotland.

Hamelin (1975) proposes a very detailed means of defining various Arctic zones based on 10 criteria. Each criterion has a value of 100 points with a maximum possible total of 1,000 points. The criteria are: 1. latitude (latitude 90° receives 100 points and 45° receives 0); 2. summer warmth (100 points for 0 days above 5.6°C and 0 points for more than 150 days above 5.6°C); 3. annual cold (100 points for more than 12,000 degree days below 0°C and 0 points for less than 1,000 degree days below 0°C); 4. the fourth criterion is based on one of three types of ice, a) permafrost, b) floating ice, c) glaciers; 5. total precipitation; 6. natural vegetation cover; 7. accessibility other than by air; 8. air services; 9. population based on either a) the number of inhabitants in the settlement, or b) demographic density of the region; 10. degree of economic activity (Hamelin 1975, pp. 81-121). Based on these criteria, Hamelin arrives at a division of Canada into four 'northern' regions. The furthest south being the 'near north'; next the moyen nord or

'middle north'; the grand nord or great or 'far north' which closely follows the tree line; and finally the 'extreme north' (p. 150). Such precision is necessary when dealing with legal or political concerns, but far surpasses the precision needed in this document.

The author, therefore, proposes to use the northern limit of trees (the tree line) as suggested by Baird and Sater. This coincides with the location of the great majority of Inuit settlements,[1] because the Inuit are hunters of sea mammals, fish and caribou, most of which are found beyond the tree line and therefore reinforces its choice as the southern limit of the arctic.

1.1 ARCTIC PHYSIOGRAPHY

The physiography of the Canadian Arctic can be described in general terms as consisting of five major regions (or physiographic provinces), and one minor region. (Sater, 1963, p. 65) The largest of these regions or provinces is the Pre-Cambrian Shield which is similar to a saucer in section. It descends from a mountainous rim in the east to a lower level in the centre, bordering Hudson's Bay and rising to a mountainous region in the west. To the north it is bounded by a series of plateaus which lie behind a band of sedimentary basins. Beyond the plateaus is a ribbon of folded uplands which is itself bounded on the north by a thin line of lowlands. Looking at the physiographic regions in detail there is:

Region 1. The Pre-Cambrian Shield Area

This region is broken down into 7 sub-regions, namely:

A. Western Shield Area.
B. Coppermine Region.
C. Keewatin Drift Region.
D. Southampton-Melville Region.
E. Ungava Region.
F. Baffin Uplands.
G. Eastern Mountain Rim.

Most of this region (A-F) varies in elevation from 150 metres to 760 metres

1 This document concerns itself with the planning of Inuit settlements because they form the permanent population and bear the long-term effects of settlement planning in the Arctic.

with only the eastern mountain rim rising to 1800-2100 metres. The landscape is generally rolling, hilly and rocky (mainly granite and gneiss) with myriad lakes and streams. The land is generally higher in the east and gradually descends to a plains area in the west. The Barnes Ice-Cap, in the northern part of the Baffin Uplands, is situated at the 450 metre level. The Eastern Mountain Rim which extends from Labrador to central Ellesmere Island has the most spectacular scenery in the Canadian arctic with long deep fjords (some of which are 'S' - shaped) cutting the ice-covered mountain peaks. From the preceding description, it is evident that there is a great variety of physiography and land forms in this region.

Region 2. The Palaeozoic Sedimentary Basins

This region is broken up into 5 sub-regions:

H. Southampton Group.

I. Hudson Bay Lowland.

J. Foxe Basin Group.

K. Boothia Group.

L. Western Arctic Group.

All the sub-regions are relatively similar in their physiographic characteristics. This is generally a low region with elevations mainly lower than 30 metres in height. This region has ponded lagoons which accompany the emerged strand lines, and a coastline that is smooth, gently sloping with few harbours. Large boulders are haphazardly strewn in the inter-tidal mud flats where the tides are large.

Region 3. Palaeozoic Plateaus

This region consists of:

M. Lancaster Plateau.

N. Banks-Melville Plateau.

It is a region composed mainly of smooth plateaus generally 600 metres in height with deeply cut rivers and sheer cliffs along the coast. The Devon Island plateau (in the Lancaster Plateau sub-region) has ice-caps near the mountain range. The Banks-Melville Plateau contains isolated rocky hill areas in an otherwise undulating landscape.

Region 4. Folded Uplands

Included in this region are the 5 following sub-regions:

O. Parry Island Belt.

P. Sverdrup Belt.

Q. Cornwallis Belt.

R. Ellesmere - Axel Heiberg Belt.

S. Yukon Mountains.

The Sverdrup Belt (which includes the lower portion of Axel Heiberg Island and Ellef Rignes Island) and the Cornwallis Belt are both generally very low in elevation not exceeding 300 metres. In the Sverdrup Belt, lakes are rare and the sea-ice between the islands is semi-permanent creating a continuous solid mass.

The Parry Island Belt (which includes Melville and Bathurst Islands) consists of highly folded rocks with some of the islands deeply indented by inlets. The elevation ranges from 300 metres to over 900 metres on Melville Island.

The next highest sub-region is the Yukon Mountains (which is a plateau), the east-west British Mountains and the north-south Richardson Mountains, and rises to 1800 metres. This area has 'Y' - shaped valleys and sharp ridges.

The Ellesmere-Axel Heiberg Belt is the highest of the 5 regions ranging from 2100 to 2500 metres in elevation from Axel Heiberg to the north of Ellesmere Island. Ice glaciers cover most of both islands and huge fjords penetrate the islands deeply.

Region 5. Tertiary and Pleistocene Lowlands

This region has 5 sub-regions:

T. Yukon Coastal Plain.

U. Mackenzie Delta.

V. Arctic Coastal Plain.

W. Baffin Coastal Plain.

X. Pond Inlet Plain.

The region is covered by parallel braided rivers with a multitude of lakes and offshore shoals and islands. There are great quantities of sand and gravel, and vegetation is rare. In the Mackenzie delta there are many "pingos", an

unusual formation of lumps projecting from the plains produced by the action of permafrost.

The central east coast of Baffin Island contains moraine material while the Pond Inlet Plain has seams of coal.

Region 6. Great Plains Sediments

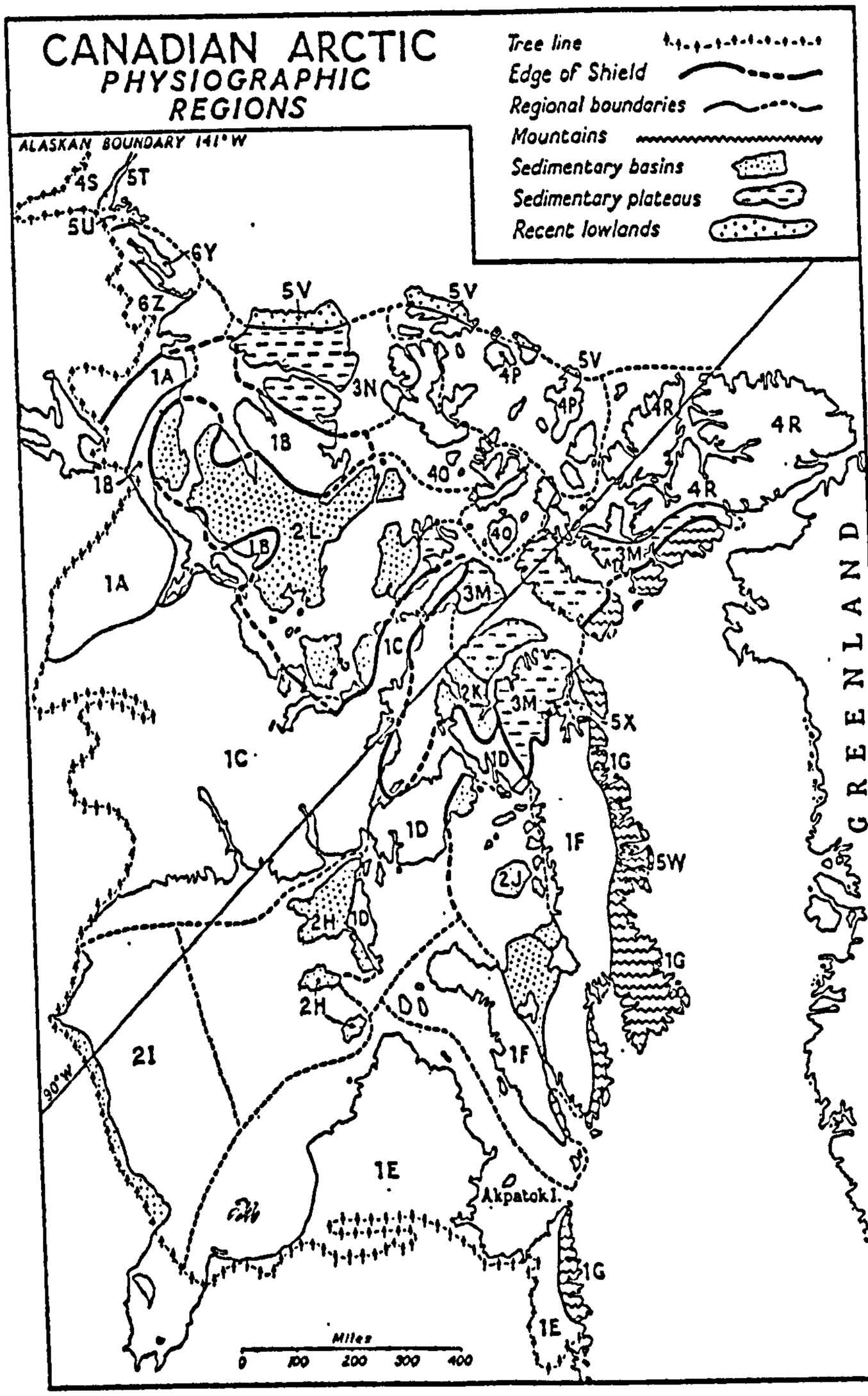
This region is made up of the following sub-regions:

Y. Eskimo Lakes Lowland.
Z. Western Plain.

This region is located between the western limits of the Pre-Cambrian Shield and the Mackenzie Delta, has low relief rising to 300 metres in the Smoking Mountains, and has deeply cut rivers.[2]

Map 2 shows the 26 sub-regions for the Canadian Arctic while Map 3 illustrates 3 major physiographic regions for the entire Arctic region.

2 The information for this section was gleaned from P.D. Baird "The Polar World", 1964, pages 183-191 and J.E. Sater, "The Arctic Basin", 1963, pages 65-66.



Key to regions:

1. *Pre-Cambrian Shield*
- 1A Western Shield Region.
- 1B Coppermine Region.
- 1C Keewatin Drift Region.
- 1D Southampton–Melville Region.
- 1E Ungava Region.
- 1F Baffin Uplands.
- 1G Eastern Mountain Rim.

2. *Palaeozoic Sedimentary Basins*
- 21 Southampton Group.
- 21 Hudson Bay Lowland.
- 2J Foxe Basin Group.
- 2K Boothia Group.
- 2L Western Artic Group.

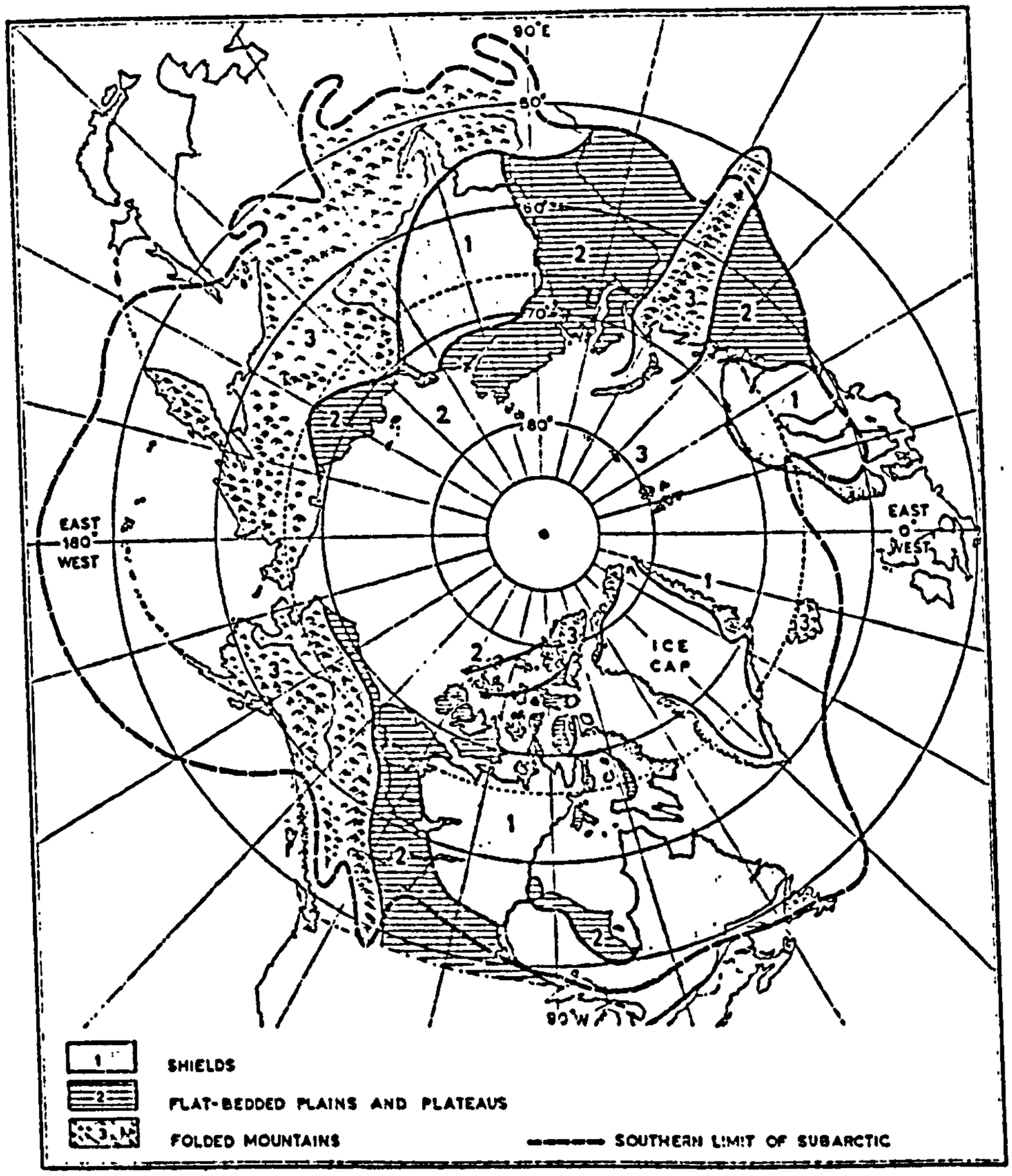
3. *Palaeozoic Sedimentary Plateaus*
- 3M Lancaster Plateau.
- 3N Banks–Melville Plateau.

4. *Folded Uplands*
- 4O Parry Island Belt.
- 4P Sverdrup Belt.
- 4Q Cornwallis Belt.
- 4R Ellesmere–Axel Heiberg Belt.
- 4S Yukon Mountains.

5. *Tertiary and Pleistocene Lowlands*
- 5T Yukon Coastal Plain.
- 5U Mackenzie Delta.
- 5V Arctic Coastal Plain.
- 5W Baffin Coastal Plain.
- 5X Pond Inlet Plain.

6. *Great Plains Sediments*
- 6Y Eskimo Lakes Lowland.
- 6Z Western Plain.

Map 2. Physiographic regions of the Canadian Arctic (From Baird, 1964).



Map 3. General physiographic regions of the Polar World (From Dunbar, 1966).

1.2 ARCTIC CLIMATE

Climatic variations in a country as large as Canada are great from one coast to another, and even greater from the United States border to the tip of the northern-most arctic island. For the sake of simplicity it would be useful to determine a latitude that is representative of the Canadian Arctic climate and to take the average of the wind, temperature and solar data in order to form a common data base for use in the model to be proposed. It is also necessary to determine which northern settlements may be considered arctic settlements. As proposed in the introduction to chapter one, using the tree line as the demarcation line for the Arctic, only settlements on or above the tree line will be considered arctic settlements.

1.2.1 LATITUDE

The latitude for settlements in the Canadian arctic varies from approximately 55°N to 85°N. Using the tree line as the southern limit of the Arctic, (see Map 2) there are 115 settlements listed in the Gazeteer of Canada, 1958, its supplements to 1973 and the Répertoire Toponymique du Québec, 1978. The average of their latitudes is 67.6° (see Appendix 1-A for the list of villages and their latitudes), therefore the author proposes the use of latitude 65°N in the analysis of the climatic and solar data for the formulation of typical data for use in the proposed planning model.

1.2.2 TEMPERATURES

Taking all the villages or settlements for which there are climatic data and which lie between the latitudes of 60°N and 70°N [3] and averaging the mean daily, the mean daily maximum and the mean daily minimum temperatures, we arrive at the following table which gives a general image of the temperatures that would be experienced at latitude 65°N.

3 A total of 36 are listed in Temperatures and Precipitation, 1941-1970, Québec; and in Temperatures and Precipitation, 1941-1970, The North - Y.T. and N.W.T. - See Appendix 1-B for the list with the temperature data.

Table 1. Average of temperatures (°C) from latitudes 60° to 70°N.

	Spring		Summer			Aut.		Winter				
	M	J	J	A	S	O	N	D	J	F	M	A
Average daily temp.	-7	2	7	6	0	-8	-18	-24	-28	-29	-25	-17
Average max. daily temp.	-3	5	11	10	3	-5	-14	-21	-25	-25	-21	-13
Average min. daily temp.	-10	-1	3	3	-2	-10	-21	-28	-32	-33	-29	-22

Summer was taken to be June, July, August and September because the average daily temperature is at freezing or above. Spring is taken as May, and autumn as October, because in both cases the average daily temperature is above -10°C, which is close to the -11°C mid-point between the lowest average minimum daily temperature of -33°C and the highest average maximum daily temperature of 11°C. Winter is taken as lasting from November to April because the average daily temperature is below -10°C by a considerable amount even in November and April.

From table 1 the warmest temperature in summer is 11°C, the coldest -2°C, and the average of the average daily temperatures is 4°C. In winter the warmest temperature is -13°C while the coldest is -33°C and the average of the average daily temperature is -24°C.

As an example of the variations that exist in the temperatures from the lower to the upper latitudes in the Arctic, the temperature for the coldest and warmest months are given for Poste-de-la Baleine in arctic Québec; Resolution Island; Alert; Eureka; and Inuvik in the Northwest Territories. These settlements either represent the upper and lower limits of latitude, or the maximum of one of the 5 temperature categories.

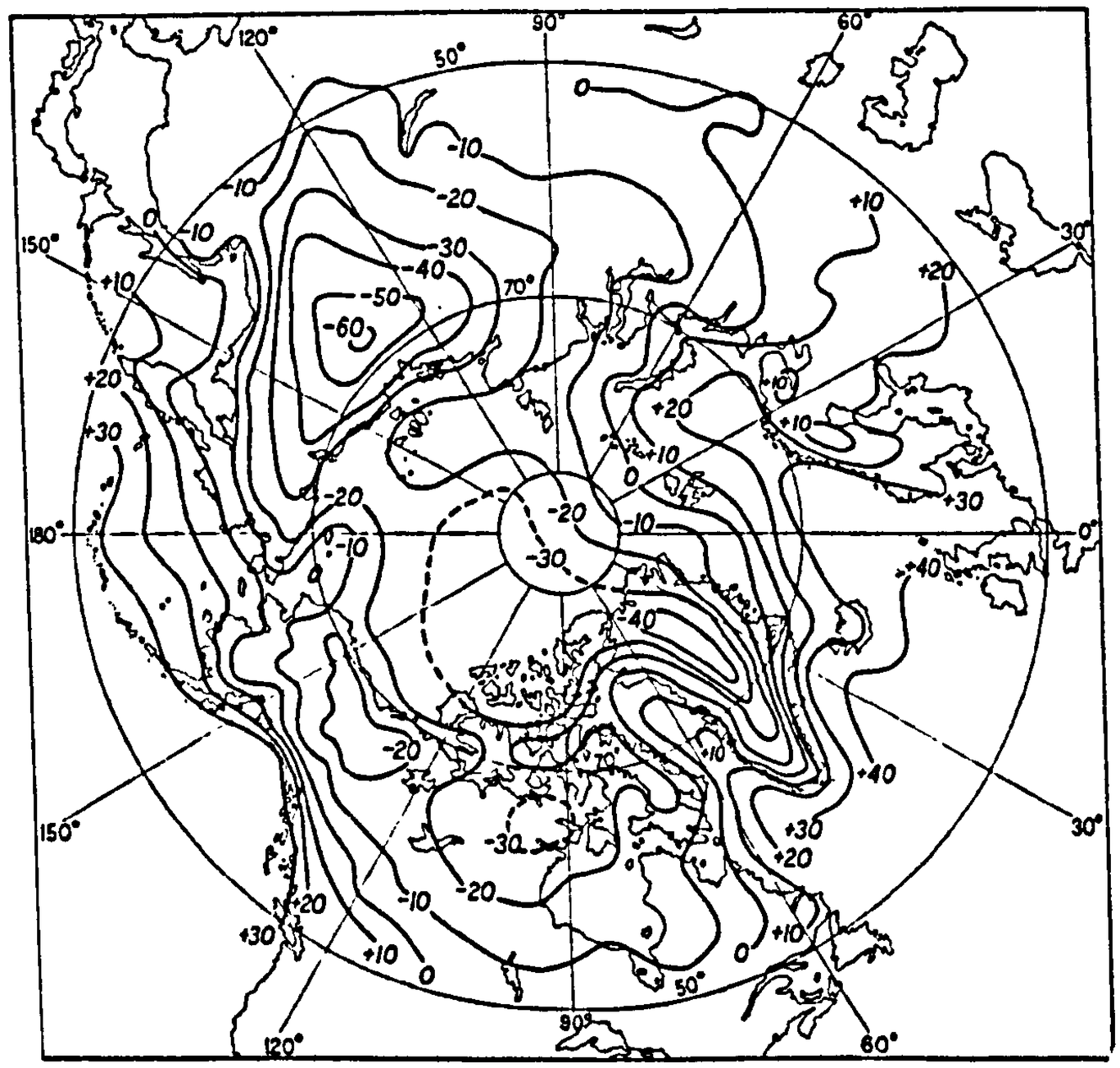
See table 2 for the comparison of mean daily, mean daily maximum, mean daily minimum, extreme maximum and extreme minimum temperatures.

Table 2. Comparison (°C) of the warmest and coldest months for five arctic settlements.

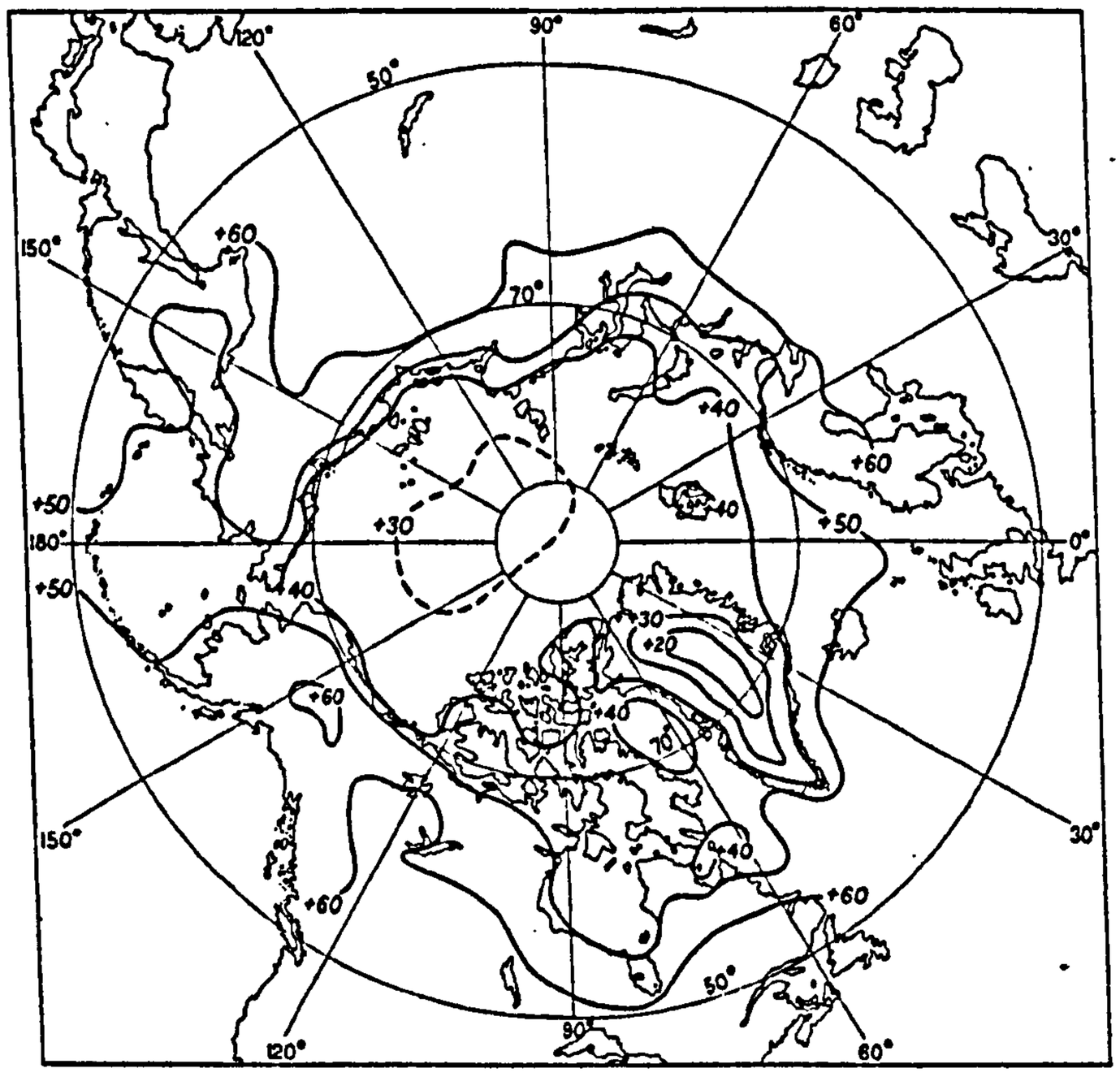
Settlement	Coldest month (Feb.)					Warmest month (July)				
	mean daily temp.	mean daily max. T.	mean daily min. T.	extreme max. T.	extreme min. T.	mean daily temp.	mean daily max. T.	mean daily min. T.	extreme max. T.	extreme min. T.
Poste de la Baleine lat. 55° 17'N	-22	-17	-28	-7	-46	11	16	6	33	-2
Resolution Island lat. 61° 18'N	-17	-14	-20	2	-36	3	5	0.9	15	-3
Inuvik lat. 68° 18'N	-29	-24	-35	3	-57	13	19	7	31	-3
Eureka lat. 80° 00'N	-38	-34	-41	-1	-52	6	9	3	19	-2
Alert lat. 82° 30'N	-33	-29	-37	1	-47	4	7	0.9	20	-6

From the table for the coldest month, the range of mean daily temperature for the five settlements is 21°C; for the mean daily maximum is 20°C; and for the mean daily minimum is 21°C. The differences for the warmest month vary from 6°C to 14°C. The coldest mean daily minimum temperature is -41°C with an extreme minimum of -57°C. The warmest mean daily maximum is 19°C with an extreme maximum of 33°C. The warmest temperature during the coldest month is -14°C with an extreme maximum of 7°C while the coldest temperature during the warmest month is 0.9°C with an extreme minimum of -6°C.

It is evident upon comparing the temperatures and latitudes at which they occur, that temperature is not completely dependent on latitude. See maps 4 and 5 for the mean daily temperatures in the arctic for January and July.



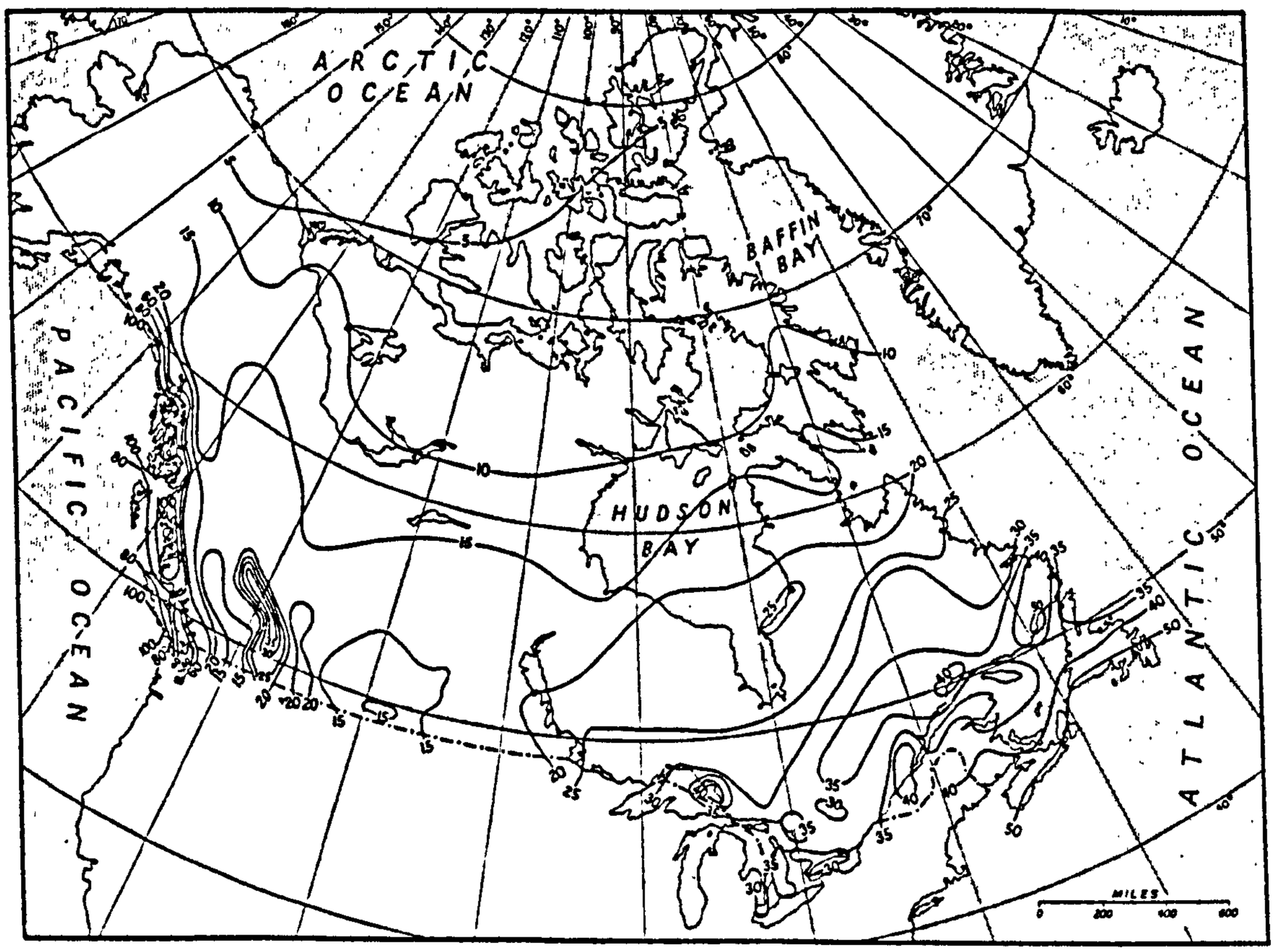
Map 4. Mean air temperature January (°F) (From Baird, 1964).



Map 5. Mean air temperature July (°F) (From Baird, 1964).

1.2.3 PRECIPITATION

An analysis of the climatic data reveals that there is snow in every month with the exception of a few settlements (3 out of a total of 36). Precipitation ranges from an annual minimum of 12.3 inches (312.4mm) at Jenny Lind Island, lat. 68°35'N, to an annual maximum of 244.1 inches (6200.1mm) at Cape Dyer, lat. 66°35'N. In general, however, precipitation is light, attaining less than 10 inches (254mm) in the western Arctic islands, and 4 inches (101.6mm) in the northern portion of the Canadian archipelago. In the continental Arctic, snowfall does not generally exceed 24 inches (699.6mm), but the maritime Arctic regions receive snow to a depth of 60-120 inches (1524mm - 3048mm) (Petterssen et al. 1956, pp. 65-68). Calculating the average annual mean snowfall for the 36 settlements from latitude 60°N to 70°N, gives an average of 53.5 inches (1359mm). (See Appendix I-C for list of settlements and precipitation.) Also see map 6 for precipitation in Canada.



Map 6. Precipitation, isohyets in inches (From Baird, 1964).

Although precipitation is light, snowdrifting does occur due to three forms of transport mechanisms; creep, saltation and turbulent diffusion (Mellor, 1965, p. 5). Thus, although very little snow falls, the immense catchment areas surrounding settlements supply snow transported by the wind to the settlements, thereby furnishing sufficient snow to produce large drifts.

From Appendix I-C it is clear that the arctic has very little precipitation of any form, and during the summer the amount of rainfall is negligable. The average of the total rainfall for summer is 3.85 inches (97.8mm) and the average total annual rainfall is 4.07 inches (103.4mm).

1.2.4 HUMIDITY

During the analysis of the humidity data it was noticed that many of the station settlements were lacking data for certain winter months. In the Climatic normals, Vol. 4, Humidity, 1968, it is noted that at some of the northern stations, a mercury wet bulb thermometer is used, which is inoperative below -37°C (-35°F) and therefore, often data is missing for the winter months.

Taking the average for each month for the 10 stations which have complete data and which lie between latitudes 60° and 70°N gives the relative humidities in table 3 below. (See Appendix I-D for the list of 21 settlements with humidity data, partial or complete.)

Table 3. Average relative humidity values for 10 stations based on the average humidity values of relative humidity at 01:00; 07:00; 13:00 and 19:00 hours for each month and the mixing ratio for the highest dew point recorded.

Season	Spring			Summer					Aut.		Winter							Mixing ratio
Month			M	J	J	A	S		O	N	D	J	F	M	A			
%			87	86	81	85	88		87	81	77	73	75	74	79			77

From the table one can see that the relative humidity is quite high especially from May through November. However, because the air is cold by

comparison to the southern latitudes, the air is capable of containing much less water vapour as is indicated by the relatively low value for the mixing ratio which in southern latitudes of Canada ranges in the low 100's. (See Climatic Normals, Vol. 4, Humidity, 1968, for mixing ratios in other Canadian cities.) The relative humidity from December to April ranges from the low 70's to the high 70's while the temperatures range from -17° to -29°C which indicates a low range of absolute humidity during the winter.

1.2.5 SOLAR RADIATION

1.2.5.1 Solar Altitude And Azimuth

One of the most important aspects of solar radiation at latitude 65°N is the sun's altitude and azimuth for the various hours of the day during the different seasons. Because the earth's vertical axis is tilted at 23°30', the arctic circle at latitude 66°30'N is the highest point on the globe and therefore has periods at the summer and winter solstices when there is 24 hours of daylight and 24 hours of darkness called the midnight sun and polar night respectively. Figure 1 shows in diagrammatic form the solar altitude at noon, the azimuth latitudes, 70°N, 65°N, and 60°N. At the winter solstice one can note that for latitude 70°N that there is no daylight but a period of twilight[4] lasting from 7:00 to 17:00 hours (Van Ginkel, 1976, pp. 12-13). At latitude 65°N there is daylight from 10:00 till 14:00 hours with a solar altitude at 3° at noon at the winter solstice, while at latitude 60°N daylight lasts from 9:00 till 15:00 hours with a solar altitude of 8°.

Looking at the summer solstice for the same three latitudes reveals 24 hours of daylight at 70°N, twilight from 23:00 to 1:00 at 65°N, and twilight from 22:00 to 2:00 hours at 60°N. The solar altitude at this same period is 43° at 70°N, 48° at 65°N and 53° at 60°N. This gives an indication of the length of day and night and the relatively low solar angles which for latitude 65°N vary from a minimum of 3° to a maximum of 48°.

4 Twilight is defined as when the sun is less than 15° below the horizon and darkness as when the sun is 15° or more below the horizon.

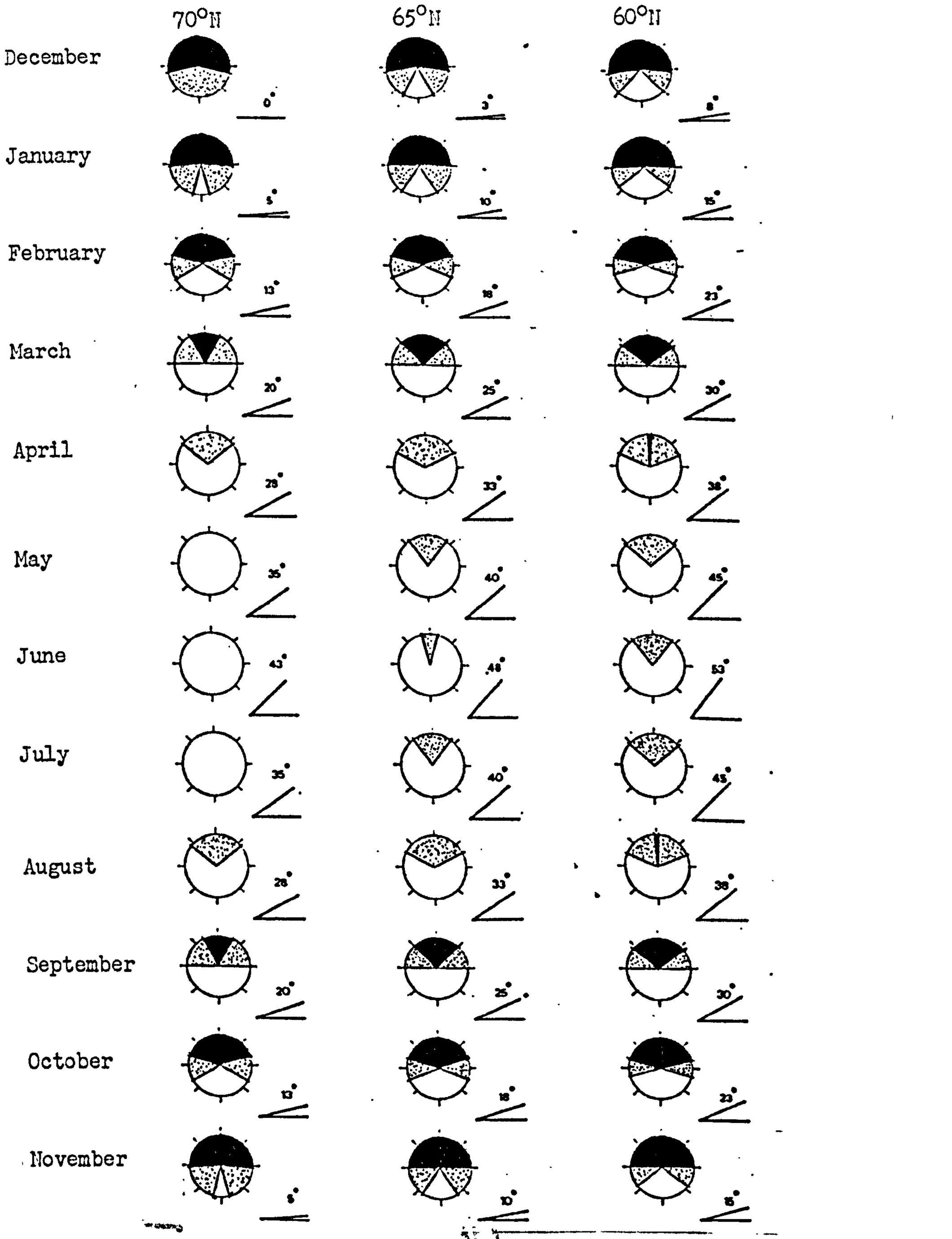


Figure 1. Daylight, darkness and twilight hours and solar altitude at noon for latitudes 70°, 65° and 60°N. (From Van Ginkel, 1976).

1.2.5.2 Number of Hours of Sunshine

With regard to the number of hours of bright sunshine, data is available for only three stations between latitudes 60° and 70°N. Table 4 gives this data with the yearly totals. (Climatic Normals - Sunshine, Cloud, Pressure and Thunderstorms - Vol. 3, Canada, Dept. of Transport, Meteorological Branch, Toronto, 1968.)

Table 4. Number of hours with bright sunshine.

Village	J	F	M	A	M	J	J	A	S	O	N	D	YEAR
Aklavik (68°14'N)	14	94	154	217	297	401	276	204	95	73	22	-	1907
Coppermine (67°50'N)	5	78	149	219	210	275	283	187	72	43	12	-	1533
Frobisher Bay (63°45'N)	26	75	184	245	174	142	190	130	80	58	38	11	1353

As one would expect, there is no direct relation between latitude and the number of hours of bright sunshine. For example, during the month of January, Aklavik has 14 hours of sunshine compared to 5 for Coppermine and 26 for Frobisher Bay when it should have approximately the same as Coppermine which is approximately the same latitude. The same is true for June when Aklavik has 401 hours of sunshine compared to 275 for Coppermine. Therefore, local conditions affect this factor greatly and there are insufficient data to take an average for latitude 65°N.

1.2.5.3 Cloud Cover

In relation to cloud cover, the same dependence on local conditions applies, but there are 14 stations with data on this factor, therefore averages were taken. See Appendix I-E for the list with data, and table 5 which follows for the average monthly conditions for use for latitude 65°N.

Table 5. Cloud normals, yearly values, average of 14 settlements, from latitude 60°N to 70°N.

	SPRING		SUMMER			AUT.		WINTER						FREQUENCY OF
	M	J	J	A	S	O	N	D	J	F	M	A	YR	
Average	65	63	57	63	74	71	56	46	41	38	36	44	54	8-10/10
frequency % for lat.	15	18	23	20	15	14	15	16	17	17	18	17	17	3-7/10
65°N	20	19	20	17	11	15	29	38	42	45	46	39	29	0-2/10
	7.2	7.1	6.7	7.2	8.0	7.7	6.3	5.3	4.9	4.6	4.5	5.3	6.2	MEAN CLOUD

From the table it is evident that on a yearly basis it would be cloudy 54% of the time and sunlit brightly 29% of the time at latitude 65°N. Upon further analysis, the winter season is more frequently sunny than the other periods of the year ranging from a minimum of sunny periods for 29% of the month to a maximum of 46%. It is sunny (0-2/10) for a greater percentage of the time than it is cloudy (8-10/10) for the months of February and March and almost equally cloudy and sunny for the month of January. Spring, summer and autumn are predominately cloudy ranging from a minimum of 57% of the month to a maximum of 74% in September. This factor is important when considering outdoor comfort in the sun and in shade.

1.2.5.4 Solar Radiation

Solar radiation data for vertical surfaces is difficult to obtain for Arctic Canada, and is not well detailed for horizontal surfaces. The data that exists gives global solar radiation and occasionally the net radiation. Of the 36 stations or settlements for which temperature and precipitation data exists, only 11 have radiation data, and of these 1 has global solar, sky, reflected solar and net radiation data; 6 have global solar and net radiation; and 4 have global solar radiation data. The A.S.H.R.A.E. 1978 Applications Handbook presents solar insolation data for south facing surfaces for latitude 64°N (pp. 58.6 and 58.7) for direct normal radiation, and total direct and diffuse radiation for horizontal and

vertical surfaces (as well as for surfaces at various other angles) which could be used to give the range of solar radiation. However, for the purposes of calculating new comfort curves for shade and sun conditions in the Arctic (see Penwarden, 1973, p. 265 for the comfort curve formula), radiation data is needed for shaded or north-facing vertical surfaces. A.S.H.R.A.E. published tables (Jordan and Liu, 1977, pp. IV - 18, IV - 19) giving total insolation values on inclined surfaces for five cardinal directions (E., S.E., S., S.W., and W.) for latitude 64°N. Once more, data for the shaded north direction is not included. It was therefore decided to use data generated by a computer program developed by Marius Thériault of the Dept. of Geography, Université Laval.

Data was generated for latitude 65°N and 45°N in order to provide a basis for comparison. Latitude 45°N corresponds approximately to the latitude where the majority of the Canadian population lives (See Appendix I-F for the radiation tables.) The data shows that the global daily radiation (direct, diffuse and reflected from the ground) is greater on horizontal than vertical surfaces only during the months of June and July. The global daily horizontal radiation varies from a minimum of 0.2MJ/m^2h (55.6 w/m^2) in December to a maximum of 31.2 MJ/m^2H (8667.4 w/m^2) in June, while the global daily vertical radiation on a south facing surface varies from a minimum of 3.5 MJ/m^2h (972.2 w/m^2) in December to a maximum of 28.1 MJ/m^2h (7806.2 w/m^2) in April. (Data was generated for the 15th of every month.)

Analysing table 5 for cloud normals indicates the sunniest months (0-2/10 cloud cover) to be February and March with frequencies of 45 to 46% sunny, while December, January and April were next sunniest with frequencies of 38, 42 and 39% sunny periods respectively. From table 1 the coldest average daily temperatures occur in December, January and March, with November and April being relatively warmer (temperatures are -18° and -17°C for November and April, and -24° and -25°C for December and March). However, November is less sunny with a frequency of 20% as compared to 39% for April. Also the global daily radiation for a south facing vertical surface is 12.5 MJ/m^2h (7476.1 w/m^2) in November, 26.9 MJ/m^2h

(7460.6 w/m^2) in March and 28.1 MJ/m^2h (7806.7 w/m^2) in April. Since March has a much lower average daily temperature as compared to April (32%) lower, and is only 15% more sunny and received only 4% more radiation, then it would seem in terms of comfort that April would be more likely to be the most comfortable of the winter months.

Comparing the average windspeeds for all directions for every month (see Appendix I-G, table 4), April has an average windspeed of 11.8 mph (5.3 m/s), while the maximum speed 14 mph. (6.3 m/s) is in October. The minimum is 10.6 (4.7 m/s) in July, and the annual average for all directions is 12.3 mph. (5.5 m/s). Therefore, in terms of wind effect on comfort, it would once again seem that April would be the most comfortable of the winter months. However, in order to calculate outdoor comfort in sun and shade it is necessary to have as examples the coldest month (February), the warmest month (July), and the transition months (May and October). See temperature tables in Appendix I-B.

Comparing the radiation values for latitudes 45°N and 65°N, it is interesting to note from tables 1 and 2 in Appendix I-F that at latitude 45°N the global daily radiation is greater on horizontal than vertical surfaces for 6 months from April to September as compared to only 2 months (June and Jul) at latitude 65°N. It is also noteworthy that the global daily horizontal radiation varies from a minimum of 6.2 MJ/m^2h (1722.4 w/m^2) in December to a maximum of 30.1 MJ/m^2h (8361.8 w/m^2) in June, while the global daily radiation on a south-facing vertical surface varies from a minimum of 12.7 MJ/m^2h (3528.1 w/m^2) in June to a maximum of 22.3 MJ/m^2h (6194.9 w/m^2) in February. The maximum values at latitude 65°N occur in June for horizontal surfaces and in April for vertical surfaces showing the effect of lower solar angles at higher latitudes on vertical surfaces.

Table 6 reveals that December generally receives more radiation at latitude 45° than at latitude 65°N, while in June the inverse is true. However, in December, 31 times more radiation is received on horizontal surfaces, and 6 times more radiation falls on vertical surfaces at latitude 45°N than at latitude 65°N. In June only 1.1 more MJ/m^2h

(305.6 w/m^2) are received on horizontal surfaces at latitude 65°N than at latitude 45°N, while on vertical south facing surfaces, 1.06 MJ/m^2h (294.5 w/m^2) more radiation is received at latitude 65°N than 45°N. It is evident, however, that in general more radiation is received at latitude 45°N than 65°N.

Table 6. Solar radiation values for latitudes 45°N and 65°N for December, March and June (from tables 1 & 2, Appendix I-F)

		Global Radiation	
		Hor.	Vert.
15 Dec.	Lat. 45°N	6.2	20.3
	Lat. 65°N	0.2	3.5
15 March	Lat. 45°N	17.3	21.2
	Lat. 65°N	9.7	24.9
15 June	Lat. 45°N	30.1	12.7
	Lat. 65°N	31.2	21.4

1.2.6 WIND

Wind is one of the most important climatic factors in the Arctic accounting as it does for great heat loss and discomfort when combined with low temperatures, and is the major cause of snowdrifting.

1.2.6.1 Wind Direction

Analysing the percentage frequency of wind direction for the fourteen stations or settlements that have wind data at latitudes 60° to 70°N, in Appendix I-G, table 1, it is evident that the dominant wind direction is northwest, but the 2nd and 3rd dominant directions are not so obvious. Grouping all the frequency data in table 3, which indicates whether a particular direction was of first, second or third dominance, and giving 3 points for the first dominance, 2 points for the second, and 1 point for a third, allows us to determine the dominant wind directions. The totals from this table indicate that the wind from the northwest is the dominant direction for both winter and summer, north is the secondary dominant direction and west the third. It is also noticeable that northeast is a fourth dominant direction in summer and east is the fourth dominant in

winter. The north-west wind is, however, almost twice as important in winter and summer as the second dominant wind.

Table 2 in Appendix I-G also gives the first, second and third highest wind speeds with their directions. From the totals of the directions, the north-west wind is highest for 9 out of the 14 stations and second for 2 stations, and third for 1 station. The north wind is second highest for 5 stations, first for 1 and third for 2 stations. The west wind is third highest for 5 stations and second for 1 station. These totals reinforce the results of table 3 (Appendix I-G).

1.2.6.3 Wind Speed

Analysing table 4 in Appendix I-G gives the average wind speeds for every month and the annual average. The average annual wind speed is 12.3 mph. (5.5 m/s) which gives a general impression of the windiness of the Arctic. Taking the average of the speeds for the winter months gives 12.4 mph. (5.5 m/s), while for the summer months the average is 11.8 mph. (5.3 m/s).

An analysis of table 1 reveals that the average maximum observed hourly wind speed is 66 mph (29.5 m/s), the average observed gust speed is 85 mph. (38.0 m/s) and the average probable maximum gust for maximum hourly speed is 93 mph. (41.6 m/s).

The climatic data presented here should provide a good indication of the arctic climate. The data that has been produced for latitude 65°N will be used in the formulation of desirable comfort limits and for the climatic requirements.

1.3 INUIT CULTURAL HISTORY

1.3.1 Inuit Prehistorical Period

It is generally accepted by archeologists that there were migrations of people from Asia to the Canadian Arctic via the Bering Strait and Alaska. The first cultural group to be truly adapted to the Arctic appeared about six thousand years ago (Giddings, 1973; Workman, Lobdell and Workman, 1980). According to Taylor (1964), this culture, given the name Arctic Small Tool Tradition, had its origins in the northern European mesolithic and the Siberian neolithic periods. Several waves of migration resulted in the spread of the Inuit people from the west coast of Alaska to the central and eastern parts of the Canadian Arctic and eventually to Greenland.

The Pre-Dorset culture was prominent in the central and eastern Arctic from 2500 to 1000 B.C. and was replaced by the Dorset culture around 800 B.C. The Pre-Dorset and Dorset cultures were nomadic races which hunted marine mammals. The Dorset culture developed the articulated harpoon, the stone oil lamp for heating and cooking, as well as the snow house (Taylor, 1968). Despite their technology, the Dorset culture disappeared between 900 and 1350 A.D. having been assimilated by the Thule culture (McGhee, 1976; Fitzhugh, 1980).

The Thule culture made an important technological advance by introducing the use of dogsleds. This allowed them to lead a semi-sedentary life because the hunters were able to exploit a larger territory without moving their habitation. Between the 16th and 18th centuries a dramatic cooling of the climate is believed to have been responsible for the disappearance of this culture (Schledermann, 1976, p. 34).

The Inuit today are, in a manner of speaking, distant descendants of the Thule people, and as such have maintained certain cultural and technological aspects of the Thule culture (Baillargeon, 1979).

1.3.2 Traditional Inuit Hunting and Settlement Cycle

In the period preceding sedentarisation the Inuit subsisted through hunting, and as a result were dependant on the seasonal migratory habits of the game. This necessitated a cycle of changing areas of habitation. At the end of

November, snow was sufficiently abundant to built snow houses or illuvigaq.[1] The Inuit built their houses near the water's edge giving them access to the seals, their major source of food at this time of the year. During December, large camps of snow houses were established on islands or peninsulas in closely packed groups of 10 or more houses. This was the period of seal and walrus hunting which required the efforts of many people. During December and January, part of the coldest period, hunting was carried out at a slower pace. Because February was the coldest month of the year, fewer Inuit hunted. However, the rules of social solidarity permitted all the people to partake of the catch brought in by the best hunters.

March was the month when the female seals gave birth to their pups, and hunting became more active. The hunters had to travel along the coast away from the camp to maximize the catch. In April with the milder temperatures, social visits were made between camps.

During the month of May, the winter camps were broken up and smaller groups were formed dispersing themselves along the coast. Seals sunning themselves were easy prey for the hunters, and this was the period of plenty. Housing was of the hybrid variety called Qulaalik which translates as a snow house with the roof made of skins to replace the dome of snow weakened by the sun. At this period the Inuit began using their tents. Some hunters and their families, taking advantage of the warm weather would travel inland to hunt caribou, but returned to the coast in June where game was plentiful. The catch at this period provided the family with the skins to make tents, covers, clothing,and boats (Qajaq and Umiak).

During the summer, provisions for the autumn and winter were accumulated. Open water permitted the use of Qajaq in hunting and fishing. At the end of June the ice broke up and moved out of the rivers. At this time the white whales became an additional source of food especially for the dogs. With the breakup of the ice during the first weeks of July, the spring camps were taken down and summer camps were formed by groups of 3 to 5 families.

1 Igloo or illu is the generic term for all solid houses from the small temporary snow houses to the prefabricated wood houses they inhabit today (Baillargeon, 1979).

The high point of the summer occurred in mid-August when the people travelled inland for caribou hunting. Because caribou were an essential part of the Inuit economy these sojourns sometimes took them 200 km. inland with the men travelling in Qajaqs and women and children following on foot. This voyage quite often took two months to complete.

The return from the caribou hunt marked the beginning of autumn, a period when migratory birds, seals and white whales were the most abundant. In certain regions collective hunting of walrus was carried out on the islands far off the coast. The period of freeze-up towards the end of October saw the hunters return to the coast. From this time until the end of November, these trips were reduced to a minimum due to the formation of ice on the rivers and along the coast which made travel with Qajaq or Umiak difficult. At this time the people lived in either semi-subterranean houses (Qarmaq) or the hybrid snow house called Qulaalik while waiting for the quality of snow necessary to build Illuvigaq (Baillargeon, 1979, pp. 51-55). See Sabo and Jacobs (1980, pp. 495-496), for an excellent table describing the South Baffin procurement systems detailing organisms, personnel, implements, etc. involved in the seasonal cycle.

Within the annual cycle were periods of mobility (from March to the end of October), followed by a more sedentary period in winter when people gathered together in large camps. Of all the various places inhabited during the annual cycle, only some became camps.[1] According to Audet (in Baillargeon, pp. 55-56), a camp which had close access to potable water, was well drained, and was easy to move about in, would never be an important camp if it was not at the crossroads of different circulation networks, or the starting point for a multiplicity of subsistance activities which were relatively near the camp.

However, this annual cycle of movement took place within a collective territory, a defined social space. The places were identifiable, not only through the names of lakes and rivers or the network of paths and trails, but also through the stories, myths and legends of the people.

1 A camp was considered to be a place of extended occupation grouping many families together.

1.3.3 European Contact with the Inuit

Contact between Europeans and Inuit began with the early polar explorers. From Cabot's first polar journey in 1497; Frobisher's first encounter with the Inuit in 1576 (on which he captured an Inuit to take home to England); Hudson's ill-fated voyage in 1610; the formation of the Hudson's Bay Company in 1670 which began the fur trade with the Inuit; Hearne's discovery of the Coppermine River in 1771; to Captain Cook's voyage along the northern Alaskan coast; the contact between Europeans and Inuit was not always happy (Keating, 1970).

The contact with whalers, who operated between Greenland, Baffin Island, and Labrador in the late 17th century; in Hudson's Bay in 1869 (Ross, 1976); and in the Copper Eskimo region in the 1890's just before whaling activity halted in 1906 (Bockstoce, 1975), brought about dramatic changes in Inuit life style. The early stages of goodwill and exchange which saw the Inuit acquiring new technology in return for food, furs and ivory developed into a situation of mutual dependence. Guns, wood whale boats and alcohol were introduced into the Inuit economy by the whalers, but according to Ross, there was more equality of contact at this time than during the late fur trading period. The settlements were influenced by the whalers' routes, and after whaling activity ceased, the Inuit returned to their former nomadic settlement patterns. They then concentrated on fox trapping, trading with the post traders, police, and missionaries (Ross, 1975).

Although the following history of European contact with the Inuit in Northern Labrador is not typical throughout the Canadian Arctic, it does provide many parallels, and will therefore be used here to illustrate the effects of this contact on the Inuit culture as a whole.

In Labrador in the late 1600's, there is evidence that the southern Inuit exchanged sealskins, baleen (used in the fabrication of corsets) and blubber with the French for European articles (Taylor, J.G., 1975). Sometimes the Inuit obtained these articles through raids on the Europeans (Kaplan, 1980, p. 649). During this period of initial contact the Inuit retained their traditional settlement sites and it was only in the early 1700's that a few new sites were founded.

Houses at this time increased in size, suggesting greater co-operation in hunting. In the mid-1700's the Moravian missionaries arrived, and by 1776 had established two stations which had a profound effect on Inuit settlement patterns (Taylor, J.G., 1975; Fitzhugh, 1980, pp. 601-602). Large numbers of Inuit took up residence near these stations, diminishing the number of settlements, whereas previously there was a multitude of small settlements evenly spaced along the northern coast. Due either to over-exploitation or climatic changes, whales and walrus became rare. This lack of large marine mammals meant that the people and those who had large dog teams to feed had to rely on seal, caribou, fox, and fish (Kaplan, 1980, pp. 650-652).

In the late 1800's firearms were common amongst the Inuit and permitted them to hunt caribou without the help of large numbers of people. Co-operative caribou drives were no longer necessary, with the result that caribou could be hunted in areas other than traditional locations. It was no longer necessary to use ridges where they could be channelled by means of rock and brush alignments towards hunting blinds, or to ambush them at water crossings where the caribou would be easier to kill (Spiess, 1979). Seal hunting did not change radically, because the means of approaching them remained essentially the same, and harpoons were still required for retrieving them from the water.

Fishing became more efficient with the introduction of European nets allowing the Inuit to exploit this resource more successfully. They were no longer restricted to shallow water fishing with spears, but could catch fish in lakes and deep rivers. The Moravian missionaries, because of their fear that the Inuit converts would stray from their new life style, provided them with nets and encouraged them to stay near the mission. They urged the Inuit to cache as much fish as they could to minimize their hunting sojourns far from the village (Kaplan, p. 653). This type of influence on the Inuit settlement patterns was radical, and the other religious missions in other parts of the Arctic placed less pressure on the Inuit than the Moravians.

The Hudson Bay Company had a more universal influence on the Inuit, but in the Labrador region ran headlong into competition with the Moravian

missionaries. The Hudson's Bay posts did not subsidize families without food as the missions did during periods of famine, but they did give credit and loaned out traps and fish nets to those Inuit they felt were good hunters and fishermen.

Trapping as an important facet of the Inuit economy began in the late 1800's, posing a dilemma for the Inuit. He required his dogs for access inland to trap foxes, but he needed to hunt seals to supply his dogs with the necessary food. He was thus required to work both locations, but in order to reduce the weight of the food he brought with him when trapping, he carried dried foods for himself purchased from the trading post. Although he made more money than the Inuit hunting seal, he spent a great deal of it on his own food and equipment. See Williamson (1974) for another account of the effect of the introduction of trapping on the Inuit culture.

The Moravian missionaries' influence, the Hudson's Bay Company trading needs, and the decline in large sea mammals resulted in a shift of hunting zones from outer island and coastal areas to inner fjord and coastal regions where marine and land game were available. The people no longer needed to hunt in large groups which caused the settlement pattern to be more dispersed and led to a decrease in the size of houses. Without the need for co-operative hunting, groups could be made up of one or two individuals using the new hunting technologies. The missionaries realizing that an over-concentration of Inuit around the mission was resulting in over-hunting, decided to set up satellite settlements that encouraged dispersement.

The missions also emphasized the desirability of single family dwellings which "led to the breakdown of social and economic co-operation within the Eskimo community" (Kaplan, p. 654). This brought about a division in the population. In some instances, non-Christian Inuit settled on one shore and Christian Inuit on another, with the Christian Inuit being unwilling to share their food with the non-Christians (Kaplan, p. 654).

The Hudson's Bay Company also contributed to this division amongst the Inuit through their policy of giving credit and loaning equipment to those they considered to be the best hunters. A good hunter in the Hudson's Bay post's terms was a successful fur trapper, while the Inuit considered a

good hunter to be one who was skilled in caribou and seal hunting. The cash value of seal hunting was far less than the advantages and cash value of fox trapping, and therefore the traditional good hunter had less access to the new hunting technologies than the fox trapper. Thus, there developed a category of Inuit known as the "Post-affiliated Eskimo", whose allegiance was with the Hudson's Bay post.

The post and the missions were in competition for the allegiance of the Inuit, but even though the Mission arrived before the post, the settlement was more or less dominated by the post making co-existence difficult. This resulted in the departure of the mission (Kaplan, p. 655). In the rest of the Arctic, a similar competition existed between the Anglican and Roman Catholic missionaries, but the relationship of these missions to the Hudson's Bay Company was one of collaboration rather than competition.

A third category of Inuit existed on the Labrador coast which had little contact and no affiliation with European groups. They were more distant from the missions and posts and retained their traditional settlement patterns and house types. In general, however, Inuit settlement patterns and socio-economic behaviour changed from the traditional mode. Kaplan (p. 656) summarizes the situation nicely when she states:

> "The overall impact on the 19th century subsistence and settlement pattern changes was the abandonment of communal hunting and sharing practices with dispersed, small hunting and trapping parties becoming the norm. Large multiple family houses disappeared in many areas, and settlements consisted of small nuclear family structures. Economic and social loyalties shifted away from the settlement or multiple family house to a particular European group. Trade networks between Eskimo communities were no longer necessary. These developments led to a breakdown of economic and social ties within and between Eskimo communities."

In the central Arctic, the effects of European contact with the Inuit were more or less similar to that of the Labrador coast, but occurred at a later date. For instance, the Hudson's Bay Company established posts at Chesterfield Inlet in 1911; at Baker Lake in 1924 on the west coast of Hudson's Bay (Williamson, 1974, p. 73); and at Cape Smith and old Povungnituk on the east coast of Hudson's Bay in 1919 and 1920 (Nunaturliq, 1974, p. 68). The opening of a mine in early 1900 at Rankin Inlet led to a migration of Inuit from dispersed settlements to the mine to take

advantage of the services offered in the village, and the opportunity for employment (Williamson, p. 98). This was the beginning of the sedentarisation process.

On the east coast of Hudson's Bay, two trading companies (Réveillon Frères and the Hudson's Bay Company) set up posts north and south of (new) Povungnituk in 1919 and 1920 around which gathered the Inuit in fluctuating numbers. The concentration of people reached its maximum at Christmas and at the end of the summer when the supply boat came for the post stores (Nunaturliq, p. 69). Gradually, the Inuit spent more and more time in the settlements. In Tuktoyaktuk in the McKenzie delta area, as early as 1934, the Inuit were spending the major portion of their time in the settlement (Cooper, 1968, p. 144).

Shortly after World War II there was a high incidence of respiratory diseases, such as tuberculosis, which led to the hospitalization of many Inuit in southern sanatoria. This had the effect of creating a more permanent population in the settlements as the people awaited the return of their family members (Thomas and Thompson, 1972, p. 9; Audet in Larochelle and Bernard, 1975, pp. 1-3). It also resulted in the dissatisfaction of many Inuit with the traditional life style with its attendant difficult periods of famine. Most of the women who came back from the sanatoria in the south were unwilling to go back to life in the camps, having been deeply affected by the affluence and ease of life of southern civilization (Williamson, 1974, p. 84). There was a somewhat similar reaction amongst the children who were sent south for their secondary education. When they returned, many found it difficult to adapt to subsistence hunting and fishing (Myer, 1977, p. 82). Most of the men who came back from the sanatoria were mentally and physically unable to sustain the hardships which were normal to their life style, although the men were less affected than the women with regard to their standard of living (Williamson, 1974, pp. 83-84).

As mentioned previously, the sedentarisation process began as early as 1934 in some areas (Cooper, 1968) and in the early and mid 1950's in other areas (Nunaturliq, 1974, p. 70; Yates, 1970, p. 45). Using Povungnituk as an example, we can see how fast material changes were brought to the Inuit way of life which in turn affected their culture. In 1951 the Hudson's Bay

Company closed its posts north and south of Povungnituk and moved to Povungnituk proper. In the same year the Federal Government made family allowance and welfare payments to the Inuit. New economic activities such as sculpture, print-making and handicrafts developed as trapping decreased in importance (Nunaturliq, p. 70).

In 1956, the Oblate missionaries established a mission in Povungnituk which had an impact on the development of the village. The first school was built in 1957, followed by the establishment of the first co-operative and the Anglican missionary's residence in 1958. In the same year the first Federal Government administrator's residence, a permanent school, two warehouses,and eight houses for the Inuit were built. The first government dispensary was constructed in 1960 which was also the year that the Inuit housing program began. In 1961 the Anglican church was established and the first permanent government administrator arrived, taking over the administrative duties from the teacher who had held both positions. The first local community council was set up in 1962, and in 1963 the Québec Provincial Government established its presence. In 1964, the Anglican mission built a recreation centre, and two years later the electricity generating plant was erected, as well as the government's large secondary school. The co-operative built workshops for making prints and sculpture for expedition to the south, as well as a store to compete with the Hudson's Bay Company store. The Hudson's Bay Company then built a new larger store and a manager's residence. The Federal Government set up offices and residences for its personnel and teachers as did the Provincial Government. Trucks, bulldozers, track tanker vehicles were brought in, and garages and oil storage tanks were established. The technical, social, and administrative infra-structure was completely installed by 1969, and after this period up to the present it was extended or modernized, but no major changes were made (Nunaturliq, 1974, pp. 71-74).

All the amenities brought to the village resulted in changes to the traditional life style, such that outwardly it would seem that the Inuit culture had been transformed, and had assimilated southern Canadian cultural values. However, as Thomas and Thompson point out, closer analysis indicates that their "...material culture has undergone a drastic change, (house type,

clothing, tools, etc.), but the means for utilizing the new material culture and the social value placed upon it have not undergone a concomitant change" (p. 13).

However, the Inuit life style was changing. As Williamson notes, "Interview records... show that for more than three-quarters of the Eskimo population, the memories of the hardships of the traditional way of life and the relative security...of the wage-earning way of life developed increasingly strong motivations towards the establishment of regular wage-earning as a permanent life pattern" (Williamson, 1974, p. 117). The attraction to the money economy led, in a majority of the cases, to a trend in the formation of nuclear families and a gradual lessening of the importance of the advice of senior parents. There is a definite tendency towards the dissipation of the "...internal strength of the family" (Williamson, pp. 156-158), and he noted that it had reached the point where the authority of the parents had been supplanted by that of the school teachers. Myers observes that in Alaska, the young Inuit "...now count on the schools to teach them their culture" (1977, p. 189). In the author's personal experience this is certainly less true in Arctic Québec where the Inuit have passed on the cultural skills of making tools, clothes, hunting, etc. that Myers indicates have been lost by the Alaskan Inuit. It is at the level of myths, legends and spiritual relationships that the culture is not being handed on or continued.

One of the effects of the young Inuit journeying south for his secondary school education,[1] or for employment, is the alienation of a fairly large segment of this group from the past, resulting in the development of a 'truncated Eskimo'. Leon and Martin (1969, p. 406) point out that "...Eskimos in particular seem to be 'lost' in the cities. They were less able to adjust to employment and vocational training and more frequently failed at these. They move frequently (and) tended to remain isolated. They displayed more anxiety. They had greater problems with alcohol, and those with families showed more signs of family disorganization." They also had more adjustment problems than other native groups and "...more of them returned to Alaska." The Inuit, Williamson believes, are "...in a process of rather rapid cultural disintegration" (1974, pp. 177-187).

1 There are now secondary schools in some Inuit villages.

In Arctic Québec, since the signing of the James Bay Agreement in 1975 the Inuit have formed their own administrative structures and are gradually taking over the decisions involving their future evolution. Whether their culture will change and modify by incorporating certain cultural and technological systems from the south without decimating their own culture remains to be seen, but at least the control and choice will belong to the Inuit themselves.

1.4 HISTORY OF ARCTIC HOUSING

1.4.1 Traditional Inuit Housing

The different types of early traditional houses (stone houses, sod houses, etc.) are difficult to date and to place in terms of a culture group (Arctic Small Tool Tradition, Pre-Dorset, etc.). Some of the archeological finds related to housing date back to the Arctic Small Tool Tradition culture and were radiocarbon-dated at approximately 3400 B.C. (Schledermann, 1978, p. 460). However, the exact form and composition of the houses are difficult to ascertain. Other finds have been dated at 2400 B.C., the period of transition from the Arctic Small Tool Tradition to the Pre-Dorset culture (Schledermann, 1977, p. 244). Schledermann mentions the dwellings of the Choris people in Alaska which were constructed as early as 1000 B.C. (1976, p. 33). In Labrador, Pre-Dorset cultural remains were found dating from 1000 B.C., as well as from the Middle Dorset period, 500 B.C. to 600 A.D. (Matthews, 1975, p. 256; Fitzhugh, 1980, pp. 598-599). Dorset dwellings dating from 140 - 570 A.D. were found in Arctic Québec (Badgley, 1980, p. 578), and Late Dorset artifacts near Igloolik dated at 500 - 800 A.D. (Maxwell, 1980, p. 509). Thule dwellings, thought to date from 100 A.D. have been found, but positive-radiocarbon dated sites have been established for northwest Hudson's Bay at 1205 A.D. (Sabo III and Jacobs, 1980, p. 492), and on Ellesmere Island dwelling artifacts have been dated at 1280 A.D. (Schledermann, 1980, p. 472). Other Thule sites have been dated in the Ungava area at 1300 A.D. and show occupation until 1600 A.D. (Matthews, 1975, p. 251). Schledermann found communal houses in Labrador which were probably begun in the 1700's (1976, p. 31), while Matthews found Thule dwellings in northern Labrador dating from the early 1800's (1975, pp. 258-259).

Many sites have been occupied on a more or less continuous basis from the early historical period until early in this century (McCartney, 1980, p. 529). Sabo and Jacobs describe such a site that was occupied successively from 1,100 A.D. until the early 1900's (1980, p. 492). Thalbitzer (1884 expedition) mentions that the Inuit in east Greenland frequently reused older sites (1979, pp. 8, 348), and Mathiassen describes houses being reused for autumn houses (1927, p. 116). Boas mentions Inuit not having to build new houses because they return to old settlements and are able to occupy existing buildings (1964, p. 139). Thus, many dwellings are difficult to attach to a particular period, and no attempt will be made to present the houses in chronological order, as it is the form and construction that is of interest. Form and construction type are more related to the availability of materials than to a particular period or culture, and this is especially true of the permanent dwellings. For instance, Mathiassen mentions a stone house built in 1920, while others have been dated to the 4th century B.C. (1927, p. 19).

1.4.1.1 Stone Houses

Stone houses are defined by this author as those whose wall structure is predominantly made of stone and are essentially an above-ground structure, even though some structures have their floors depressed below ground level.

1.4.1.1.1 Single Stone Houses

Stone dwellings varied in form, size and roof structure, but few structures were completely made of stone. Jenness describes a stone house shaped like a truncated cone. It was 4' 6" (1.37m) in diameter at the base, tapering to 2' 6" (76cm) at the summit, with an overall height of 6' (1.83m). The door faced WSW and was 2' 6" (76cm) high by 1' 6" (46cm) wide, and 1' 6" (46cm) above the floor. The roof was formed by corbelling the small single stones, as no single stone was large enough to span the open space (Jenness, 1922, p. 57). See Fig. 2.

An east Greenland stone house described by Thalbitzer (1979, pp. 41-42) was used by families unable to reach their normal 'wintering-places'. They were entirely built of stone without turf, and were made impermeable by

filling the spaces with snow. These houses were quite unlike their usual winter houses made of turf, stone and whale bone. Mathiassen, describes a hunting shelter which consists of a row of stones placed in a circle or square, covered with two layers of skins. These shelters were only used for one night, and only when hunters had no tent with them (1928, p. 138).



Fig. 2. Stone hut (Adapted from Jenness, 1922).



Fig. 3. Beehive stone structure (Adapted from Matthews, 1975).

Stefansson describes a stone house which as the Inuit explained was ... "built by the spirits before the human race inhabited the land", indicating it was an ancient dwelling having lost any cultural attachment to the present generation. The house had an oval plan measuring 5' x 7' (1.5 x 2m) covered by a dome-shaped roof without rafters, giving the author the impression that it was a self-supporting structure (Stefansson, 1913, p. 275).

Matthews also describes beehive-shaped stone structures which he suggests could have been a fall trap, food store, or an igloo-like shelter. The best preserved of the two completely stone structures found was 2m high, 1.8m in diameter at the base, with a low square entrance 45cm x 60cm, having an opening at the summit of the same dimensions. He places the structures at less than 300 years old and hypothesizes that they were likely fox traps rather than as Bell proposes "... hiding places or 'stands' from which to kill game" (Bell 1885, in Matthews, 1975, pp. 251-252). See Fig. 3.

Some of the oldest stone structures date from the 4th or 5th century B.C.,

but they seemed to have driftwood roof supports (Arnold, 1980, pp. 400 - 403). Matthews describes finding a variety of stone dwelling forms. He found oval, circular, elliptical, square, rectangular and pentagonal forms (1975, pp. 249 and 257). See Figs. 4 and 5.

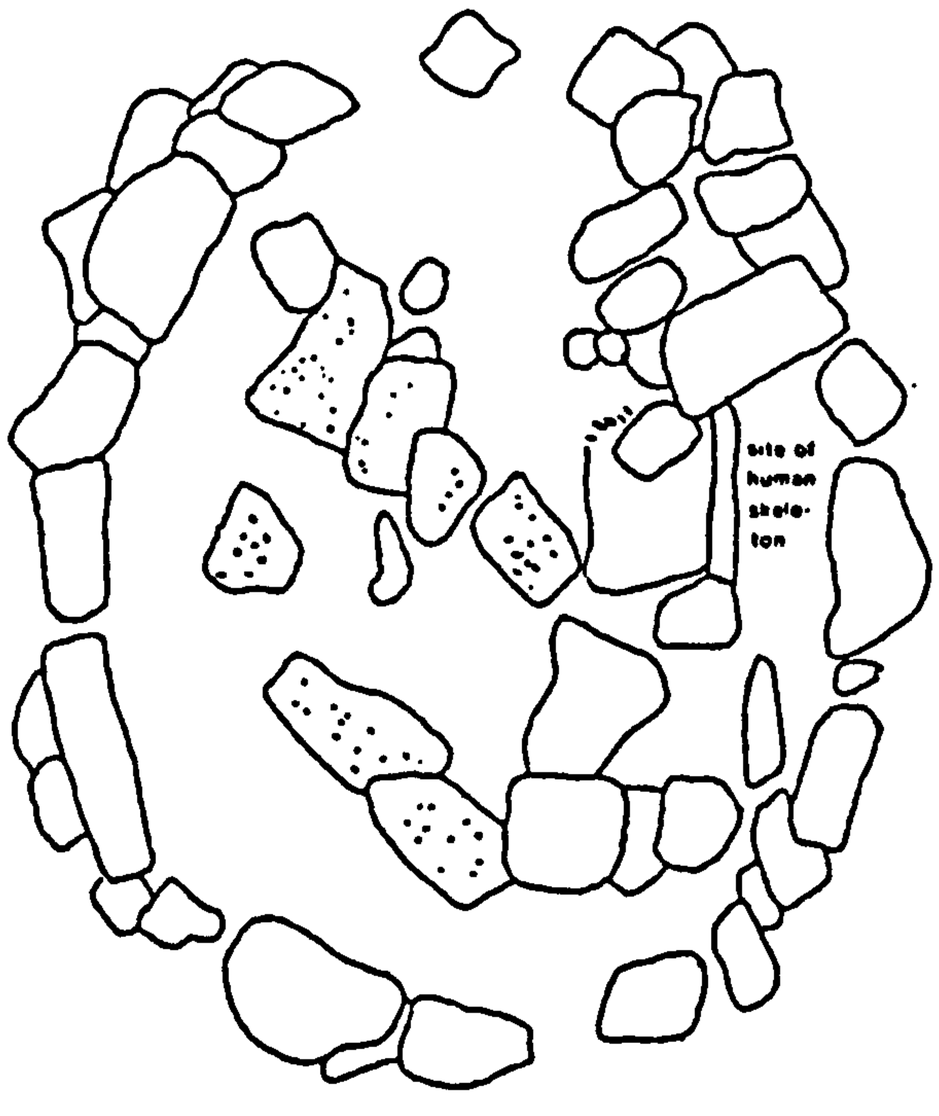


Fig. 4. Oval stone dwelling (From Matthews, 1975).

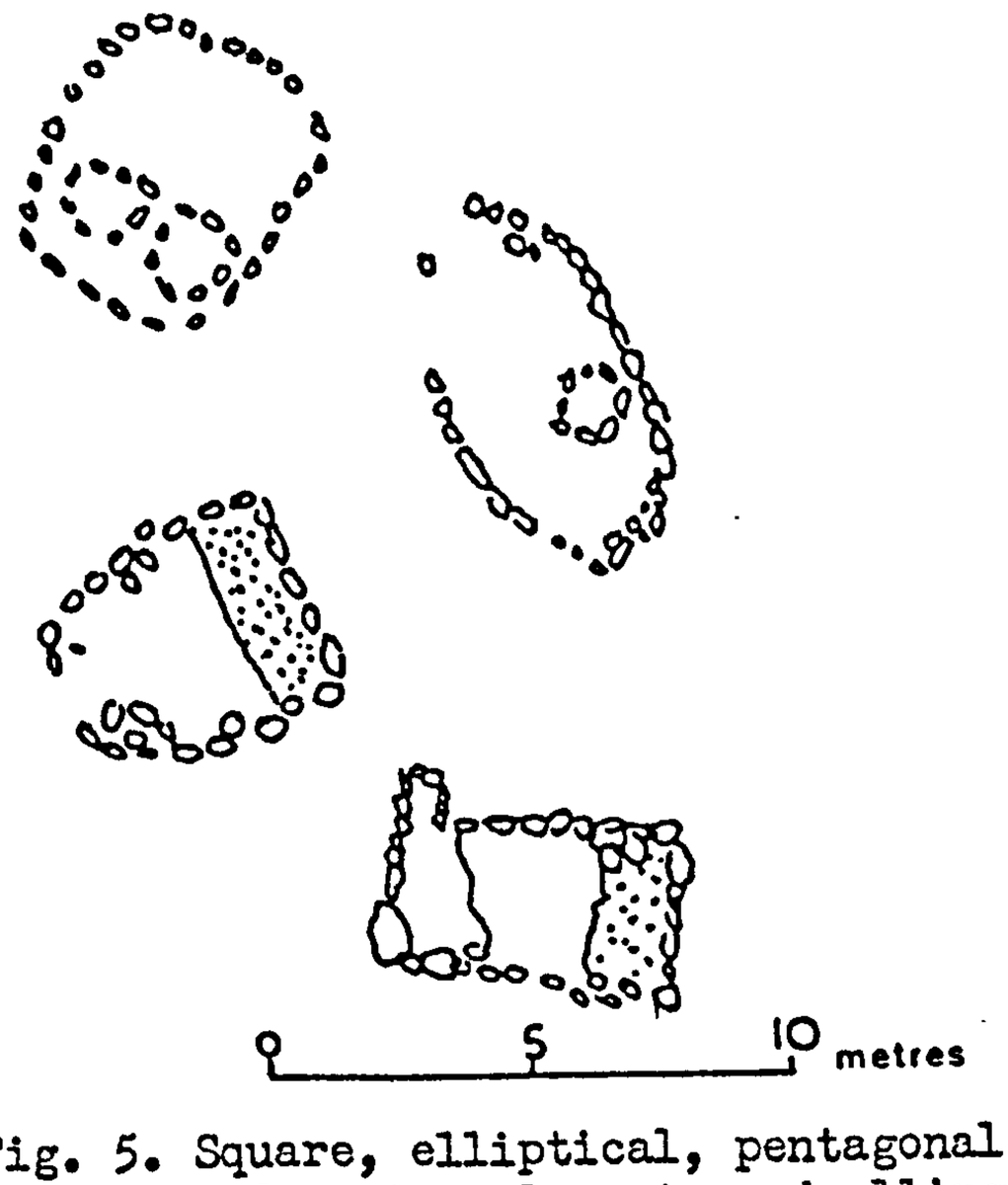


Fig. 5. Square, elliptical, pentagonal, and rectangular stone dwellings (From Tanner in Matthews, 1975).

These structures varied in dimensions, the oval being 2.5m x 3.0m, to a maximum of 2.4m x 5.1m with walls of stone up to 75cm in diameter (some partly hewn) piled to a height of 1.0m (pp. 249-250). The largest rectangular stone structures found measured 2.1m x 4.5m with the interior space divided into separate chambers by stone walls. Matthews also notes that some pentagonal structures had these stone divisions recalling a European influence (1975, p. 259). One of the rectangular structures (see Fig. 5) had a projection resembling a porch which is a rarity for stone structures. These structures were dated at approximately 400-600 years old (p. 251).

Boas (1901, pp. 400-401) describes stone structures constructed of stones, whale bone, sod and earth. The main space was slightly below ground level and was roughly circular in shape, 5 to 7m in diameter. In the centre there was a stone platform 60cm above the floor from which a stone pillar built

of stone slabs became the central support for the roof members made of whale jaw and crown bones. These bones extended from the central support to the outer walls which were made of whale scalp bones. Flat stones spanned the space between the bones, and were covered with sod and earth. The entrance tunnel, made of flat stones, was long to minimize the penetration of cold air. The sleeping platform was raised to the same height as the centre platform. Space for each family on the platform was sometimes delineated by a wall of stone and earth projecting from the outer wall and in other cases by skin screens. See Figs. 6 and 7.

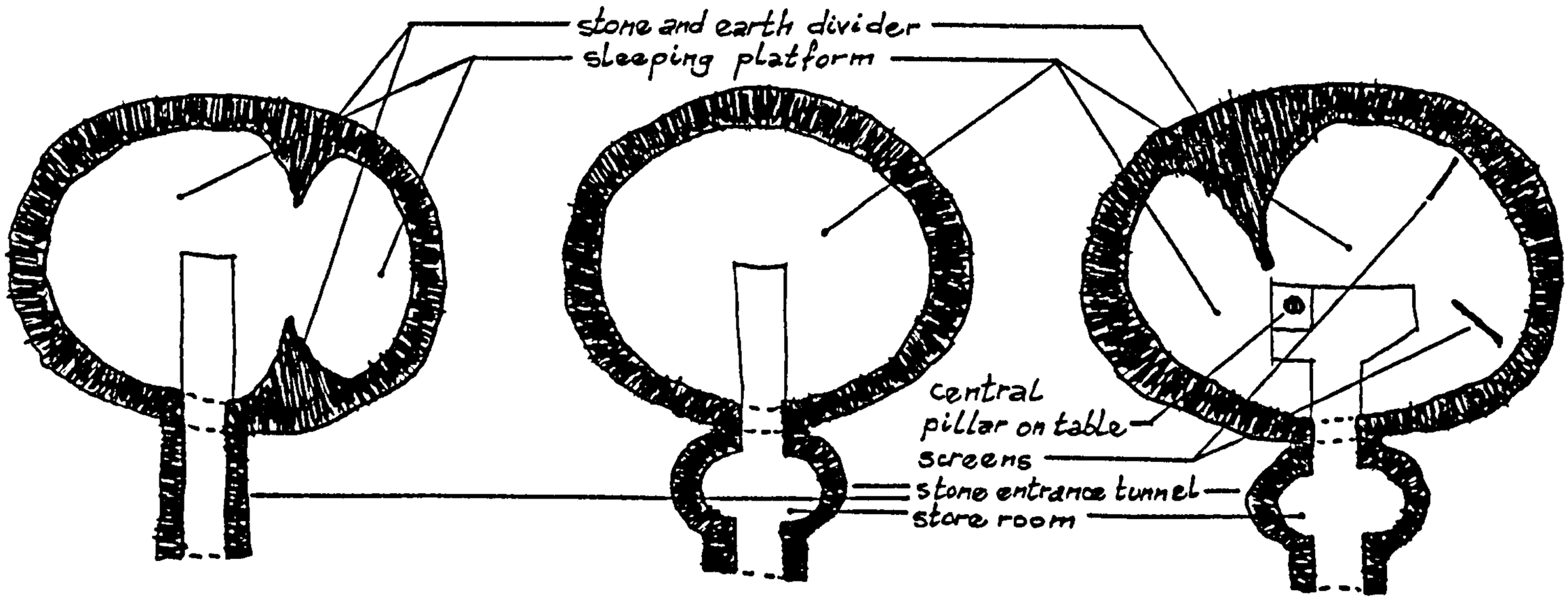


Fig. 6. Stone house plans (Adapted from Boas, 1901).



Fig. 7. Exterior appearance of stone houses (Adapted from Boas, 1901).

Mathiassen illustrates some typical single stone houses. These dwellings were either circular or oval in shape. The latter were either oval in the width or the length in relation to the entrance porch (1927, pp. 18, 20 and 134). See Fig. 8.

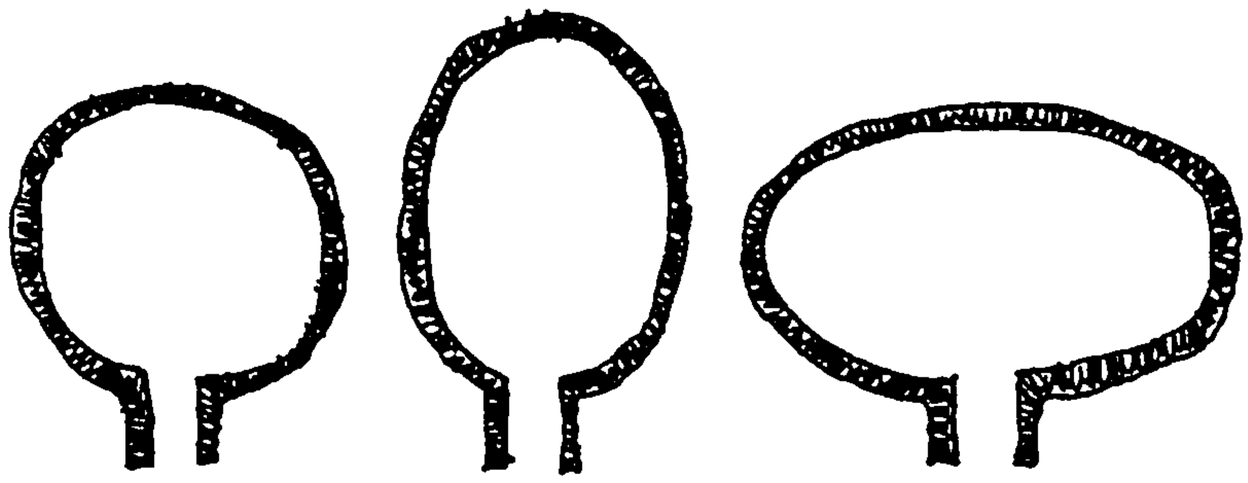


Fig. 8. Circular and oval stone house plans (Adapted from Mathiassen, 1927).

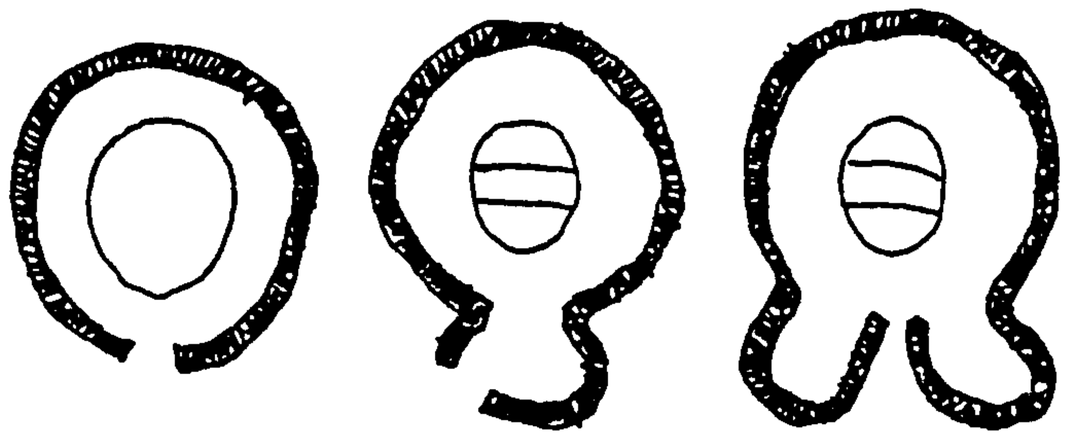
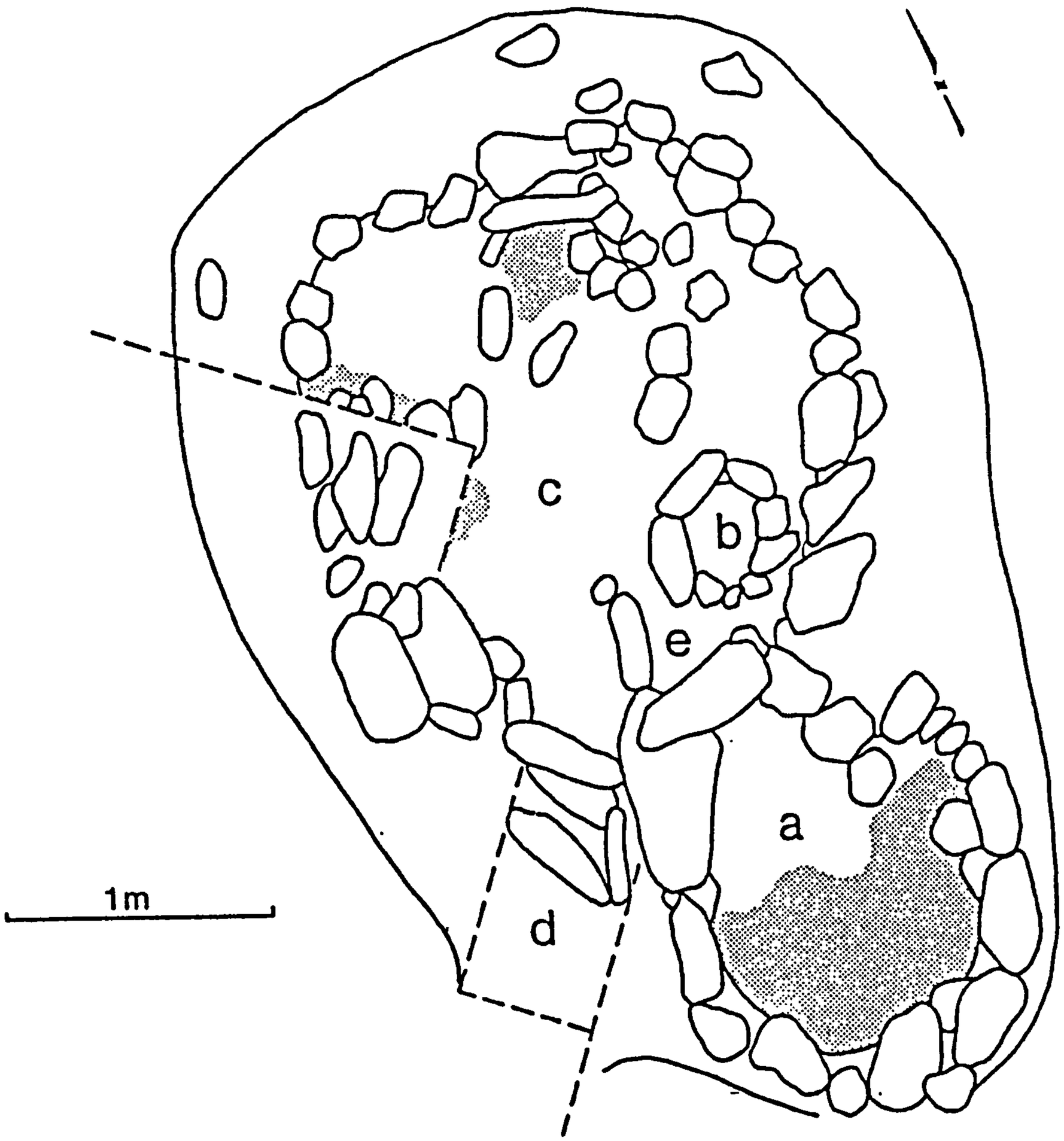


Fig. 9. Circular and modified circular stone singing houses (Adapted from Boas, 1974).

Boas gives three examples of circular and modified circular plans for singing houses known as Qaqqi. From Fig. 9, one observes that the first house is circular with no entrance tunnel; the second has an entrance tunnel or alcove; and the third has the entrance between two alcoves. The singing houses had no roofs, only stone walls, and were often used to celebrate successful whale hunts. These festivities were similar to religious feasts (Boas, 1974, p. 603). Mathiassen describes festival places used for whale flensing. They were oval in shape with walls of loose stones 5' (1.5m) high, 41' to 27' (12.5-8.1m) long, and 18' to 33' (5.5-10m) wide (1927, p. 123). Schledermann (1978, pp. 467, 470 and 471), mentions stone festival longhouses on Ellesmere Island which were square and similar to the house styles of the western Thule culture of Alaska and the Bering Strait which demonstrates that there were a variety of forms for dwellings with similar functions. He describes the festival houses as being square or sub-rectangular, measuring from 5 to 7m inside the walls. They were built of sod, whale bone and very large boulders for the walls with the roof made of baleen covered by skins. The festival houses were either attached to house structures or very nearby (Schledermann and McCullough, 1980, p. 834).

Maxwell observes that there are "... 10 to 20 variants of Dorset housing depending on the level that one distinguishes varieties", the most important of which is the "mid-passage" or axial structure. These structures have central "... linear features which usually run perpendicular to the nearest body of water," the form of which may be round, oval or rectangular (Maxwell, 1980, p. 506). A variation in the interior organization was the rounded, angular,or square Thule houses which had kitchen alcoves parallel to the entrance passage (Schledermann, 1978, p. 470 and Schledermann and McCullough,



House 6, Skraeling Island site: a) kitchen; b) meat pit and location of clinch nail c) gravel floor, d) entrance passage, and e) location of chain mail and needle case Shaded areas indicate charred material (blubber, wood and bone pieces).

Fig. 10. Thule stone house with kitchen alcove parallel to entrance (From Schledermann, 1978).

1980, p. 836). See Fig. 10. These houses, dated at about 1270 A.D., often became more angular in form with the addition of one or more sleeping alcoves. Short tunnels led to the small central space containing several small fire hearths. The kitchen alcoves were common throughout the early stages of Thule culture.

The stone longhouses mentioned by Schledermann (1977, p. 244; 1978, p. 467) and Maxwell (1980, pp. 508, 509) are another important variant of the Dorset houses. Schledermann hypothesizes that the Ellesmere Island longhouses

were never roofed and were more symbolic than functional, unlike the later Thule longhouses. See Fig. 11 for a Dorset stone longhouse structure.

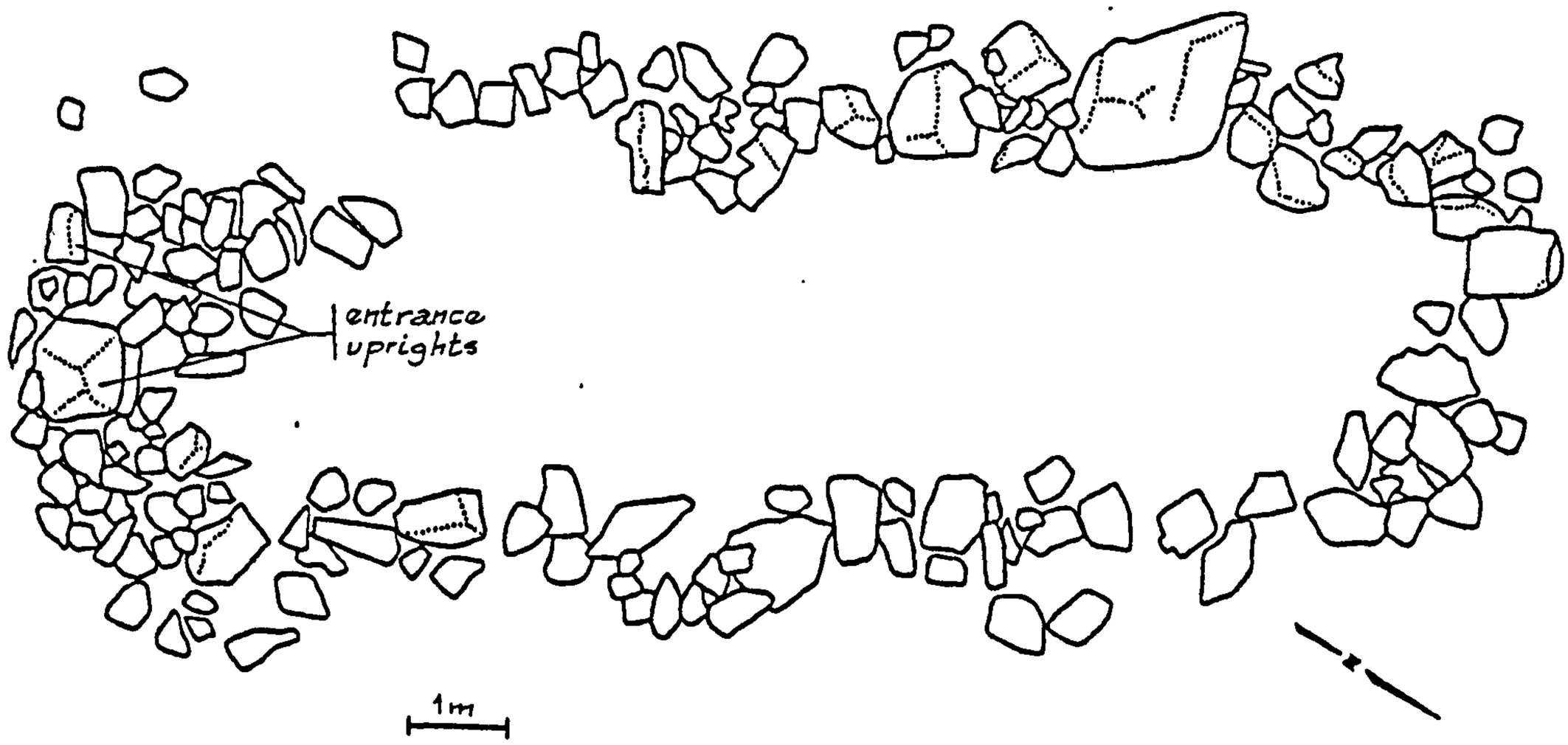


Fig. 11. Dorset stone longhouse structure (From Schledermann, 1978).

The Dorset stone longhouses described by Maxwell situated on Baffin Island were enclosed by a roof structure supported by driftwood poles. The dwellings were divided up into separate family zones as suggested by the multiple cooking areas and the caribou and sealskin coverings found on the sleeping benches. The benches were 30m long in the Baffin Island longhouses and 40m long on Ellesmere Island (Maxwell, 1980, pp. 508-510; Schledermann 1977, pp. 244-245). It should be mentioned that some of the larger circular houses could have been multi-family dwellings as were the longhouses, because the largest diameter was 8m while the smallest was 3m (Mathiassen, 1927, pp. 105, 109, 111, 115, etc.).

Schledermann describes stone wall structures containing from 3 to 18 hearth and platform units, the longest being 32m in length. This Dorset cooking row was used in summer as it had no roof, and served as the hearth to prepare the meals from where they were taken to be eaten in the longhouse (1978, pp. 463, 466, 467, 473).

It is interesting to note that although the doorways were in almost every case oriented towards waterways, most of the doorways faced the southern half of the cardinal points. For example, Mathiassen noted that most of

the doorways faced SE, SSE, S, SSW, SW, WSW and W (1927, pp. 10-20, 134, 138-142 and 226), although he did notice a few rare examples oriented E and N (pp. 14, 138).

It should be mentioned that the interior living arrangement and use of space in the stone houses was similar to that of the snow houses.

1.4.1.2 Double Stone Houses

Two houses joined together does not seem to be too uncommon in stone structures. The example in Fig. 12 represents the beginning phase in the evolutionary process of the double-house type. Because the two houses each have a small portion of the entrance way which is private before becoming a common entrance, and because the two house structures do not touch each other, they retain separate identities (Mathiassen, 1927, p. 12). In this case the two families would seem to be related, but sufficiently individualistic to want to retain their separate living space.

Boas gives an example which shows two houses joined together sharing a common entrance. See Fig. 13. This house, as can be seen from the section, had walls made of piled-up boulders entirely above ground. There were two distinct sleeping platforms and four cooking-lamp areas supported by small

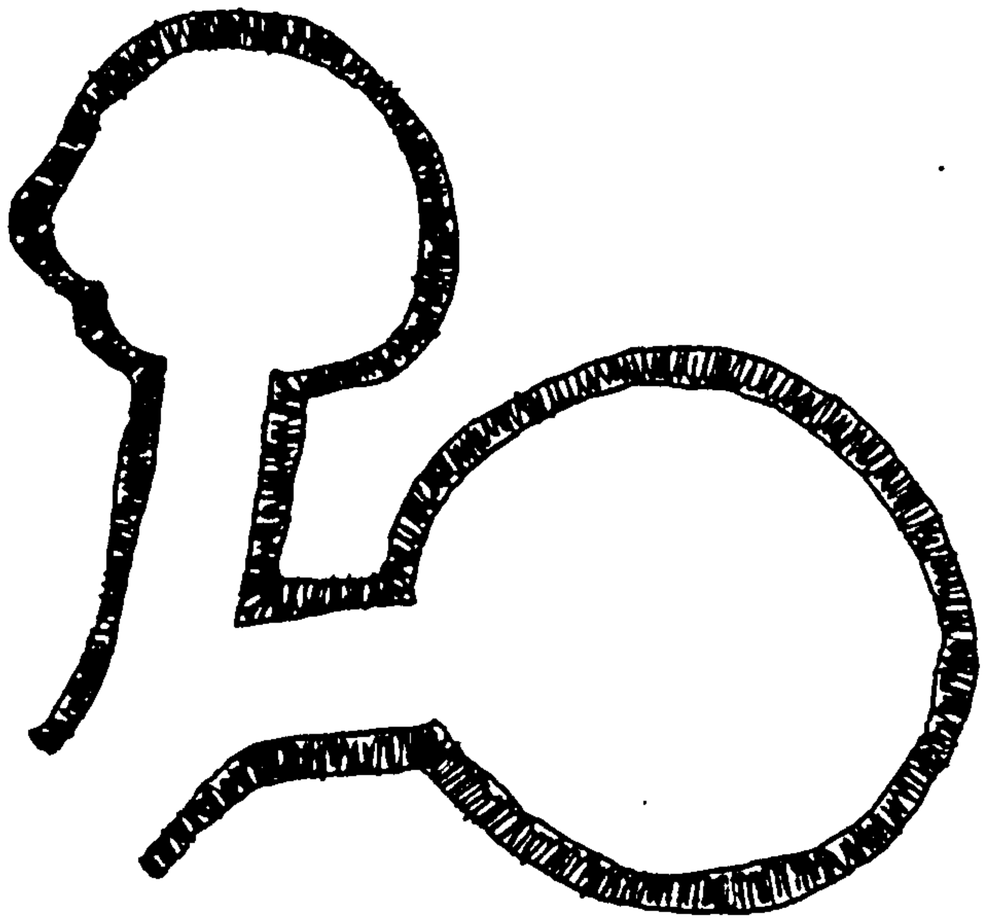


Fig. 12. Double stone house with separate private portion to common entrance tunnel (Adapted from Mathiassen, 1927).

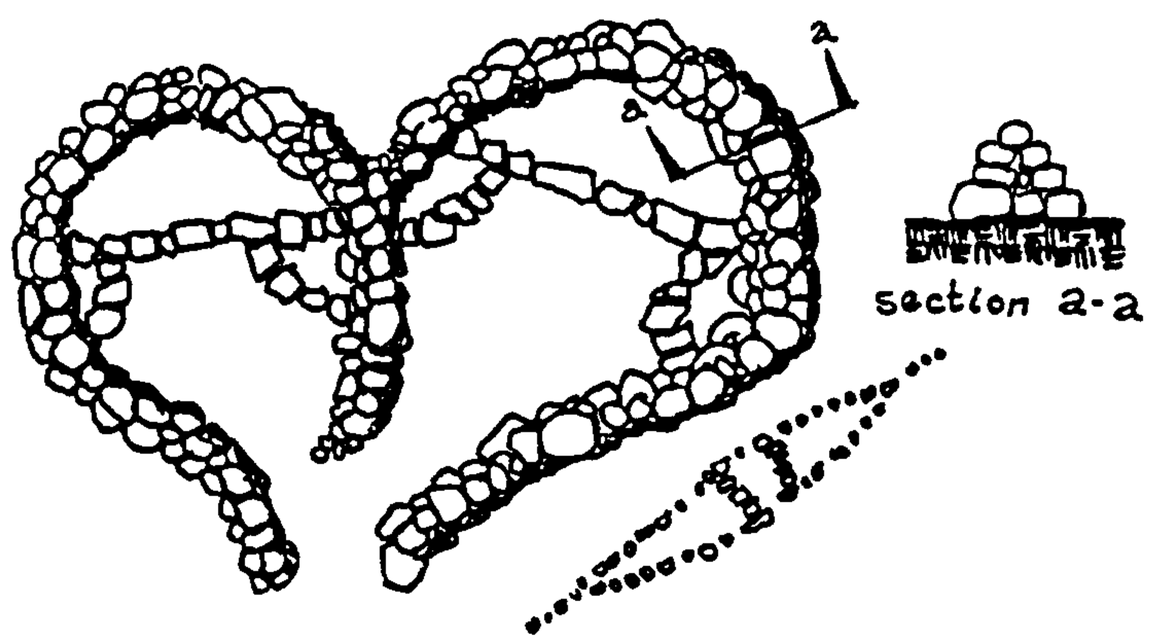


Fig. 13. Double stone house with separarate entrances from common entrance tunnel (Adapted from Boas, 1974).

stone walls. The roof was made of whale rib structural supports covered with two layers of sealskins enclosing a layer of moss or brush, similar to the semi-subterranean houses. The entrances were usually made of snow (Boas, 1974, pp. 548-550).

The evolution in the double-house dwelling type as a single entity is demonstrated in Fig. 14 where the houses are contiguous but separate. The interior dividing wall effectively separates the house into two distinct houses sharing a tiny forecourt and entrance (Mathiassen, 1927, p. 18).

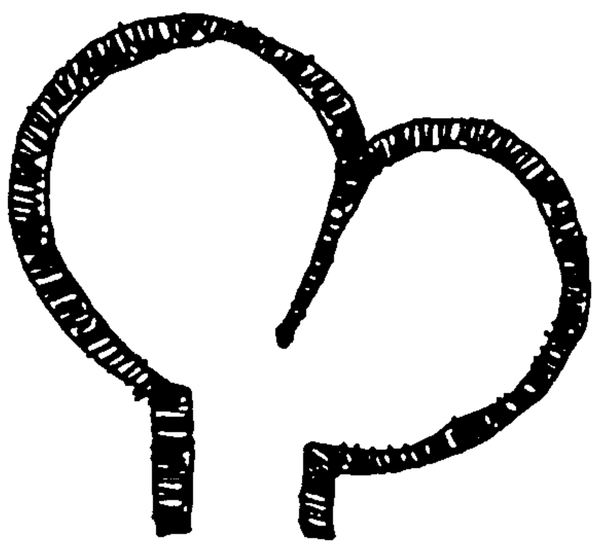


Fig. 14. Double stone house with contiguous stone interior separation (Adapted from Mathiassen, 1927).

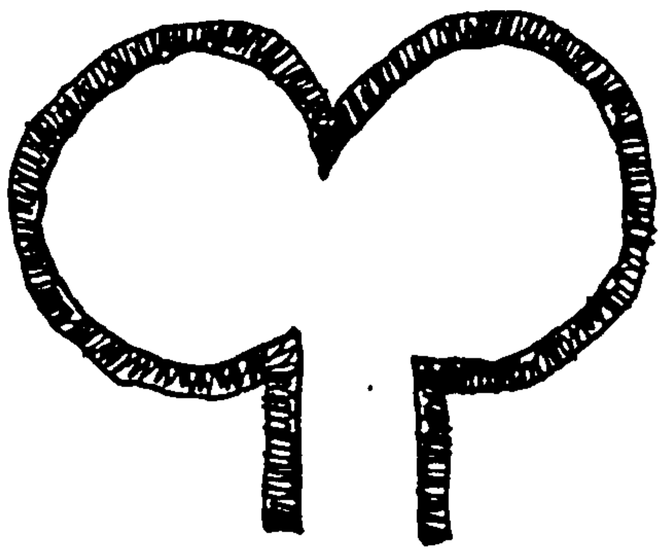


Fig. 15. Double stone house with common central space (Adapted from Mathiassen, 1927).

The double house begins to lose its double-house identity in the example shown in Fig. 15 when two circular houses are joined together, sharing a common central floor space and entrance (Mathiassen, 1927, p. 10).

Fig. 16 shows two houses which are even less identifiable as a double-house type. The two houses are approximately equal in area, but they share the same central floor space and have a common entrance (Mathiassen, 1927, p. 253).

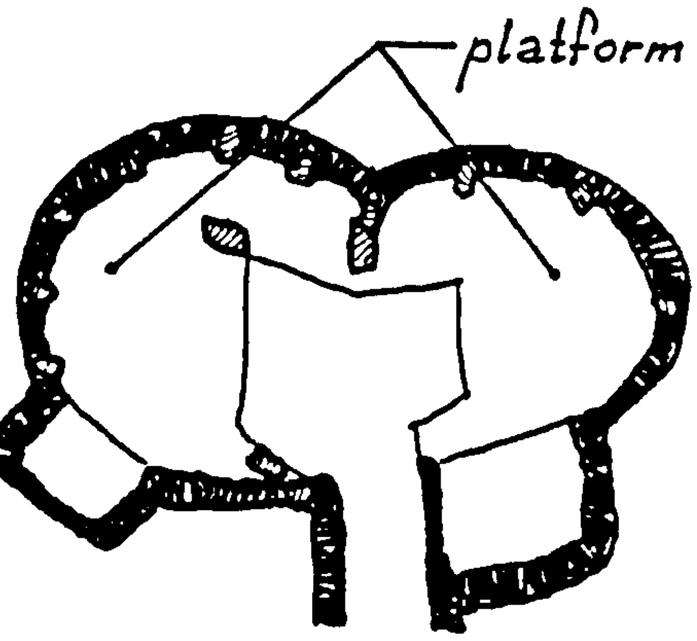


Fig. 16. Double stone house with contiguous interior space (Adapted from Mathiassen, 1927).

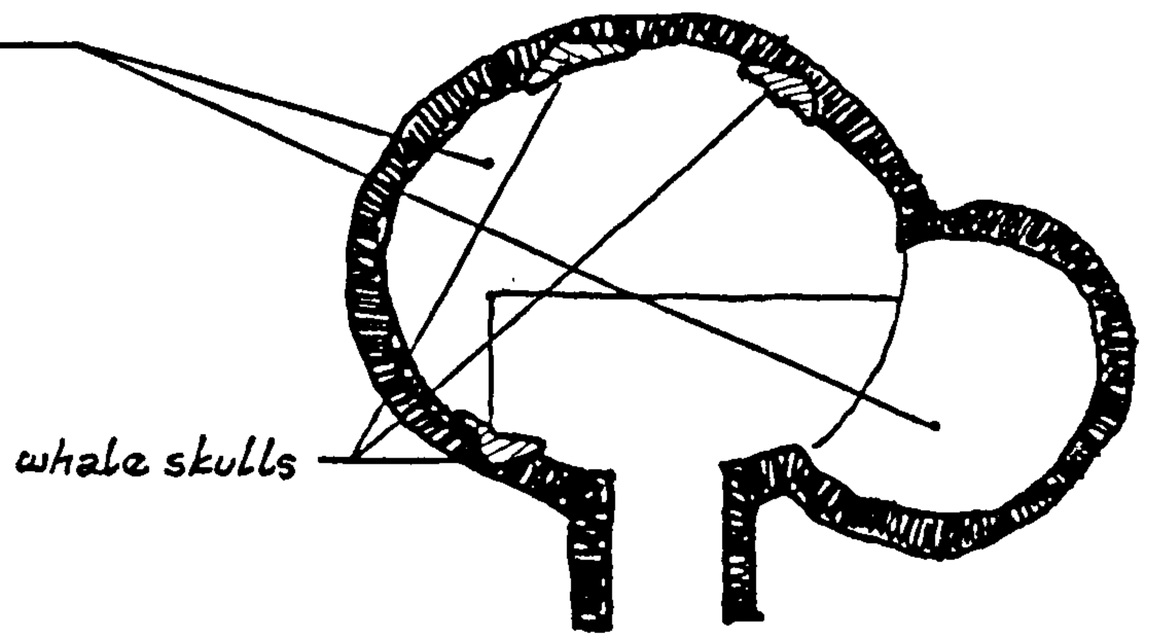


Fig. 17. Double stone house with platform alcove off central space (Adapted from Mathiassen, 1927).

Fig. 17 is an example of what might be called the last phase in the evolutionary process, ie., a single dwelling with an alcove added to receive a second sleeping platform with a common entrance (Mathiassen, 1927, p. 11).

The final example is a special case and less common because it is a double house that has been transformed into two single houses. It is included because it demonstrates the flexibility of function and use-transformation within a seemingly rigid construction material. According to Mathiassen the houses in Fig. 18 originally had a single entrance way with an opening between the two houses, making it somewhat similar in its original state to the example in Fig. 14. The opening was blocked up at a later date, and a separate entrance way was added, necessitating a change in the sleeping platform position. This seems to indicate that the houses were inhabited by different families than those who built them, or that unrelated families decided to occupy the two houses and decided to completely separate them (Mathiassen, 1927, p. 308). All the preceding examples have been classified as belonging to the Thule period (Mathiassen, 1927, part II pp. 132-134).

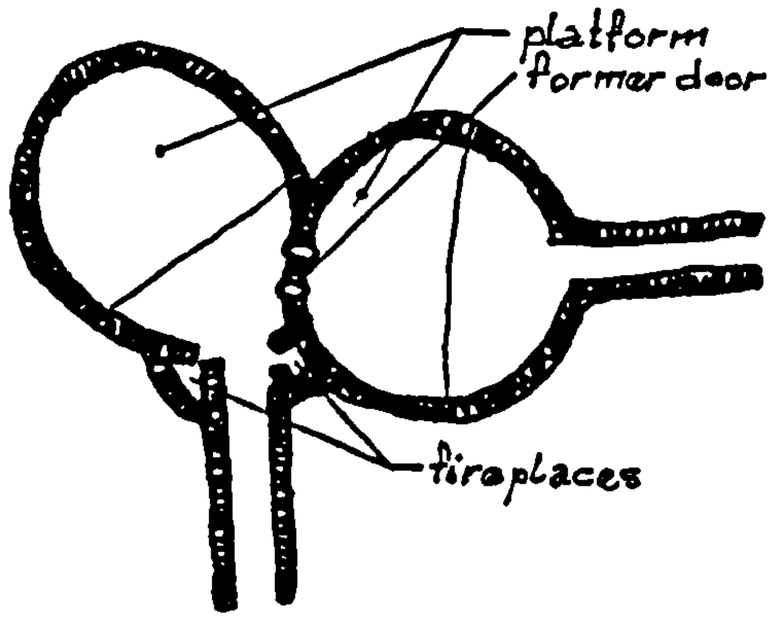


Fig. 18. Double stone house with separate rooms (Adapted from Mathiassen, 1927).

1.4.1.1.3 Triple Stone Houses

The literature perused seems to indicate that the triple house was the largest grouping found in stone houses. Larger groupings took the form of longhouses and were inhabited by as many as 5 families (Maxwell, 1980, p. 508), but stone longhouses were not so common, and their precise use and construction are not completely known. In the following examples, it will be seen that the triple house in most cases can be clearly identified as three dwelling units attached together to form this house type. This is quite unlike the longhouse, which from the exterior gives no indication of the number of dwellings contained therein, except that the length suggests that many dwellings are grouped together.

The first type of triple house is the "clover leaf" house mentioned by

Schledermann (1977, p. 244) and illustrated by Mathiassen in Fig. 19. Here the three houses are clearly discernable from the exterior, but the interior has one central floor space and a common entrance (Mathiassen, 1927, p. 234).

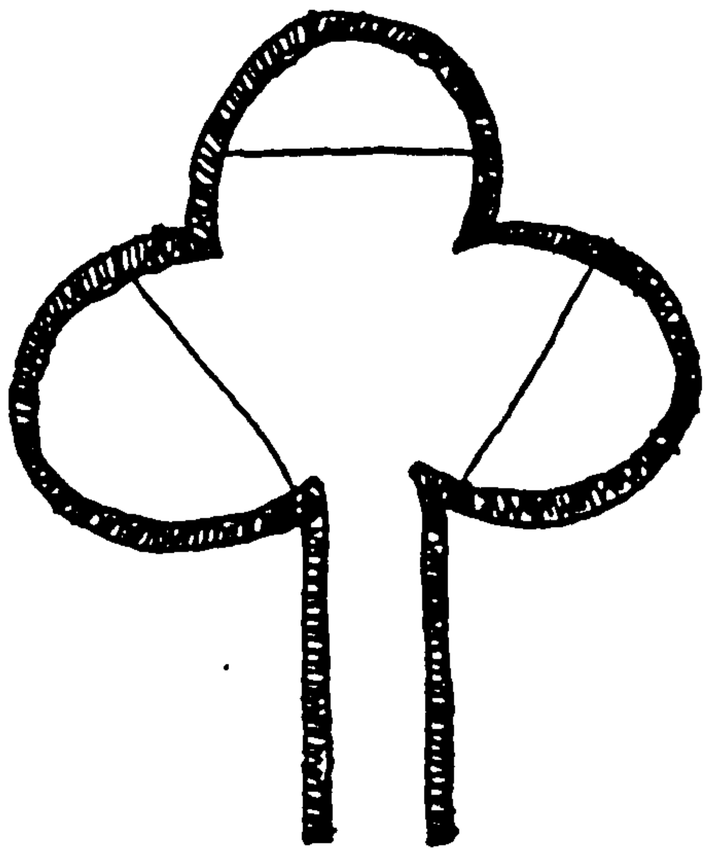


Fig. 19. Triple stone house with common central space (Mathiassen, 1927).

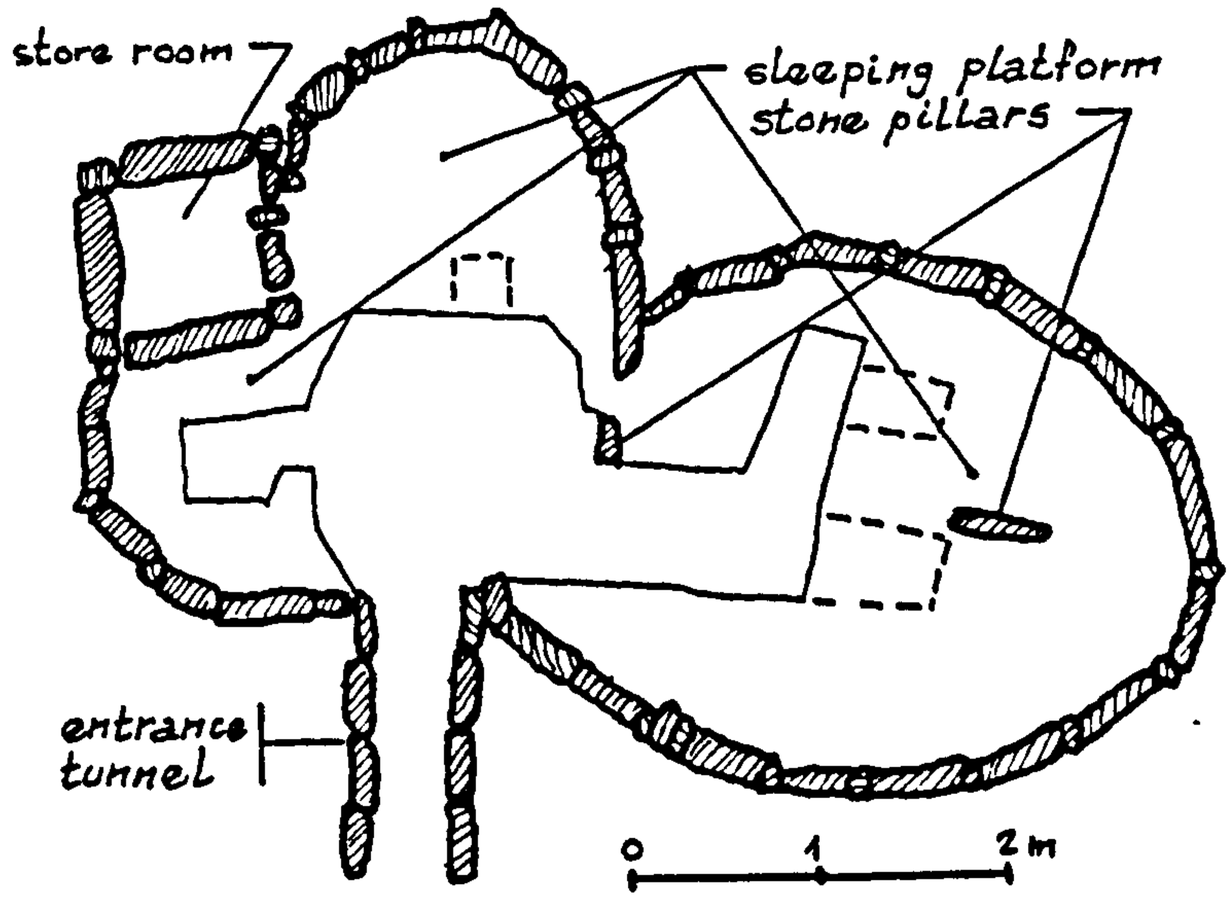


Fig. 20. Triple stone house with three unequal sleeping platforms (Mathiassen, 1927).

Fig. 20 shows a triple house with the three dwellings still clearly defined, with two smaller and one larger unit. This house has a stone storeroom separating the two small platforms, but retains a common central floor space and entrance.

The next example in Fig. 21 shows what could have been a single volume with two sleeping platforms to which was added an alcove containing a third platform. The three units share a common central floor area and entrance. By dividing the volume into two on the exterior, the alcove creates the visual effect of three semi-circular volumes joined together (Mathiassen, 1927, p. 12).

The last example is unusual because it seems to have been a double house to which was added a third house. See Fig. 22. However, the third house, although it has its own entrance tunnel has an opening from its central floor space to that of the double unit. The double unit has its own separate entrance tunnel giving the impression that it was built first and another relative or friend decided to build into the original unit (Mathiassen, 1927, p. 309).

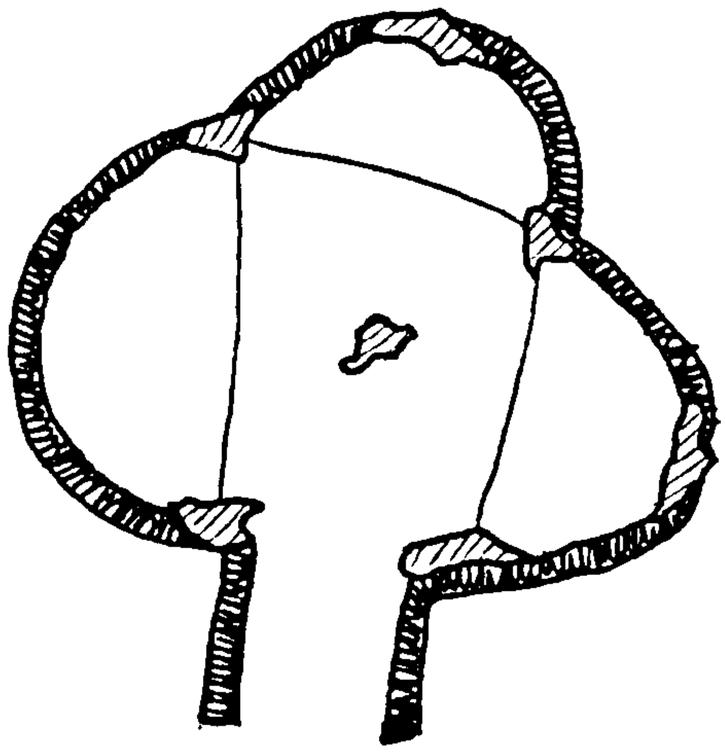


Fig. 21. Triple stone house with one central space (Mathiassen, 1927).

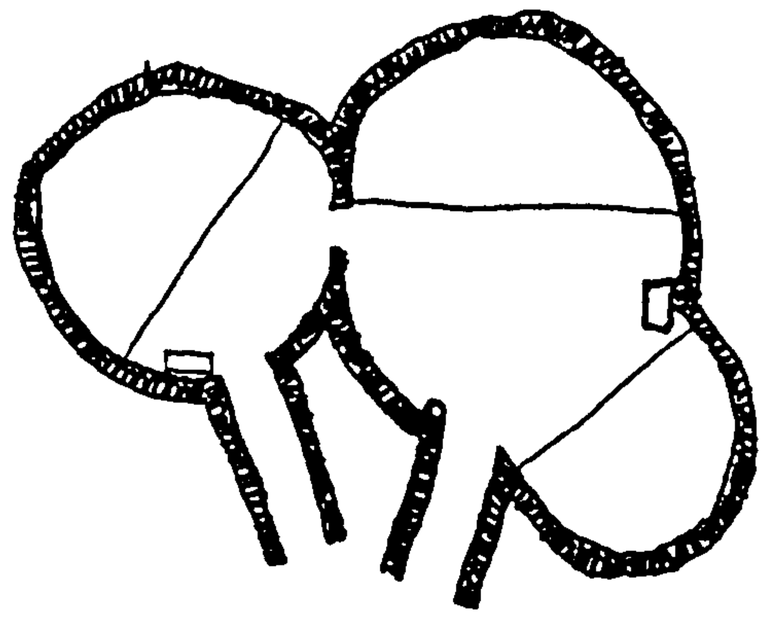


Fig. 22. Triple stone house with common central space for 2 houses and 1 separate central space (Mathissen, 1927).

1.4.1.1.4 Stone House Construction

Mathiassen describes the house in Fig. 20 in detail as it was the best preserved house he came across on Southampton Island. The two smaller platforms were separated by a raised storeroom, with the larger platform a little removed from the other two. The walls were constructed of a row of stone slabs placed vertically at various distances with horizontal slabs laid on top. Whale skulls were used in the walls which were covered with turf on the outside. The walls were often composed of whale vertebrae, walrus skulls and jaws, and pieces of whale jawbones. The stone sleeping platforms were supported on vertical slabs leaving spaces underneath the platform for storage. The floor was covered with stone slabs, and stone pillars supported a roof structure composed of whale jawbone, ribs and vertebrae, with caribou antlers serving as infill between the structural members. This was then covered with stone slabs and a thick layer of turf. The entrance tunnel and floor were made of stone measuring 1.6m long, 0.8m high, and 0.6m wide and covered with 20cm of turf. The storeroom was constructed entirely of stone and covered with 35cm of turf (Mathiassen, 1928, p. 228).

The structure just described was a permanent or winter dwelling, but at a later cultural stage Quarmat or autumn houses were built of similar materials, but less solidly. The Quarmat roof used the skins and poles of the summer tent. The walls were made of stone, earth and whale skulls with moss infill between the stones. The walls projected 80cm above the platform

which was covered by flat stones as was the entrance door. Over the door (1m wide by 0.5m high), was a whale rib which formed the upper frame of a window made of gut skin. Some of the "autumn" houses had snow roofs when sufficient snow of the proper consistency accumulated. The plan forms were similar to those of the snow houses and varied in volumetric form from the relatively flat or low sloping tent roofs to the dome shape of the snow roof (Mathiassen, 1928, pp. 136-137).

1.4.1.2 Sod Houses

Sod or turf houses existed in many areas of the Arctic, although they were not quite as common as the stone or semi-subterranean houses. Sod houses were especially common in Alaska, but examples have been found in Labrador and the central Canadian Arctic.

These houses were all above ground structures (Maxwell, 1980, p. 506) as were the majority of the stone houses. Their form was generally round, although some were rectangular or square. Wilkins (in Mathiassen, 1927, p. 141) describes a large village of 30 sod houses found in the western Arctic on one of Stefansson's expeditions. The houses were circular cone-like structures made of carefully cut sod placed around a framework of whale bones.

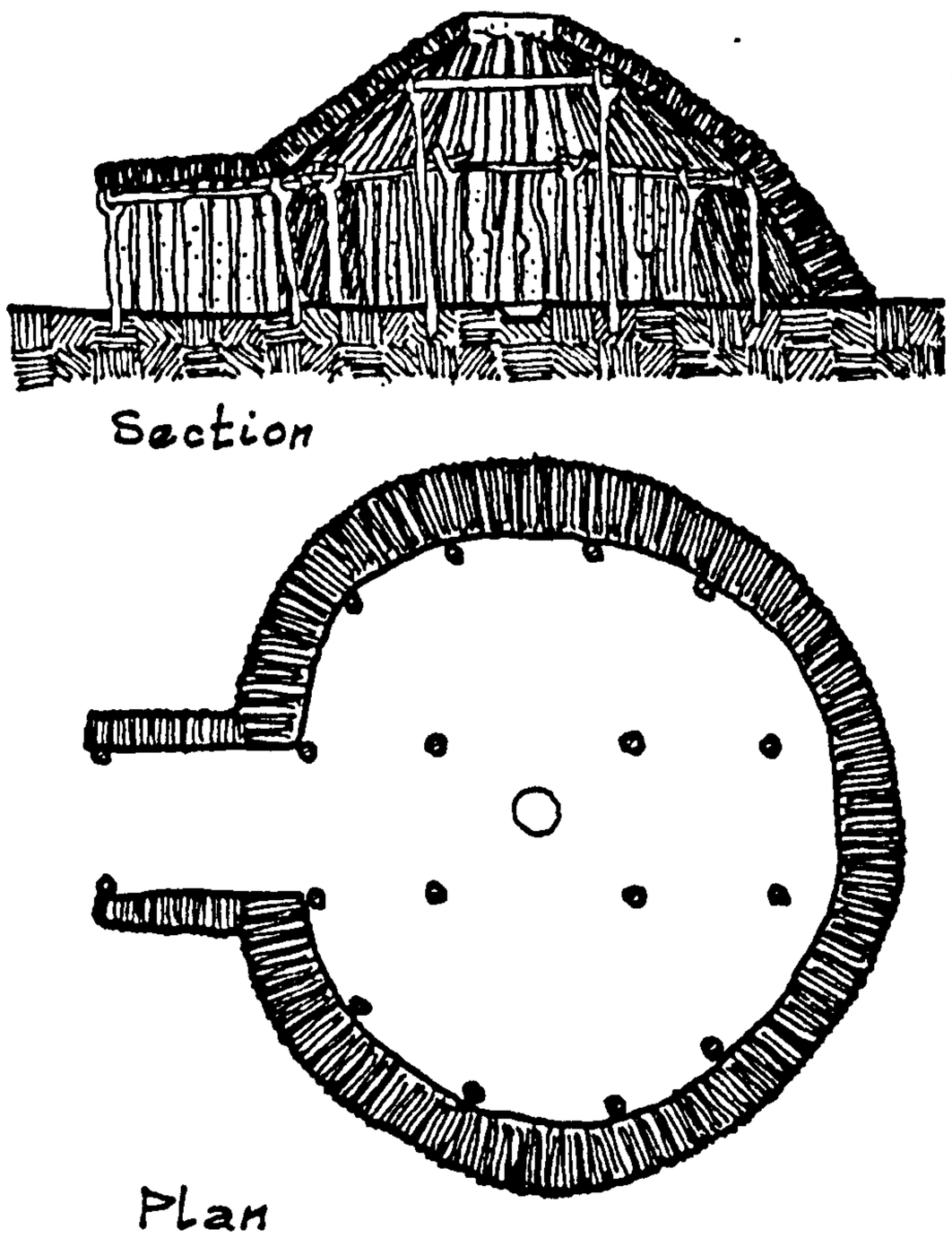


Fig. 23. Nunamiut sod house (Koerte, 1974).

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Koerte describes a circular sod house that bears a strong resemblance to the snow houses. This house, called the Nunamiut moss house and shown in Fig. 23 is constructed of a framework of forked poles acting as columns supporting horizontal poles. Upon this framework are attached small sticks which in turn support slabs of sod or moss. The entrance tunnel is shorter in comparison to that of the snow house, and the floor of the tunnel is not lower than the floor of the house, allowing the cold air to enter directly. The sod or moss blocks are cut into slabs approximately 8" (20cm) thick and are dried, making them an excellent insulation material (Koerte, 1974, p. 129).

Hutton describes sod houses that are more square or rectangular in floor plan, which was common in Labrador. These houses were built of sod or turf around a structure of stones and wood. A foundation wall of stone was built to support the wood beams and joists cut from trees found inland or from driftwood. Turf was used for the walls and roof. The single square room housed a variety of functions such as the family sleeping area, the heating and cooking zone, food and hunting equipment storage, and a place for newborn dogs. One corner contained a table upon which sat the stone



Fig. 24. Sod house showing entrance porch framework to support snow blocks (Hutton, 1912).

oil lamp for cooking, heating and light (sometimes a paraffin oil stove took its place) and another corner was "curtained or partitioned-off for a sleeping-place" (Hutton, 1912, pp. 308-311). See Fig. 24 for a sketch of this type of house in which we see the European influence on the wood window frames which were covered with seal intestines (later glass was used). In winter, long snow tunnels made of blocks of snow supported by a wood frame were added to prevent cold air from entering the house. See Fig. 25. Baillargeon also provides us with a drawing showing a sod house

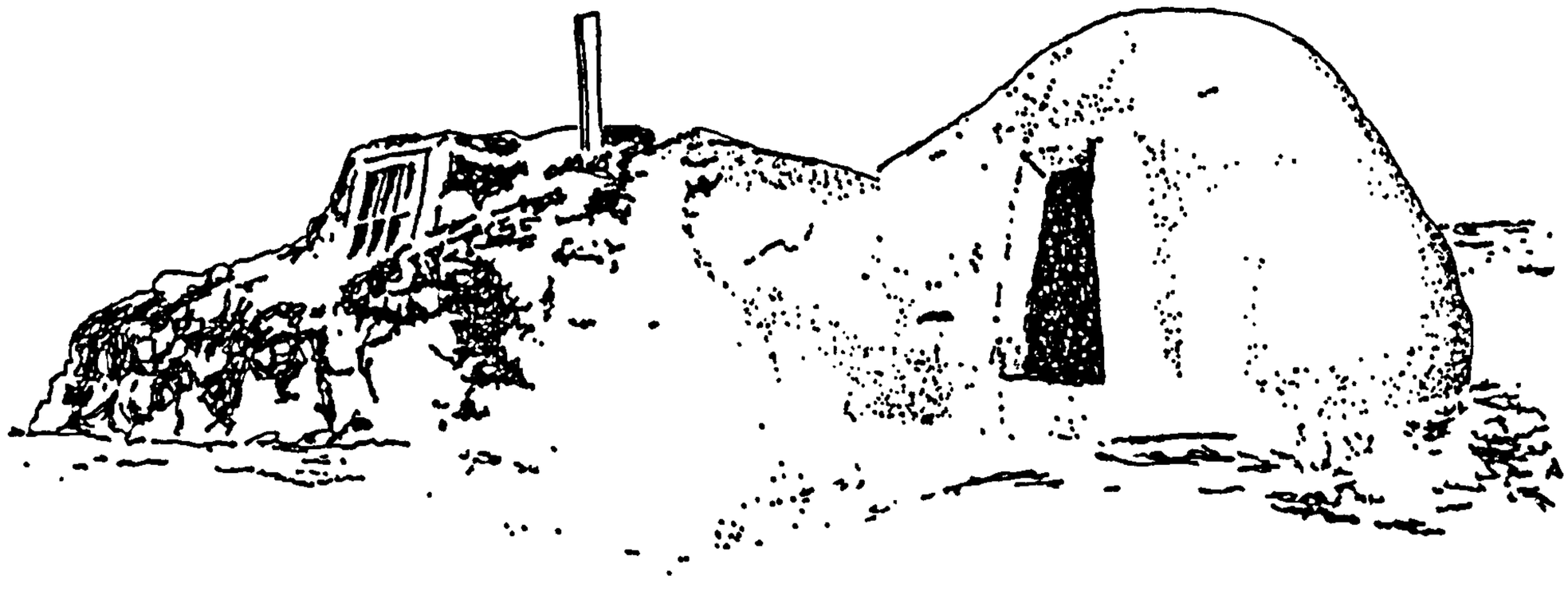


Fig. 25. Sod house with snow porch (Hutton, 1912).

with a snow porch or tunnel, built in Igloolik in the central Canadian Arctic (1979, p. 30). See Fig. 26.

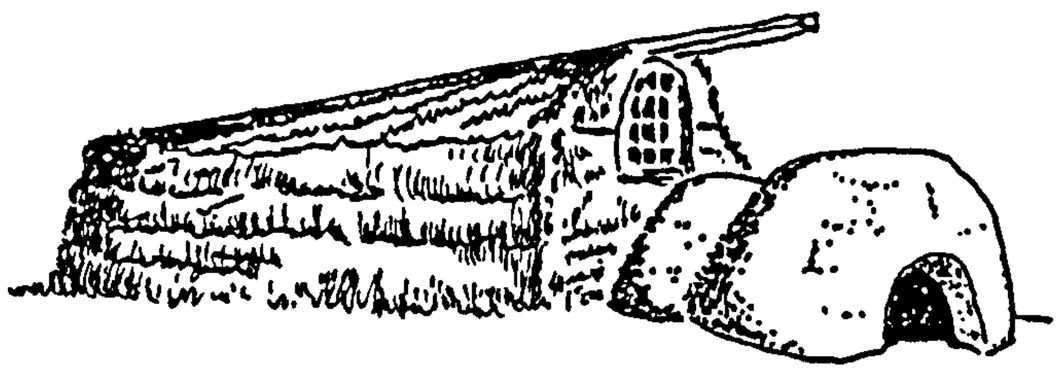
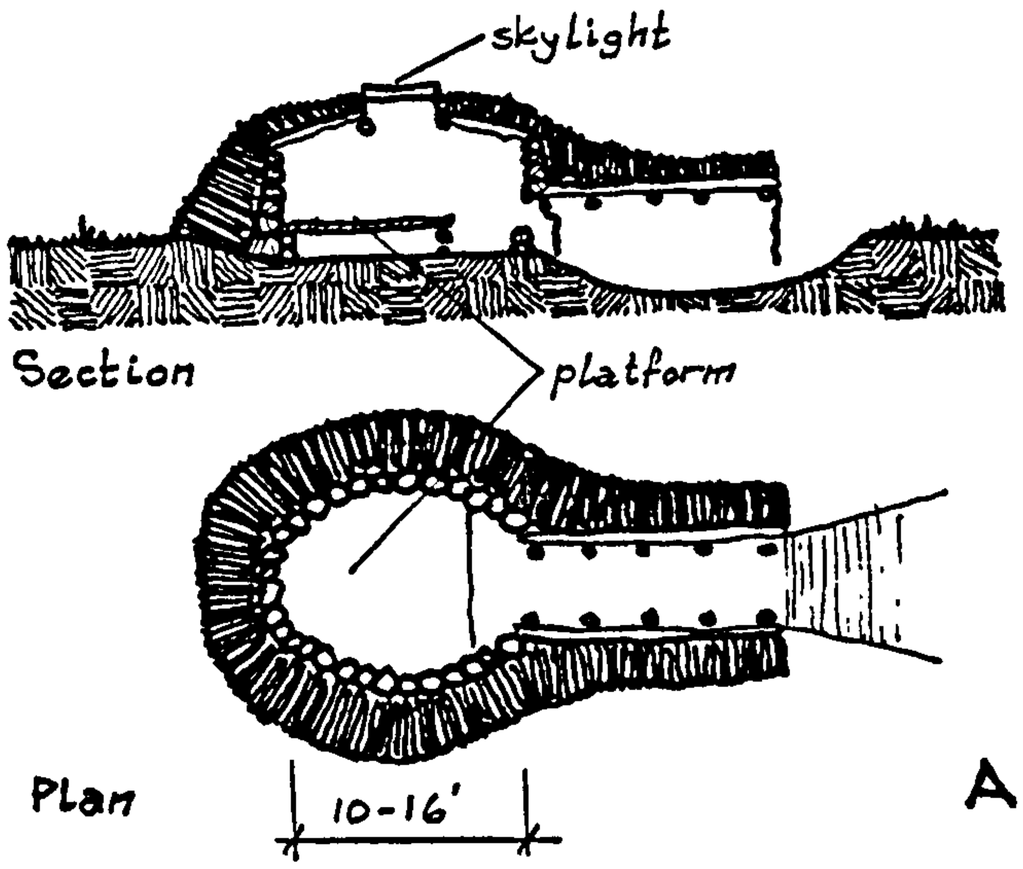
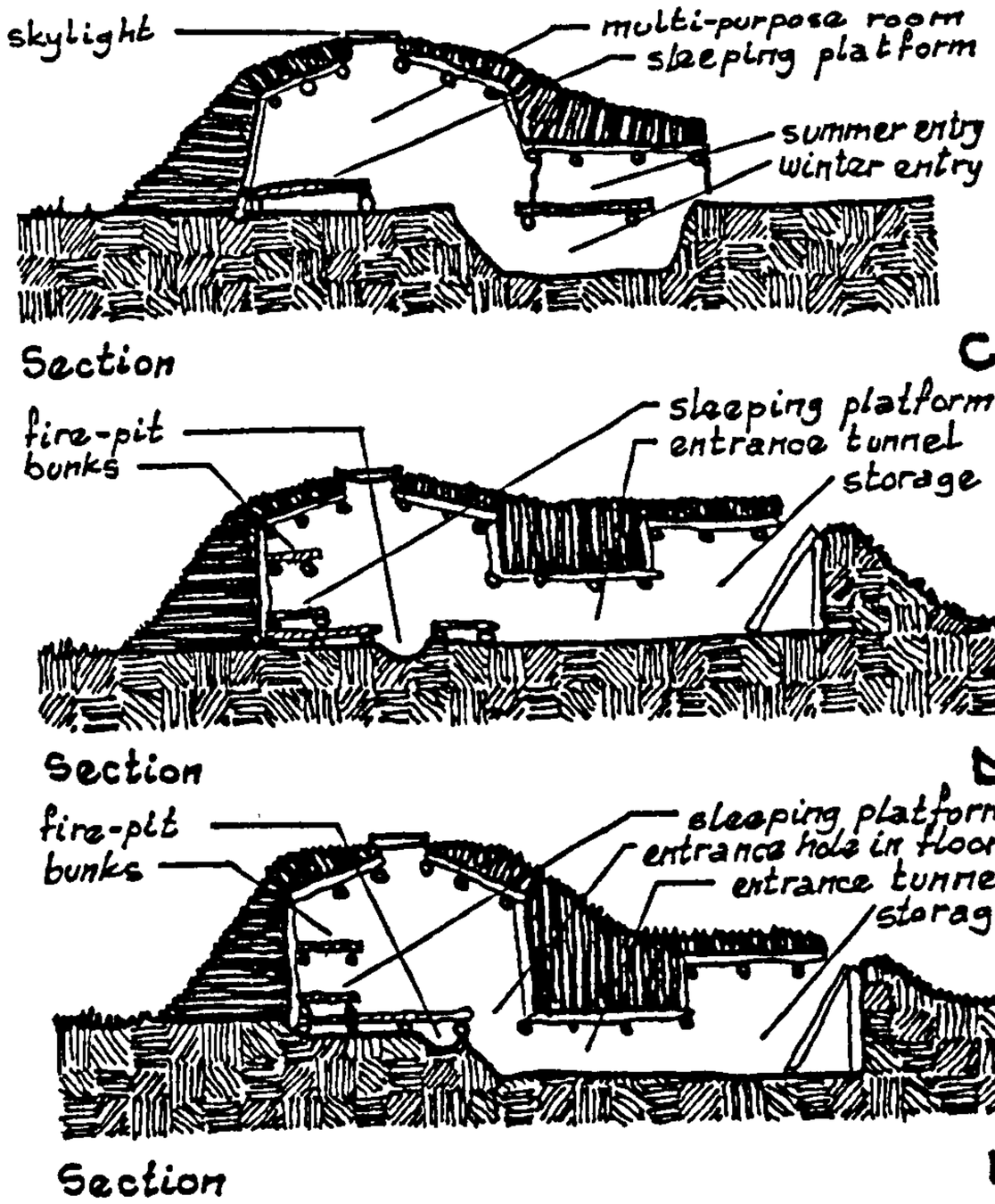


Fig. 26. Sod house with snow dome porch (Baillargeon, 1979).

Another variation of the sod house is the Alaskan type which is similar to the Nunamiut house in that it has a wood structure and could be either oval, elliptical or rectangular in plan, but with an entrance tunnel which was more important and efficient in keeping out cold air. See Fig. 27. The walls were made of stone or whalebone covered with sod if the floor plan was round, because of the limitations of the materials. The plan was rectangular if the walls were made of driftwood. The main multipurpose room varied in size from 10' to 14' (3m to 4.3m) long with a skylight that was placed either in the middle of the roof or above the penetration of the entrance tunnel into the main room. The sleeping platform was raised up off the ground on a wood structure and as shown in examples D and E, a bunk was suspended above. The entrance tunnel descends slightly in houses A and B, creating a cold air trap closing off the entrance from the outside by two skin flaps, one directly at the exterior, and the other at the entrance to the main room. In type C there are two entrances, one for summer which leads directly into the main room at the same level as the exterior, and another





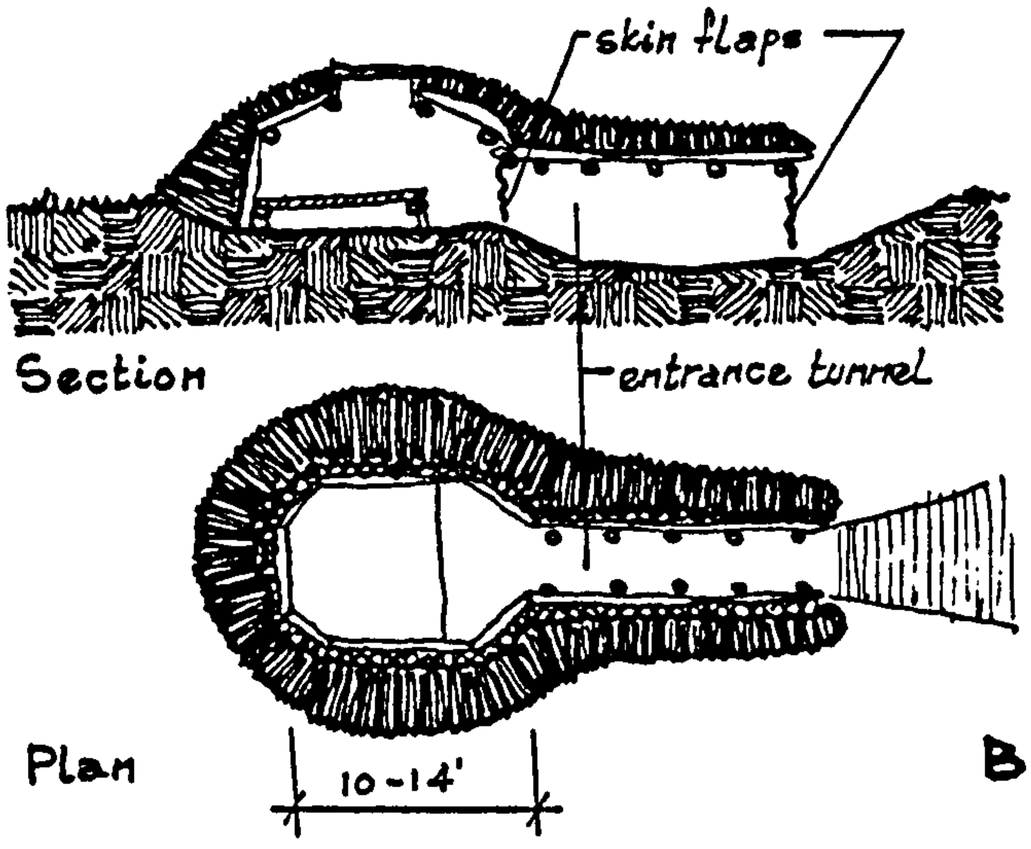


Fig. 27. Traditional Alaskan sod houses (Jorgensen, 1968).

for the winter situated under the floor of the summer entrance, penetrating the main room from below. In type D one enters the tunnel from above, and the tunnel floor is on the same level as the earth floor of the main room. Type E is a variation of type D in that the tunnel floor is below the level of the floor of the main room. According to Jorgensen (1968 (a) p. 9) the sod houses became very damp in spring forcing the people to move to tents. The newer sod houses are slightly modified by the use of ordinary windows in the roof and walls, and by the enlargement of the entrance and storage area.

In general, there is no evidence to indicate the existence of multiple family houses in this category in contrast to the stone, subterranean and snow house types.

Stefansson also describes a sod house which is very simple, consisting of a structure of two vertical posts 20' (6.1m) apart and 9' (2.7m) high with a horizontal ridge pole on top. The roof load was carried on walls that were stabilized by sloping them inwards (1913, p. 346). The thickness of the walls was such that they retained the heat and prevented air infiltration. The walls were supported by a wood framework similar to the previous examples. The long entrance tunnel was open all winter long providing constant ventilation as the air escaped the house through the ventilation hole in the roof. Two or three seal oil lamps were used to keep the interior temperature between 60°F (15.5°C) and 70°F (21.1°C), 24 hours a day throughout the winter (Stefansson,, 1913, p. 86).

1.4.1.3 Semi-Subterranean Houses

The semi-subterranean houses, as the name implies, were set into the earth. Compare Fig. 28, the plan and sections of a semi-subterranean house; with Fig. 16, a plan and wall section of a stone house; and Figs. 23 and 27, plans and sections of sod houses.

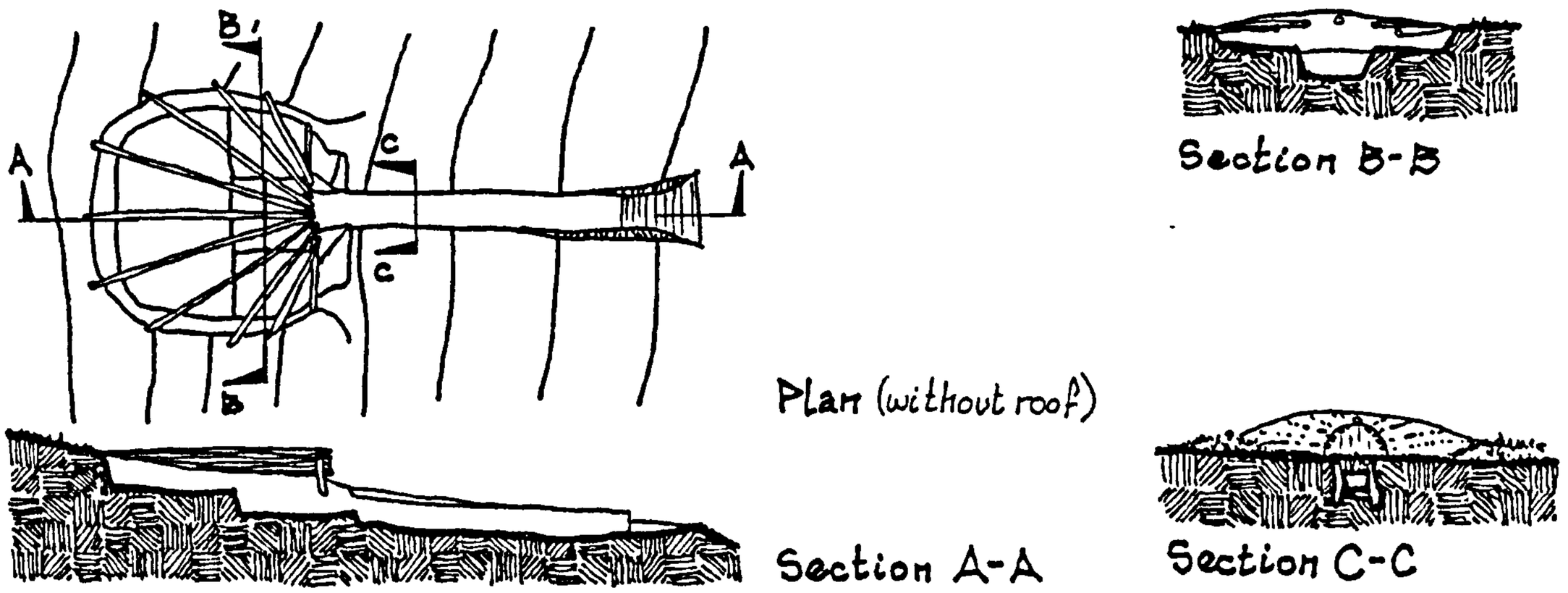


Fig. 28. Semi-subterranean house (Boas, 1974).

Mathiasson classifies as semi-subterranean all houses that have any part of their floor below grade (1927, Part II, 132-134), regardless of their wall structure. This author classifies semi-subterranean houses as those that are dug out of a hill-side or have their floors sunk substantially below ground level.

1.4.1.3.1 Single Semi-Subterranean Houses

Plumet and Badgley's work in Arctic Québec has turned up some interesting Dorset period semi-subterranean houses that had been built in five phases representing different historical periods. These five phases have been found in five superimposed layers of earth (see Plumet and Badgley, 1980; Julien, 1980; and Badgley, 1980). See Fig. 29 for an axonometric section through the site showing the dates corresponding to different layers (Plumet and Badgley, 1980, p. 550). Badgley notes that all of the 9 houses excavated were single family households and dates the second phase of their occupation from 140 to 570 A.D. according to radiocarbon samples (1980, p. 577-582). Dates could not be determined for phases 1 and 3, but phases 4 and 5 were dated from 1120 A.D. to the end of the 15th century (Badgley, 1980, p. 584). See Fig. 30 for a drawing of phase 4, the example which showed the most complete habitation features.

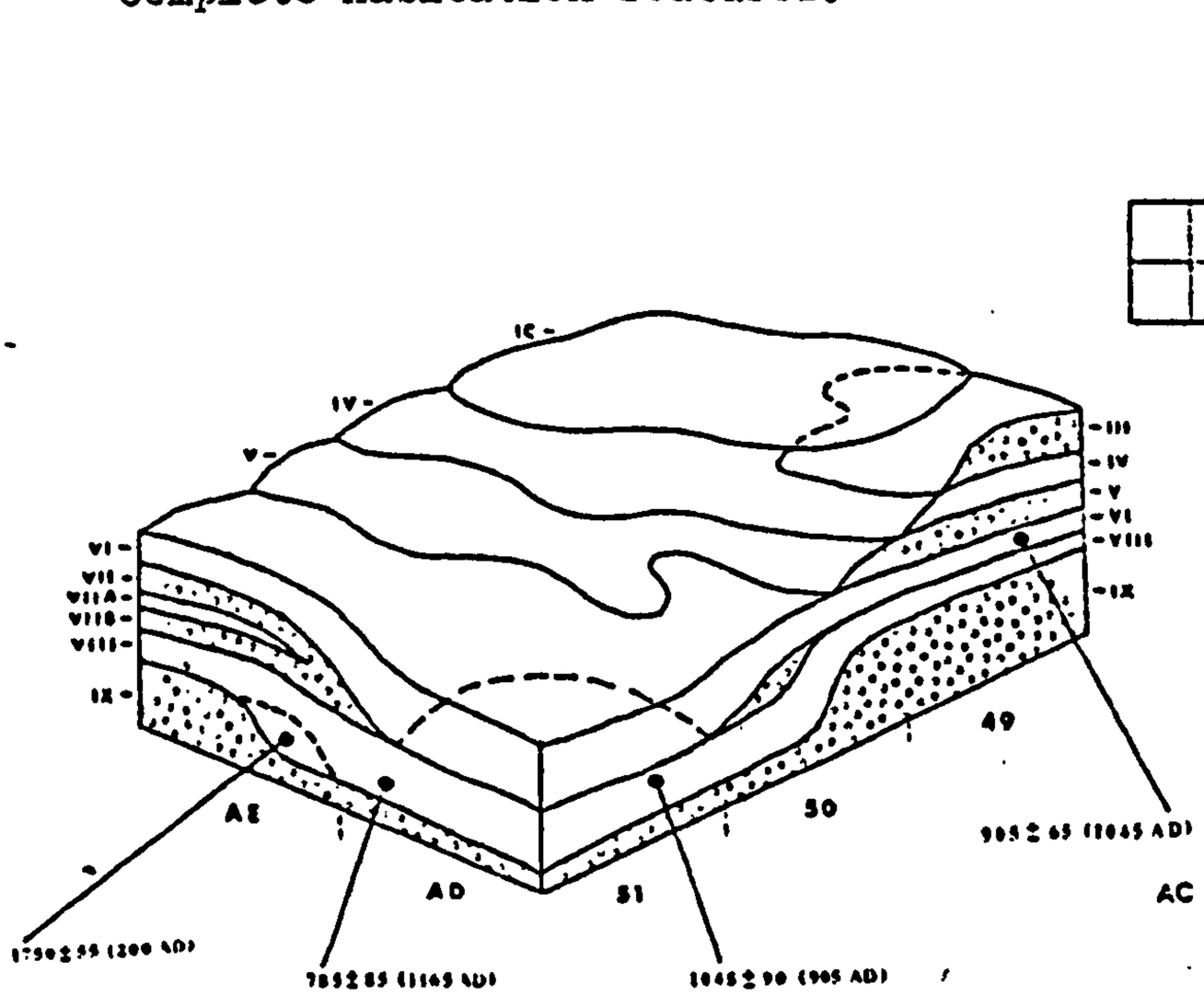


Fig. 29. Axonometric section through archeological site showing layers of housing occupation (Plumet and Badgley, 1980).

Fig. 30. Plans of semi-subterranean houses at phase 4 (Badgley, 1980).

These houses varied from deep to shallow earth depressions with vertical stone slabs and/or blocks on the perimeter. The house interiors were characterized by stone hearths, "...slab-lined "boxes" and circular or oval storage pits" (Badgley, 1980, p. 574). As can be seen from Fig. 30, the houses were

generally oval or square in form.

Fitzhugh notes that the shallow semi-subterranean houses first emerge in the Early Dorset culture. The Late Dorset houses are shallow as well, but have strongly defined axial pavements and have no entrance tunnel. Other evidence suggests that these houses were not permanent residences, but rather used as autumn and early-winter dwellings before moving to snowhouses (1980, pp. 599-600). Cox and Spiess support this hypothesis, noting that semi-subterranean were built on the inner islands to provide protection from autumn north-west gales and access to good seal hunting. In winter they built snow houses on the outer islands to take advantage of the seal and walrus hunting at the ice edge (1980, p. 660). In summer they would move once again to the inner fjord islands where there was open-water seal hunting, plentiful fish and access to island caribou. There is speculation that some Inuit built semi-subterranean houses on the outer islands as well as the inner fjords, so that they might have inhabited two different semi-subterranean houses, changing them with the seasons (Cox and Spiess, 1980, p. 665).

Mathiassen notes that semi-subterranean houses were found in the same area as stone houses (northern Baffin Island), indicating that the same region was inhabited by successive cultures using different construction techniques (1927, p. 136). Sabo and Jacobs show the changes in semi-subterranean house

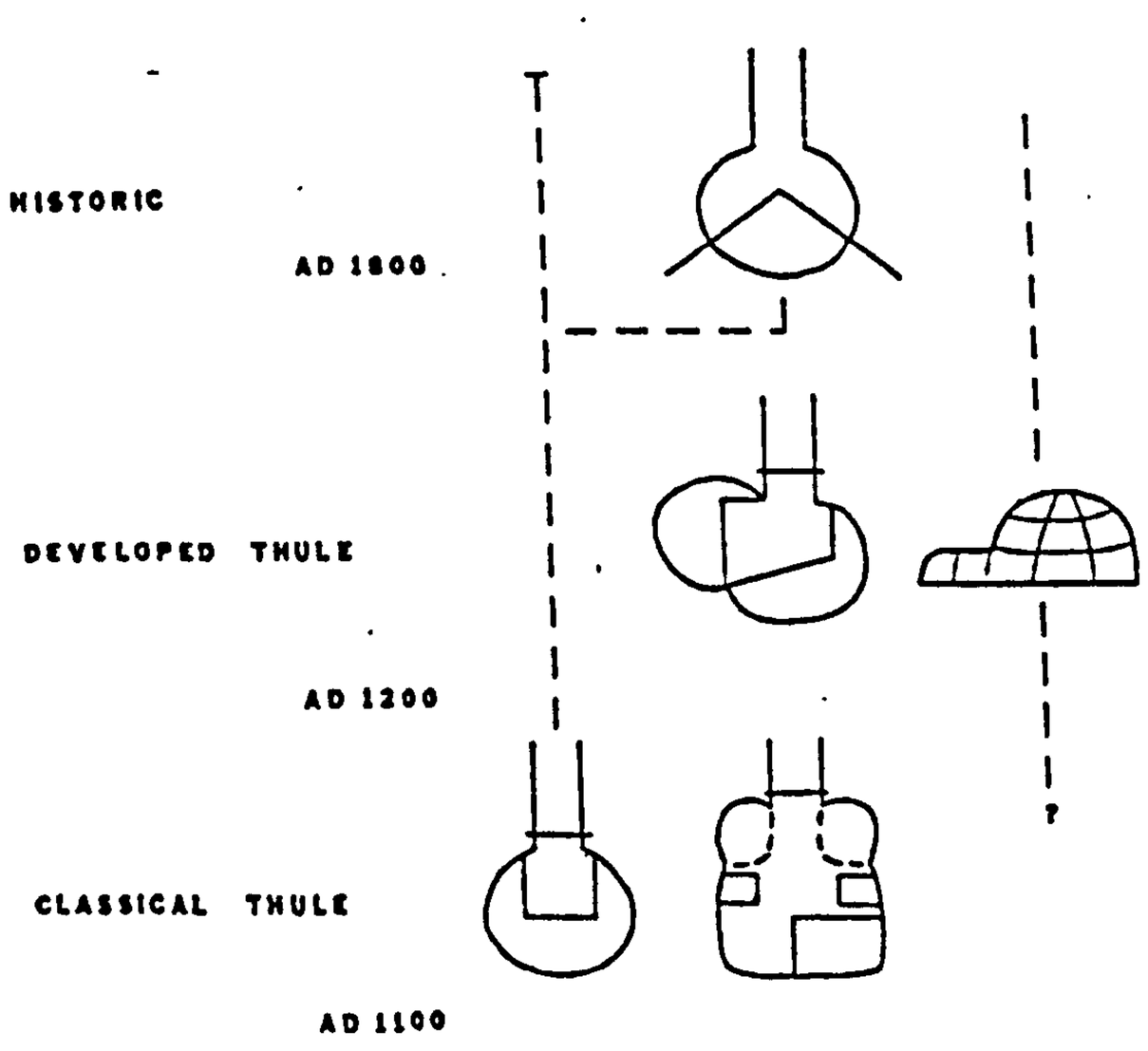


Fig. 31. Evolution of semi-subterranean and snow houses over cultural phases (^ indicates tent covered qarmat, Sabo and Jacobs, 1980).

plans during the development of the Thule culture from the classical to the Historic period (1980, p. 493). See Fig. 31. One can see from the drawing that the semi-subterranean house must have been used during the autumn and spring while the snow house was used during the winter. The semi-subterranean house evolved from a single space with two kitchen alcoves in 1100 A.D., to a double space in 1200 A.D. and eventually to the Qarmat in 1800 A.D. During the Classical Thule period, the semi-subterranean house was replaced by the snow house as a winter residence, and the Qarmat (snow house with tent roof), supplanted it as the autumn residence as well.

We have seen that the snow house and the semi-subterranean house often were used at the same time, but the latter was eventually phased out of use altogether. Mathiassen also noted this transition from semi-subterranean to snow houses (1927, pp. 133-134). This shift of dwelling type corresponds, according to Sabo and Jacobs, to a general cooling of the climate resulting in the earlier formation of landfast sea ice, requiring the Inuit to move out onto the sea ice in order to be closer to food resources. The colder more severe weather resulted in longer periods of snow cover, rendering the food for caribou less accessible and thereby causing a decrease in the caribou population. This required a shift in the type of food the Inuit hunted, and they thereby concentrated on sea mammals (Sabo and Jacobs, 1980, p. 502).

As Mathiassen noted, the semi-subterranean house in its circular form was common to the Thule Inuit of the central Arctic and was not thought to exist in Alaska where the rectangular or square form was prevalent. However, he mentions that Nelson found "...15 ruins, small and roughly circular, with a short passageway leading into them, the entire structure having been partly underground" (1927, Part II, p. 152), thus demonstrating the existence of this form throughout the North American arctic.

Boas gives a good description of the semi-subterranean house which was often excavated out of the side of a hill as in Fig. 28. The walls sometimes had slabs of stones to raise them above the ground (1974, p. 548), but as Mathiassen remarks, whale bones, especially whale skulls, have been a common material for the wall construction. He also notes that the roof structure was made of whale jaw bones and ribs, or wood or stones depending on which materials were available. In some cases the roofs may have been made of

skin if materials for a permanent roof were lacking (Mathiassen, 1927, p. 132). Boas describes the entrance tunnel as approximately 15' to 20' (4.6 - 6.1m) long sloping upward towards the main room. The last 4' (1.2m) of the entrance was covered with a large slab of stone which was the same height as the sleeping platform. The floor of the main room was 8" (20cm) higher than the tunnel floor to prevent the penetration of cold air. The sleeping platform occupied the rear half of the room, with spaces for the cooking lamp on either side of the central floor area directly in front of the entrance way.

In the examples shown in Figs. 28 and 32, the roof was formed by tying a number of poles to the whale rib which formed the arch at the front of the house. The space in the arch of the rib was covered with sealgut to serve as a window. The roof poles rest on the walls at the back and sides of the house and were covered with a layer of sealskin tied to the whale rib and weighted by rocks on top of the wall. Moss was laid on this skin which was in turn covered with another layer of skins fastened in the same way as the first layer (Boas, 1974, p. 548).

Fig. 32 illustrates a semi-subterranean house that has only the central floor area excavated while the sleeping platform is at ground level. In this case, because the wall does not exist, the roof, in a manner of speaking becomes wall and roof. The roof is made of whale ribs placed so that their ends cross in a series of arches upon which are attached poles which carry the double-layered roof described in the preceding example (Boas, 1974, p. 550).

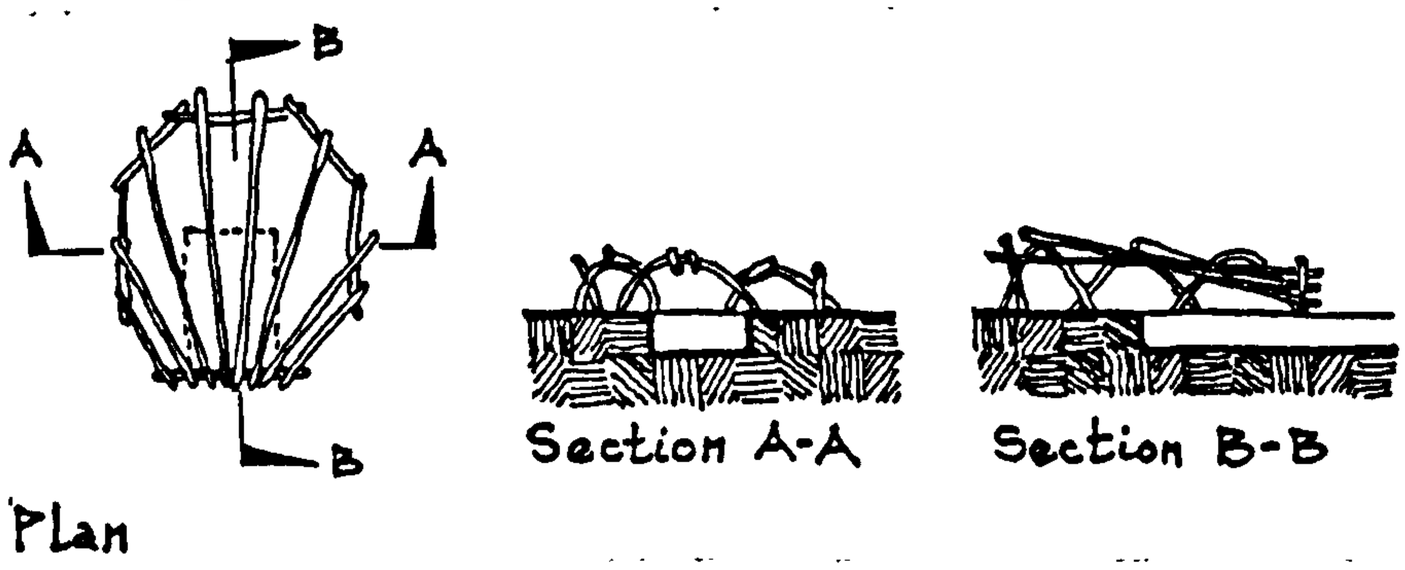


Fig. 32. Semi-subterranean house (Boas, 1974).

A modified cloverleaf form is shown in Fig. 33. This Greenland semi-subterranean house differs from the Central Inuit houses by its shape which is broad at the entrance to the house and narrow at the rear. The polar Inuit, unable to easily procure whalebone or timber were obliged to make the roof entirely of stone. In order to cantilever the stones to support the

roof, the span over the platform area was reduced (Mathiassen, 1927, Part II, pp. 147-148). (Note: Although the roof is entirely made of stone, the author considers this house semi-subterranean because it is dug into a hill and the depression in the earth forms the walls.)

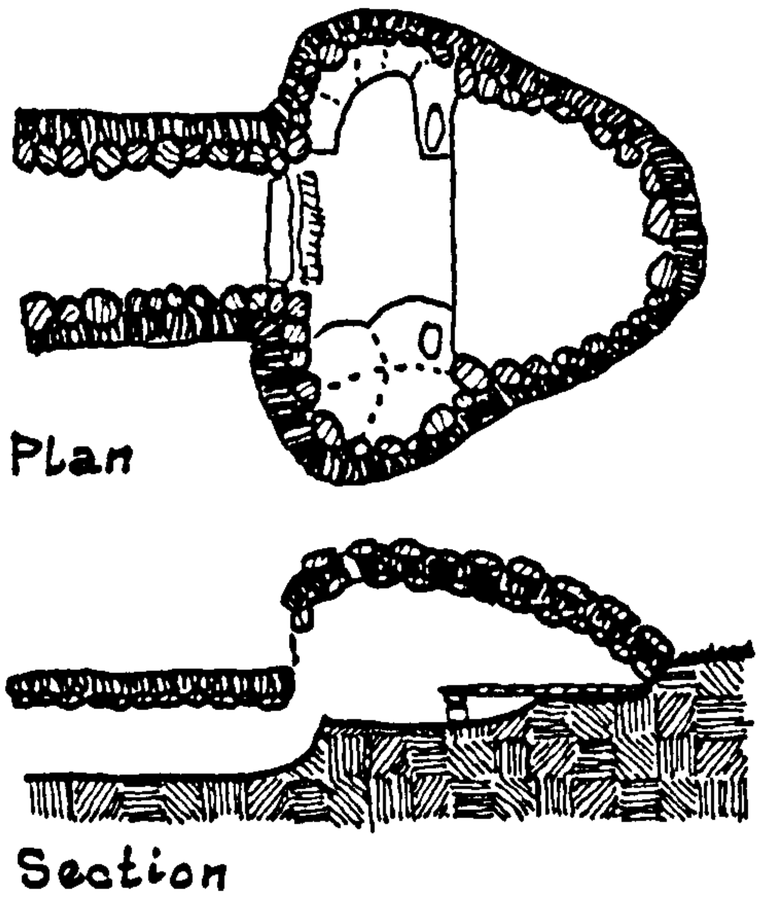


Fig. 33. Polar Eskimo semi-subterranean house (Mathiassen, 1927).

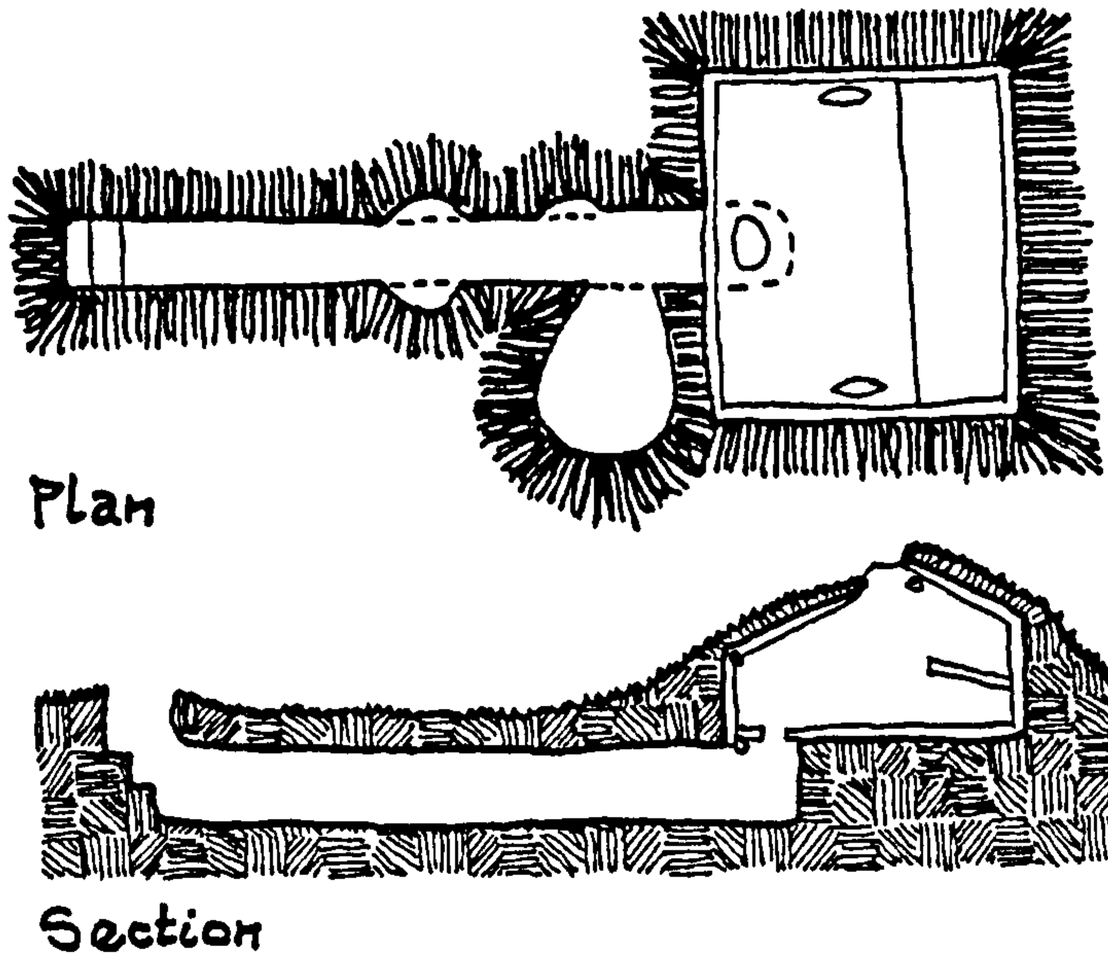


Fig. 34. Alaskan Eskimo semi-subterranean house (Mathiassen, 1927).

Finally, the square form of the Alaskan semi-subterranean house is illustrated in Fig. 34. This house resembles the sod houses in Fig. 27 in construction technique and in shape, with the difference that the entrance tunnel is completely below grade, while the house itself is slightly above-ground built of wood and covered with earth and turf. The rectangular living space is 12' to 14' (3.7 - 4.3m) wide by 8' to 10' (2.4 x 3.1m) deep and is reached by an underground tunnel 25' (7.6m) long penetrating into the living space by means of a hole in the floor. In the tunnel there are little storage alcoves and a larger alcove used for cooking. In the living area the sleeping platform is at the back of the room with the cooking lamps nearer the front. The exterior plan is similar to the majority of the Inuit houses, except that the sleeping platform is suspended above the floor. In the roof of the front part of the living area, a window is usually placed much as they are in snow houses (Mathiassen, 1927, Part II, pp. 152-153).

1.4.1.3.2 Double Semi-Subterranean Houses

There were only two examples of a double house to be found in the literature consulted where the form of the house expresses two dwellings. One presented by Steensby is shown in Fig. 35. In the drawing two distinct platforms are discernable. These are separated by a wall with cooking lamp spaces on a central shelf projecting between the two sleeping platforms. This plan would be similar to a longhouse sleeping platform if the dividing wall was removed. Steensby suggests that if wood were available they would have built a "...longhouse with a single long main platform on which each family had its "berth" or division separated at the sides by a hanging skin" (Steensby in Schledermann, 1976, p. 33).

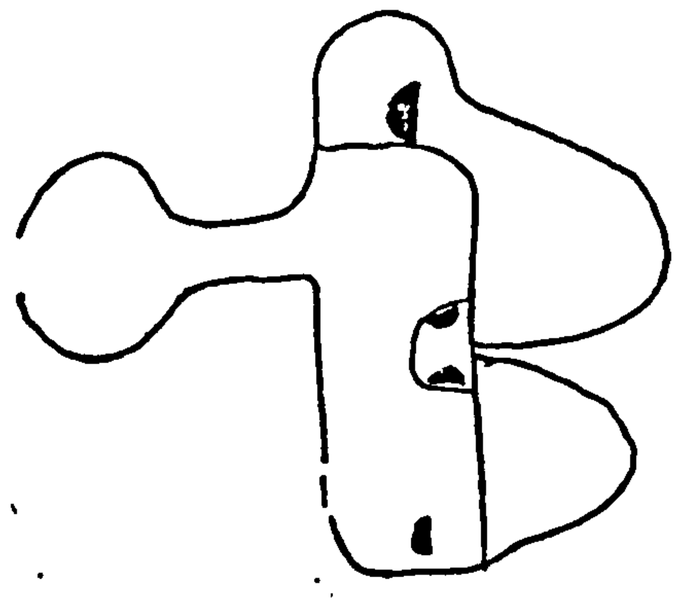


Fig. 35. Sketch of a double semi-subterranean house (Schledermann, 1976).

The second example is found in the Sabo and Jacobs drawing in Fig. 31 where the two sleeping platforms form 2 distinct volumes (1980, p. 493).

1.4.1.3.3 Triple Semi-Subterranean House

The only example found of the three-family house is the one shown in Fig. 36. This is a minor variation of the house in Fig. 28 in that the whale rib arch serving as a support for the roof poles and window is advanced to a position directly above the entry from the entrance tunnel to the main room. A side room has been added for storage somewhat resembling the kitchen alcoves of the stone houses. See Figs. 10 and 13. The roof covering in this model was extended by sewing an additional skin to the main-roof skins in order to cover the storage space (Boas, 1974, p. 549). Although this is a house for three families, it is a single-dwelling space, and therefore, except in size and storage alcove, is similar to the single family house.

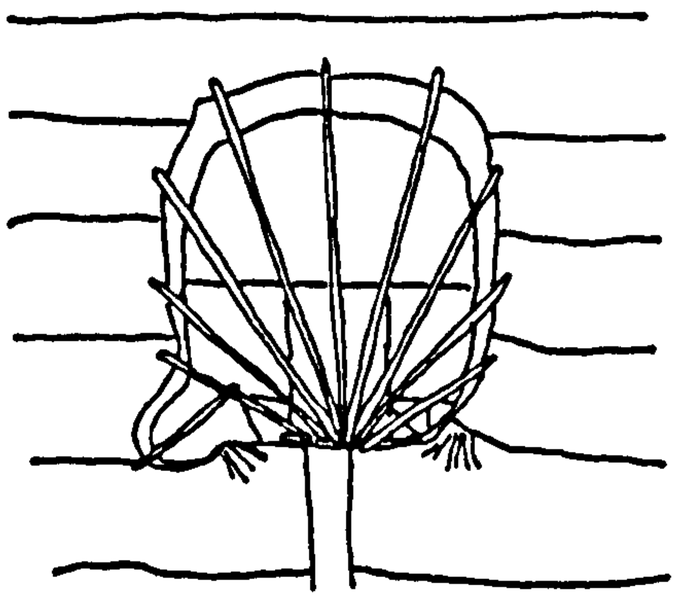


Fig. 36. Semi-subterranean house, 3 families (Boas, 1974).

Schledermann (1977, p. 244), Mathiassen (1927, p. 132) and Thalbitzer (1979, pp. 360, 363, 364) mention a pear-shaped or cloverleaf-shaped house which was made up of 3 sleeping platforms, the largest of which was in the middle and almost separated by dividing walls from the smaller platforms on either side of the entrance (Thalbitzer, 1979, p. 676). No sketches or photos could be found of this type, but from the description it is likely that it would resemble the houses in Figs. 19 or 21.

Thalbitzer also mentions that in some cases small longhouses were inhabited by as few as one, two or three families (1979, p. 353) demonstrating the existence of another house form for both double and triple houses. The longhouses were generally rectangular as will be seen from the description in the following section.

1.4.1.3.4 Longhouse Semi-Subterranean Houses

The longhouse is a communal-type dwelling which Schledermann states could contain 40 people and was known to house on the average 20 people (1976, pp. 27, 29). The houses found by Schledermann in northern Labrador were built of stone, sod, whalebone and driftwood, and were rectangular in shape.

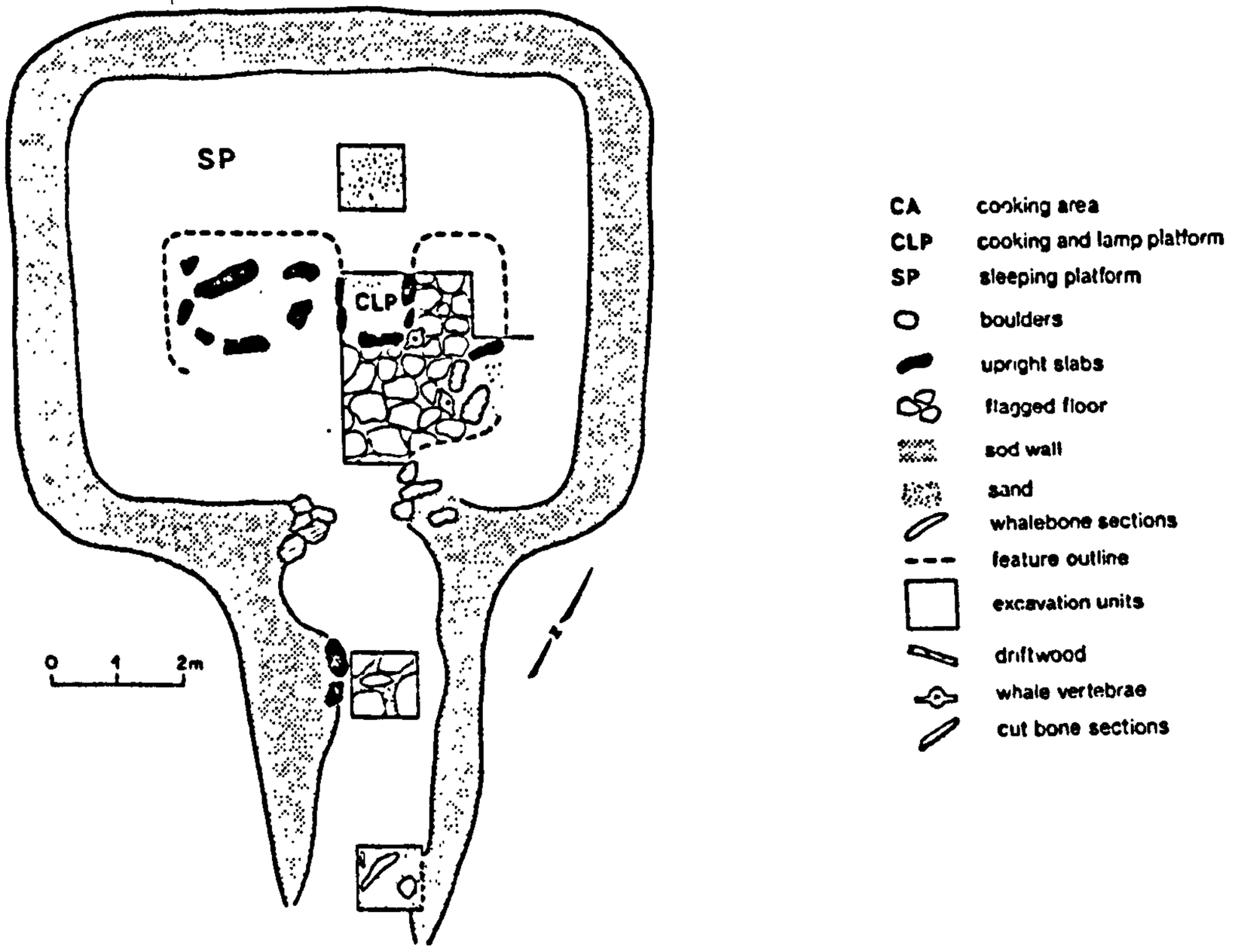


Fig. 37. Square semi-subterranean communal or longhouse (Schledermann, 1976).

Figs. 37 and 38 show two houses roughly square in shape and Fig. 39 illustrates a large rectangular house. Most of these dwellings are, however, longer in the direction perpendicular to the entrance tunnel. In Fig. 39 the sleeping platform runs the length of the rear wall, while in Figs. 37 and 38 the sleeping platform stretches around the perimeter terminating on either side of the entry.

Schledermann suggests that these houses were established in Labrador, approximately in 1700 and that it was a form that replaced the smaller, semi-rounded houses (1976, pp. 31,32). Other researchers mentioned by Schledermann indicate that communal houses existed in Alaska among the Choris people as early as 1000 B.C. and that the Dorset people in the Ungava area of northern Québec also used communal structures indicating the existence of much earlier precedents (1976, p. 33). He also suggests that evidence indicates that it was a form imported from Greenland.

Schledermann proposes three main factors for the development of the Labrador communal houses:

1) "the tendency of the Thule-culture Eskimos to establish multi-family households;"
2) "the availability of different kinds of construction material such as driftwood, which is found in greater quantity in the near sub-arctic regions;"
3) "the deteriorating climatic conditions during the Neo-Boreal period, which caused a reduction in the hunting of whales, which in turn upset the subsistence base of the Eskimo community." (1976, p. 35).

(For the importance of whales in the Inuit economy see McCartney, 1980, pages 518, 519, 530, 531.)

The third factor is important because by living communally, the food which was in short supply would be divided more equally amongst all inhabitants of the house and it was also a means of using more efficiently the scarce supply of seal oil for heating. (There is a parallel to draw in today's situation with the dwindling oil supply and its dramatically increased economic value.)

It has been proposed that there was a transition from the skin-covered Quarmat sod-wall house to a cloverleaf-shaped communal house between 1650 and 1700 due to a major decline in whales (Schledermann, 1976, p. 36). This is

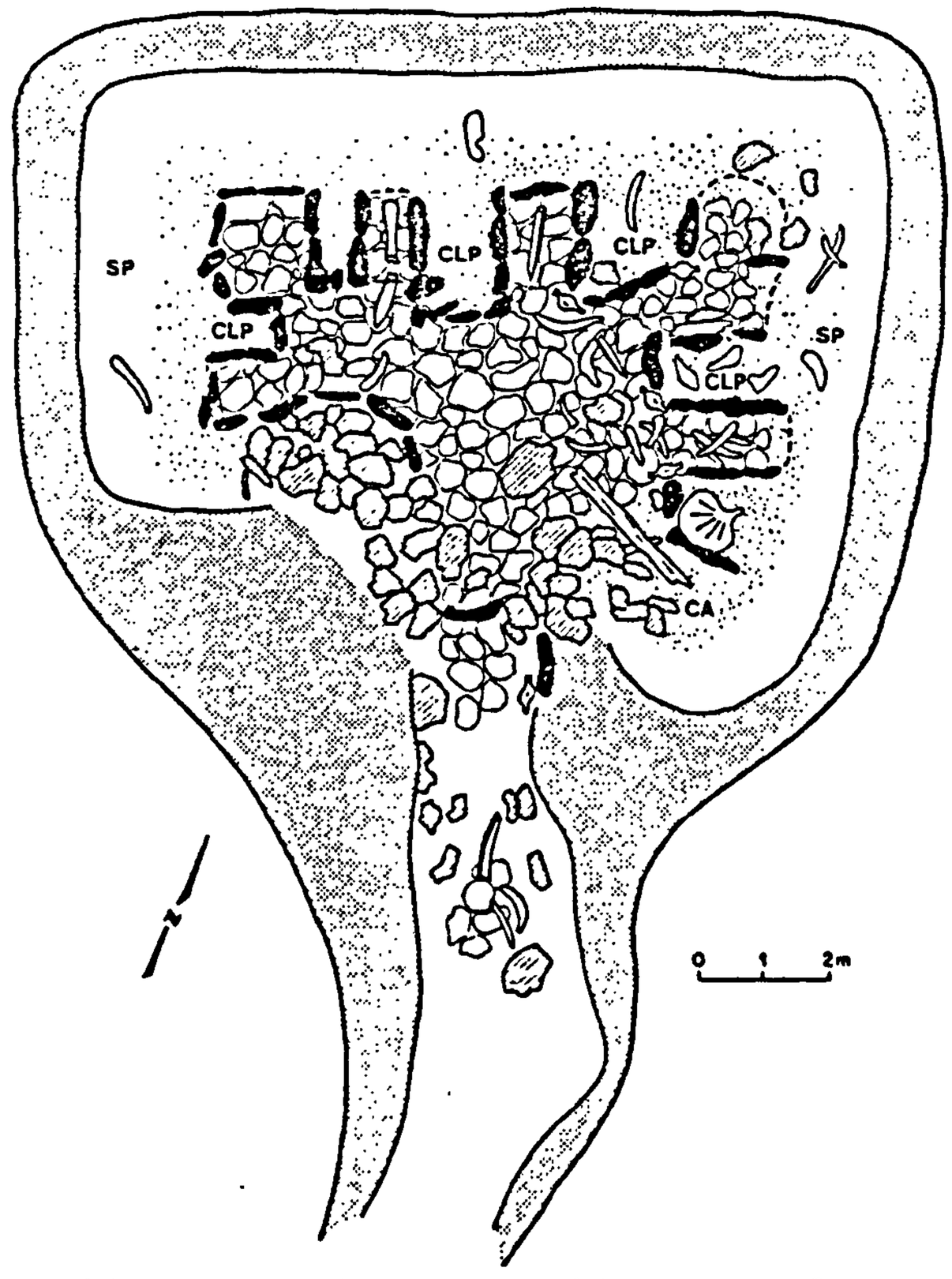


Fig. 38. Rectangular semi-subterranean longhouse (Schledermann, 1976).

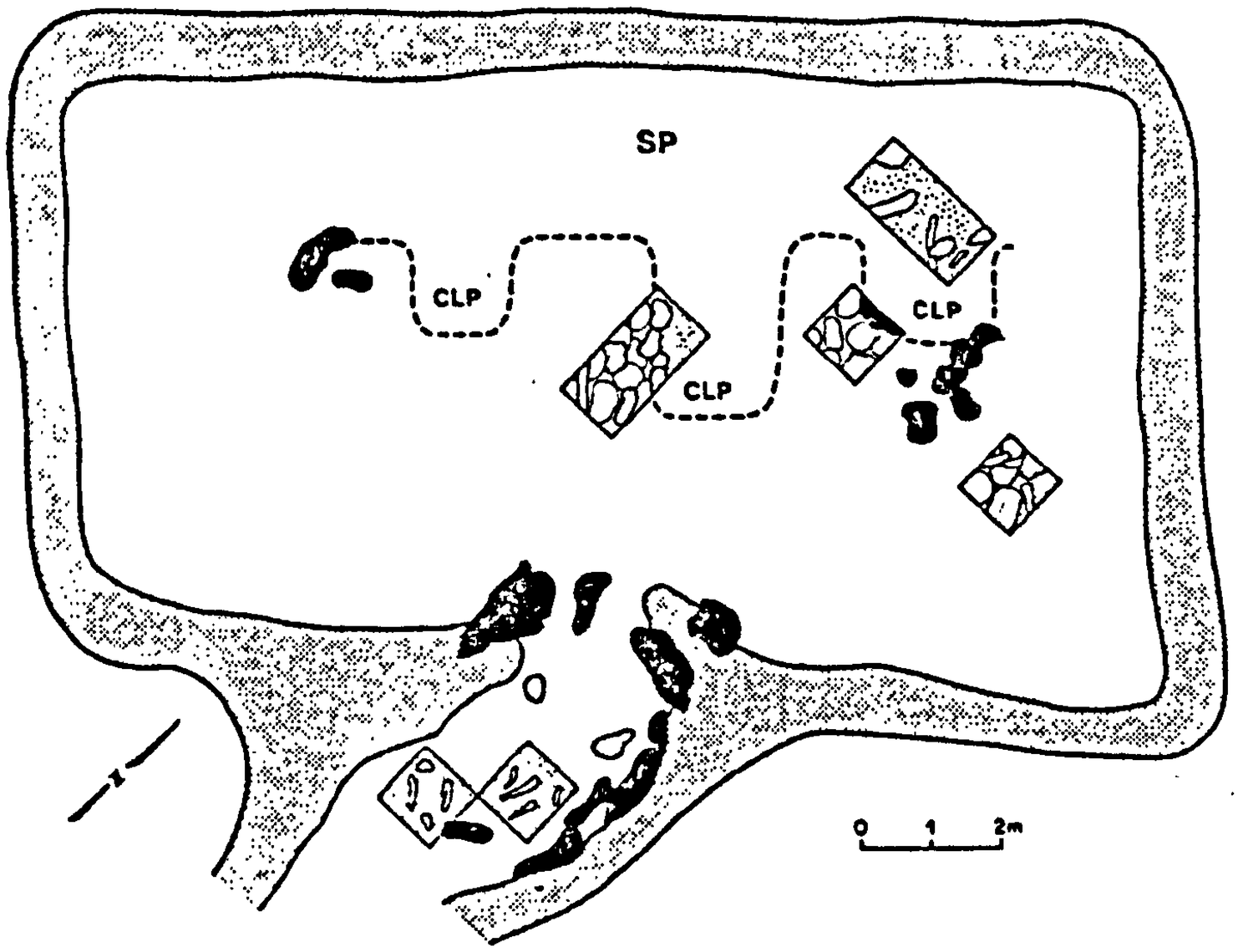


Fig. 39. Elongated rectangular semi-subterranean longhouse (Schledermann, 1976).

probably a result of the need to conserve fuel and to share food, rather than the lack of whale bone as a construction material. There was, as has been pointed out earlier, the re-use of existing house sites with its construction materials, so that whale bones would have been available from older house sites, minimizing the importance of this factor (see McCartney, 1980, pp. 530-531).

In Thalbitzer, one finds an excellent description of the east Greenland semi-subterranean communal or longhouse. These houses were composed of one room varying in size from 4.3m to 10.9m long, and from 1.9m to 6.0m wide depending on the number of families housed (1979, pp. 356, 357). In many cases the entire village lived in one house which contained on an average 32 persons (Thalbitzer, 1979, pp. 10, 57, 349, 362, 363). These houses were generally built on sloping ground (see Fig. 40) in proximity to and facing the sea. However, the orientation of the house was of less importance than a suitable site and good direct access to the sea. The walls were partly in the earth with the back wall the same level as the ground. As can be seen from Fig. 40, the back wall was slightly longer than the front wall. The ridge of the roof which was the highest point of the house consisted of a wood beam supported by poles placed at the front edge of the sleeping platform. The maximum height of the interior room was 5' 6" (2m). From the ridge member, driftwood pieces were extended to the walls with smaller pieces of wood placed between them. The roof was then covered with large sods, the grass side laid under. A layer of earth was placed on top of this, and then another layer of sods with the grass side up and the whole roof was then covered with old skins, weighted down by rocks (Thalbitzer, 1979, p. 37).

Penetrating the front wall was the entrance tunnel and three windows covered with a translucent gut. The entrance tunnel was not centred on the front wall and was at a slight angle to it. The tunnel was 20' to 30' (6.1 - 9.2m) long and 3' (91cm) high, with the entrance door being even taller and made from the wood frame used for their tents. The floor of the tunnel was a few feet lower than the floor of the house, and the roof of the tunnel was slightly above the floor of the house. The entrance tunnel was built in the same manner as the house, i.e. of stones, sod and timber (Thalbitzer, 1979, p. 37).

The sleeping platform was made of wood, measuring 6' (1.8m) wide and 1' 6" (46cm) above the stone-paved floor, and was supported on a layer of stone and turf at the back wall. At the front of the house there were narrow platforms made of wood boards that projected into the window alcoves. The main sleeping platform was divided into compartments by animal skins hung from the ceiling members, stopping short of the rear wall, thereby leaving a passageway along the back of the house. Skins were used to line the interior of the house as well as to cover the platforms. Covers were made

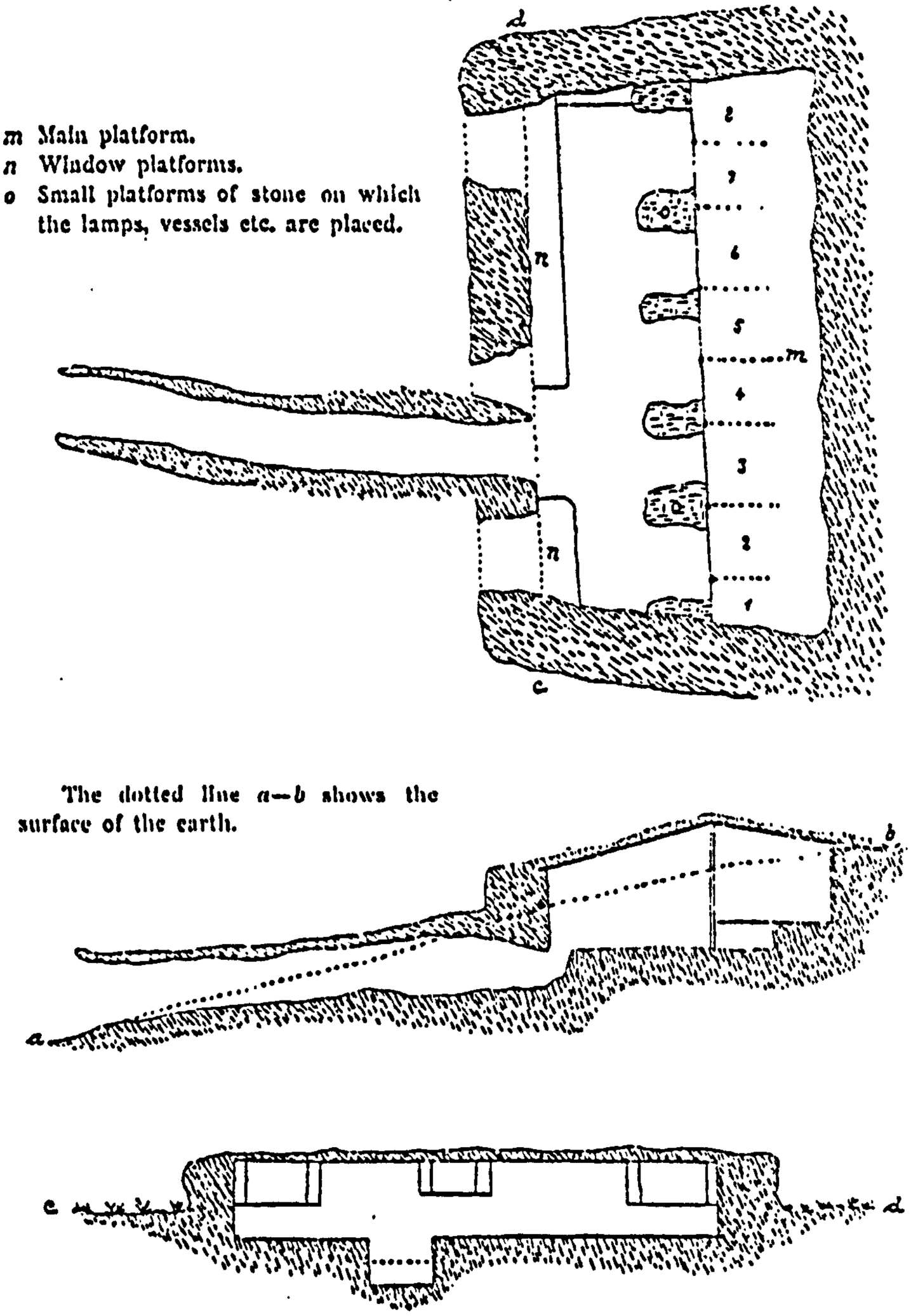


Fig. 40. Large rectangular semi-subterranean long-house (Thalbitzer, 1979).

of seal or dogskin edged with bearskin. The hair was face down on the first cover, and the second cover, which was used clothing, had the hair face up. One cover was used over the whole family, while clothes worn during the day were used as a pillow.

The main platform was inhabited by married people, their unmarried daughters and small children, each family having a space from 3' to 5' (91cm to 1.5m) wide depending on the number of people in the family. The married people lay with their feet toward the wall and the unmarried women had their feet toward the front of the platform. The unmarried men, older boys and casual guests slept on the window platform. The main platform was also used as a place to work during the day by the women. The space under the platform was the "marriage bed". Each married woman had her own stone oil lamp (used for cooking, heat and light) set on a stone platform in front of the sleeping platform. When two living compartments were adjacent, the families shared a stone platform for their lamps. The women kept the lamps burning day and night while they sat on the platform preparing skins, twisting sinew thread and cord, sewing clothes and doing embroidery. They spent the greater part of their time on the platform, while their husbands sat on the edge of the platform with their feet on their tool boxes while they worked. Above the lamp, a frame of wood sticks was hung for drying boots and clothes as well as for hanging pots. The space under the platform was used for storing provisions, tool boxes, skins, blubber buckets, meat trays and the urine tubs used for the preparation of skins. (Thalbitzer, pp. 35, 37-40, 60).

1.4.1.4 Snow Houses

Traditional Inuit snow houses are one of the most commonly known housing forms in the world. It seems that snow houses were used as early as the Middle and Late Dorset periods - about 500 A.D. (Maxwell, 1980). Sabo and Jacobs mention a change in dwelling type during the Developed Thule Phase which was related to climatic changes necessitating a modification in the procurement system. The Thule Inuit during the period mentioned relied more on ringed seals which demanded easier access to winter sealing grounds, requiring the dwellings to be set up on the sea ice itself. The only type of winter house that could be built on the sea ice was the snow house. It

seems, however, from artifacts and found remains that "...onshore winter dwellings continued as a seasonal option in addition to snow houses on the sea ice" (Sabo and Jacobs, 1980, pp. 500-501). From this period on, the snow house gradually supplanted the permanent winter houses. From approximately 1800, the snow house became the only winter dwelling type, and in the form of the Quarmat it replaced the permanent dwellings in the autumn and spring as well (Sabo and Jacobs, 1980, pp. 493, 500, 501; and Mathiassen, 1927, pp. 133-134). See Fig. 41.

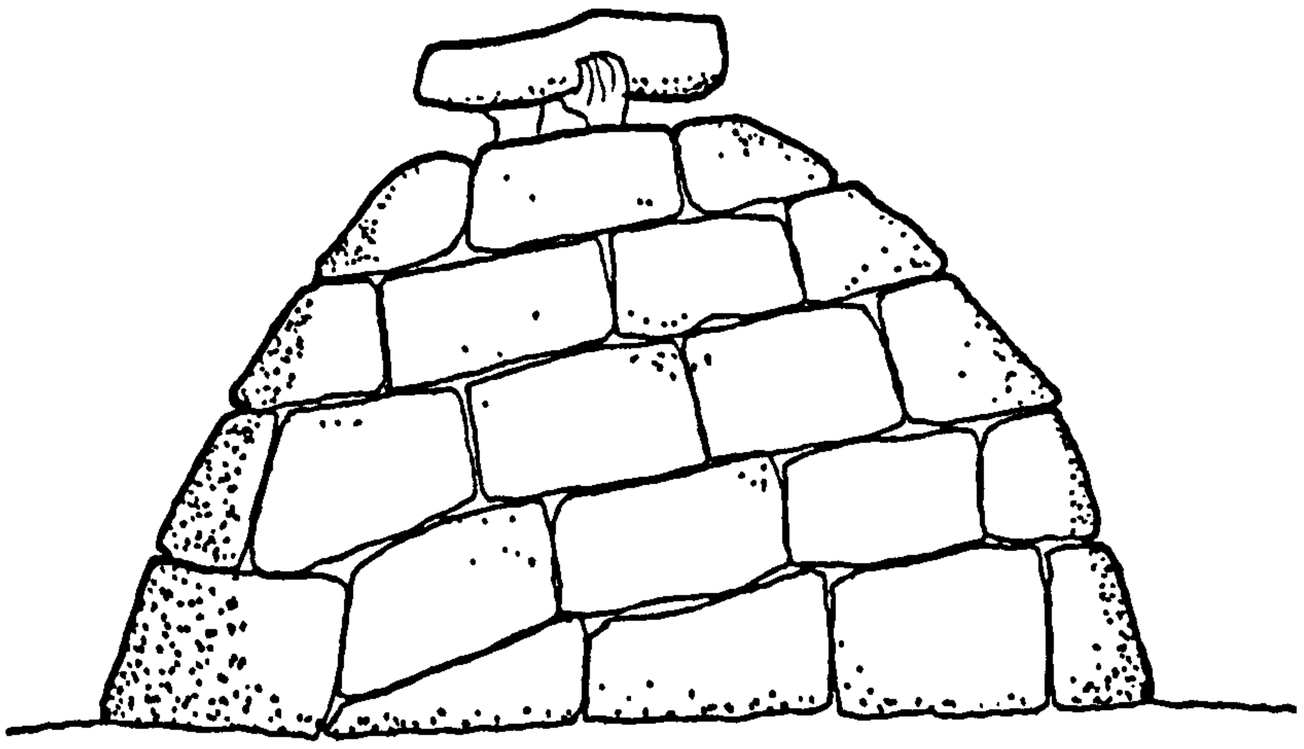


Fig. 41. Snow house construction - elevation (Koerte, 1974).

1.4.1.4.1 Single Snow Houses

The snow house was not a hemisphere as is commonly supposed. In reality it approximated an inverted paraboloid or catenoid with a maximum safe diameter of 34' (10.4m) and a corresponding height of 12' (3.7m), resulting in a height to diameter ratio (h/d) of 0.35 (Handy, 1973, pp. 277, 279). Single family snow houses have been observed to vary in dimension from 10' (3.1m) to 11' (3.4m) long by 6' 9" (2.1m) to 9' 6" (2.9m) wide by 4' 6" (1.4m) to 6' 8" (2.0m) high (Jenness, 1922, pp. 60, 64, 65, 69). One of the largest snow houses reported by Stefansson, a dance house, was 30' (9.1m) in diameter (Handy, 1973, p. 280). The parabolic form gave the snow houses its unusual strength and as Jenness mentions, "...even half a hut will stand alone and unsupported" (1922, p. 64).

The construction of the snow house was a process demanding great skill. The construction began with the selection of a suitable site which had a sufficient depth of snow of proper consistency, that is, snow which was firm and not granular or soft. Blocks were cut from the area which would serve as the central floor space. The blocks of snow were 3' to 4' (91cm - 1.2m)

in length, 1' 6" to 2' (46 - 61cm) in height, and 6" to 8" (15 - 20cm) thick. A first row of blocks was laid out in a circle leaning tightly together and then 2 or 3 blocks were cut down diagonally to start the spiralling form. The top of the first row of spiralling blocks was cut slanting inwards so that the spiral became smaller as it rose. The last block was pushed up through the opening, lowered down into position and trimmed to the exact size of the hold (Boas in Koerte, 1974, pp. 78, 79). See Figs. 41 and 42.

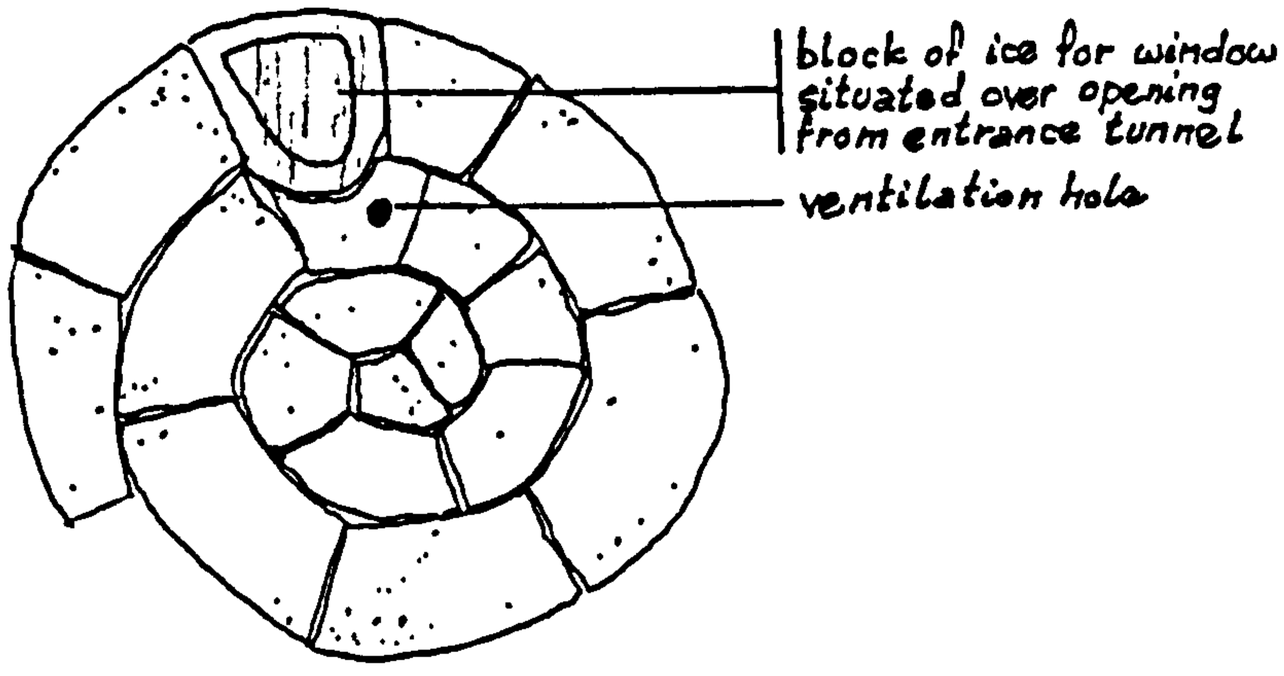


Fig. 42. Roof plan of central room - snow house (Mathiassen, 1928).

Jenness (1922, p. 60), however, contends that the symmetrical spiral form so often described was in fact rare, and that an asymmetrical oval dome-shape was more common with the blocks being set in any manner as long as they held together. Jenness describes the oval-shaped snow house construction as that of building up the walls closer together until the space could be closed by large blocks. Jenness was describing the Copper Eskimo snow house while that reported by Boas in Koerte, was the Central Eskimo house which could account for the difference in construction technique.

The entrance tunnel according to Boas (in Koerte, 1974, p. 74) was formed by 2 or 3 small vaults or domes. The first was a small dome approximately 6' (1.8m) high with a 2' 6" (76cm) high door while the second section of the tunnel was an elliptical vault 6' (1.8m) high, with a 3' (91cm) door leading to the main room. There were two small exterior vaults, one attached to the junction of the dome and the vault, and the other between the vault and the

main room. See Fig. 43. The first was used for clothing and harness and

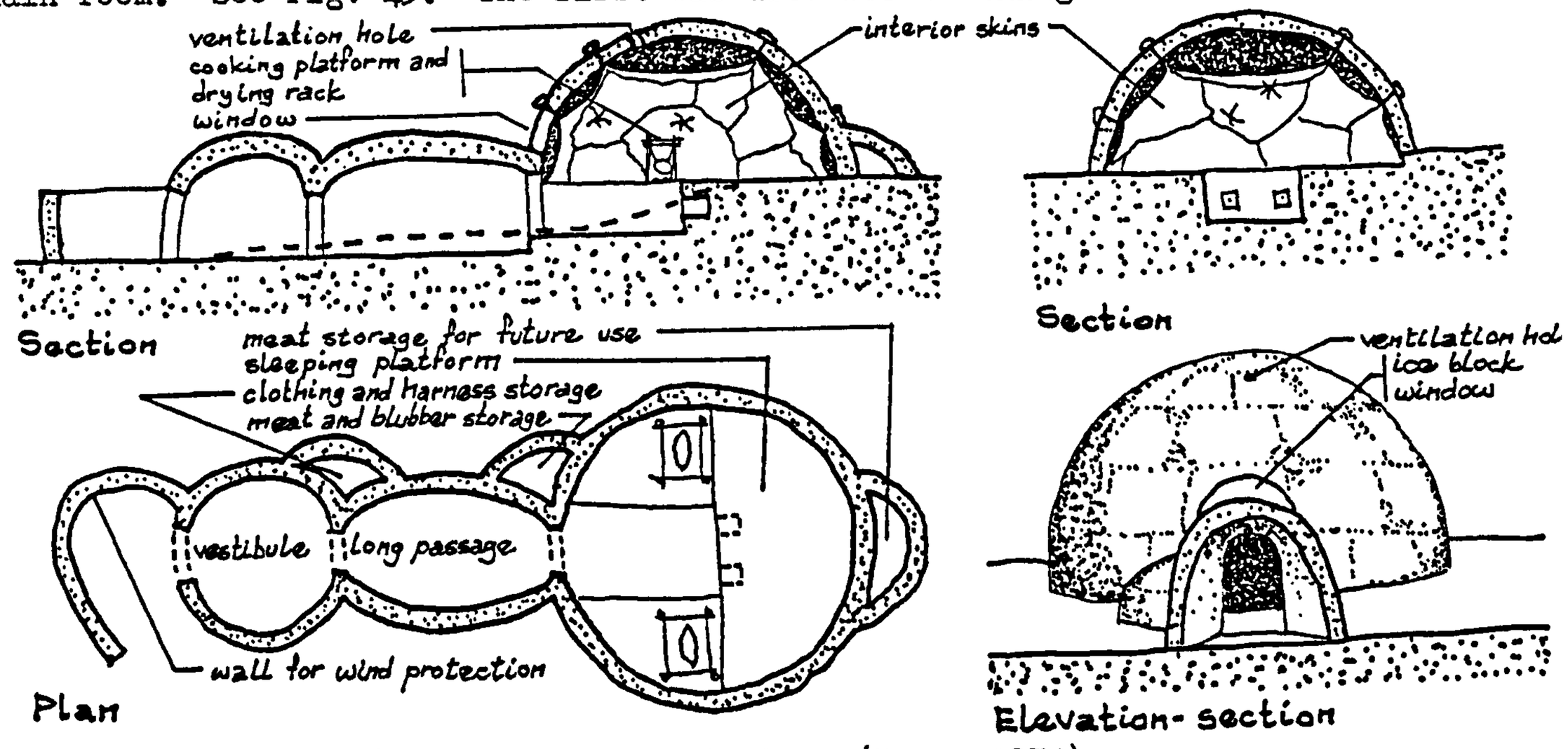


Fig. 43. Snow house sections and plans (Boas, 1974).

the second, with access from the main room, was for meat and blubber. There was a third exterior vault attached to the rear of the main room which was used for storing future meat supplies (Koerte, 1974, pp. 81-82).

According to Jenness (1922, pp. 61, 64, 65, 70) the entrance tunnel was constructed by building two straight walls 3' (91cm) apart and 4' to 5' (1.2 - 1.5m) high, roofed over with flat blocks of snow. Temporary snow houses had short tunnels, whereas more permanent snow houses had longer tunnels ranging from 10' to 40' (4.6 - 12.2m) to conserve heat. They were sometimes made short when the house was first built and lengthened after the first storm, curving away from the wind, terminating in a T-shaped entrance that could be opened on either side, depending on the wind direction. The house and entrance tunnel in general, were built facing south, but frequently the snow depth dictated the orientation. Where possible, snow houses were sited in the lee of a protective ridge facing the water. The entrance tunnel was often partly below the surface of the snow and lower than the floor of the house as can be seen in Fig. 43. To facilitate the construction of the tunnel, the snow house was often built on slightly sloping terrain, similar in this respect to the sites chosen for semi-subterranean houses. The top of the doorway was usually the same height as the top of the sleeping platform so that any cold air entering would not directly sweep onto the platform (Koerte, 1974, p. 93). To inhibit air infiltration around the

base of the main room of the snow house, a small rampart was built around it approximately 6" to 1' (15 - 31cm) away, and the space filled with soft snow (Jenness, 1922, pp. 59, 60).

The space within the snow house was roughly divided into one-half for the sleeping platform which had a snow base raised 1' to 2' (31 - 61cm) above the floor, while the other half was taken up with the cooking-heating area which had shelves and a drying rack on one side of the entranceway and a storage space on the other side if there was no other family sharing the house. See Fig. 43. An alternate division of the interior space is shown in Fig. 44. The sleeping platform for the two families were on either side of the central floor area parallel to one another. At the rear of the room and at the front adjacent to the opening to the entrance tunnel were platforms for the lamps.

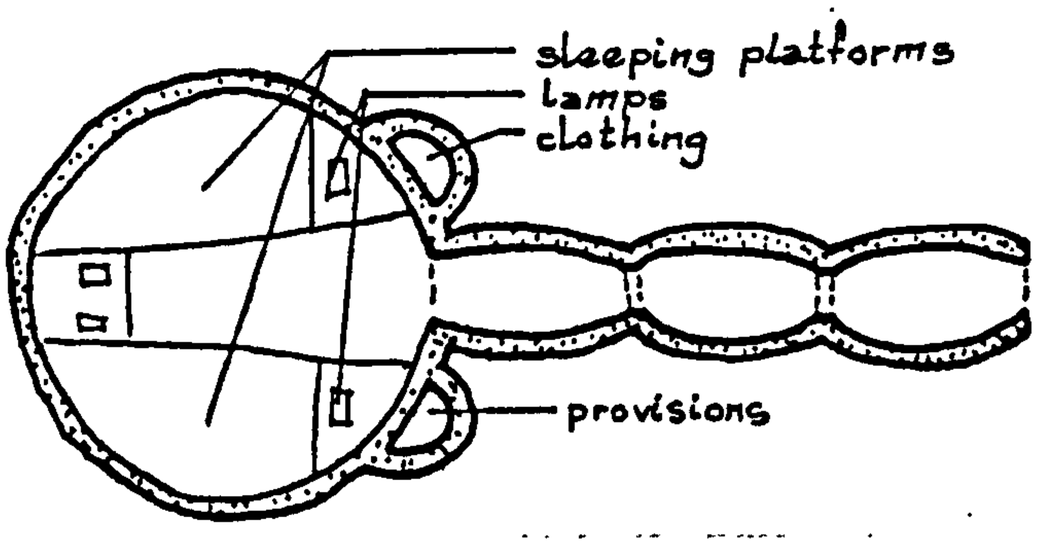


Fig. 44. Snow house plan variation - 2 parallel sleeping platforms (Boas, 1901).

The sleeping platform often had a hole under the front edge where clothes and other items could be stored. This is similar to the space found under the platforms in the permanent houses described previously. This hole, as well as the rest of the platform was covered with willow twigs, tied together to form a mat, over which were placed planks of wood which in turn were covered with animal skins. Jenness (1922, p. 61) mentions that the Inuit quite often used a first layer of musk-ox skins with a second layer of deer or caribou skins, hair downwards, plus a third layer of caribou skins with hair upwards and pointing towards the entrance to aid the cleaning of the platform.

Sometimes the inside of the snow house was lined with skins hung from cords passing through the walls and fastened to wood toggles on the outside. These skins formed a layer of insulating air between the heat of the room and the snow structure. The ceiling skins were hung flat leaving a large space of cool air above the highest point in the room where heat gathered by natural convection. If any snow melted, it would fall on the skins,

accumulating as ice at the bottom of the air space (Boas in Koerte, 1974, pp. 88, 89). The snow houses described by Jenness (1922, p. 63) did not have a skin layer inside, so that when melting occurred, the spots were patched up with lumps of snow, or holes punched through the walls so that warm air escaping would eventually clog up the hole through the formation of ice. The ice film that formed on the interior as well as on the dome shape, reflected the heat towards the centre making the snow house a relatively energy-efficient dwelling.

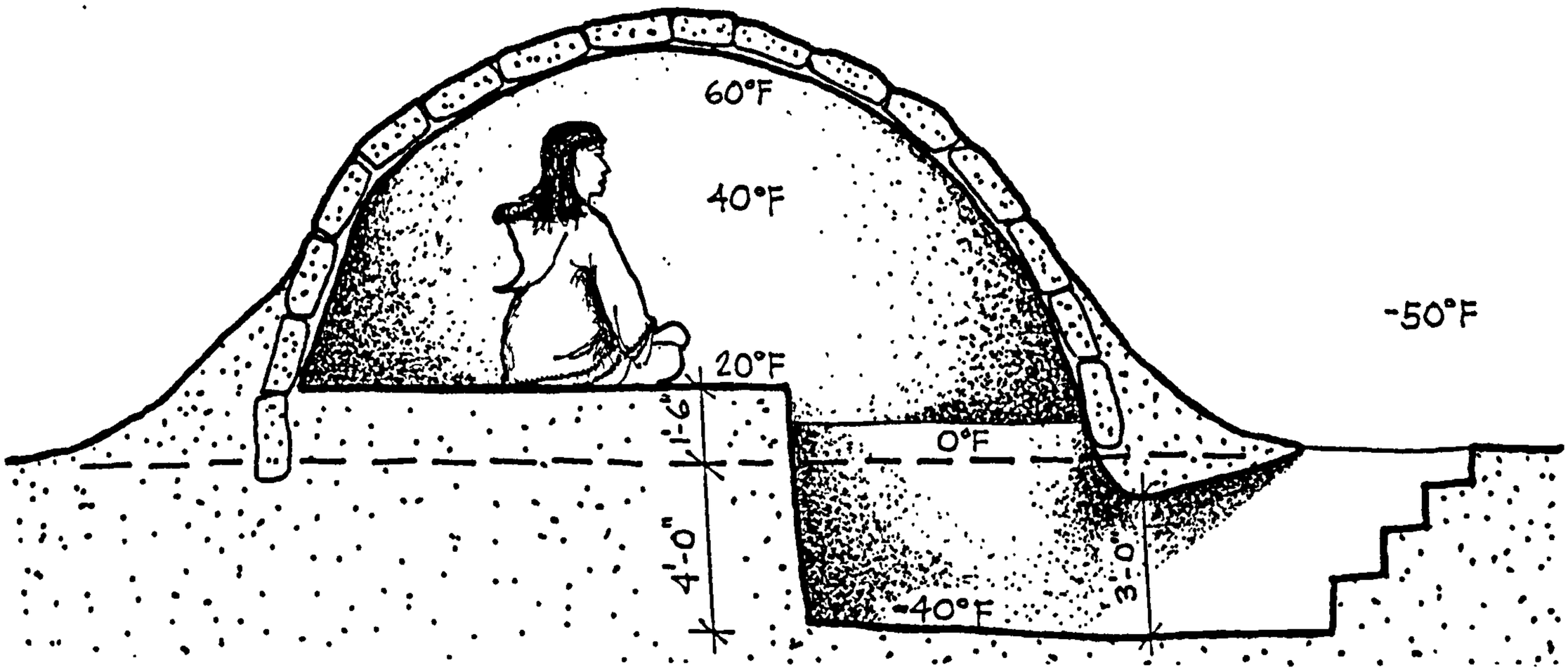


Fig. 45. Section of a snow house showing variation in temperature (Brown, 1965).

Figures on the temperatures inside a snow house vary depending on the author. For instance, Fig. 45 shows the temperature gradient in a snow house described by Brown. This house did not have an entrance tunnel, but rather an entrance pit from which one penetrated into the main room from underneath. With an outside temperature of -50°F (-46°C) the temperature at the bottom of the pit was -40°F (-40°C); 0°F (-18°C) at the level of the snow outside; 20°F (-7°C) at the height of the platform; 40°F (4°C) at the shoulder level of a person seated on the platform and 60°F (16°C) at the top of the snow house (Brown, 1965). Jenness (1922, p. 63) does not give temperatures but mentions that snow houses were comfortable unless the temperature outside was very low with a raging storm. He also notes that if the inside temperature rose above freezing "...the ceiling immediately begins to drip," which suggests that it was a condition the Inuit avoided if possible.

Fitch and Branch give maximum temperatures at the ceiling of a snow house as 39°F (3.9°C) at an outside temperature of -10°F (-23°C); and 35°F (1.7°C) at -30°F (-34°C) (1960, p. 138).

Boas, (1974, pp. 543-544) however, notes that in the snow houses without interior skins "...the temperature cannot be raised higher than two or three degrees centigrade above the freezing point, while in the lined houses it is frequently from ten to twenty degrees centigrade." Boas notes that all eastern Inuit used the lined houses while southern and western Inuit used unlined houses, but covered the house with a loose layer of snow for added insulation.

A window was set into the snow house wall just above the entrance which was usually made of ice cut from fresh water lakes or rivers. The window measured 2' to 2' 6" wide (61 - 76cm) by 2' to 2' 3" (61 - 69cm) high (Jenness, 1922, pp. 62, 65). The window was often arch-shaped and was sometimes made from seal intestines (Koerte, 1974, pp. 73-74), and it usually faced south or toward the water from where people would normally arrive. The ventilation hole was placed on the leeward side of the snow house roof and was sometimes built up with small snow blocks to aid ventilation (Jenness, 1922, p. 63).

There are some variations in the form of the single snow house which are worthy of note. Figs. 43 and 44 show minor variations in the internal

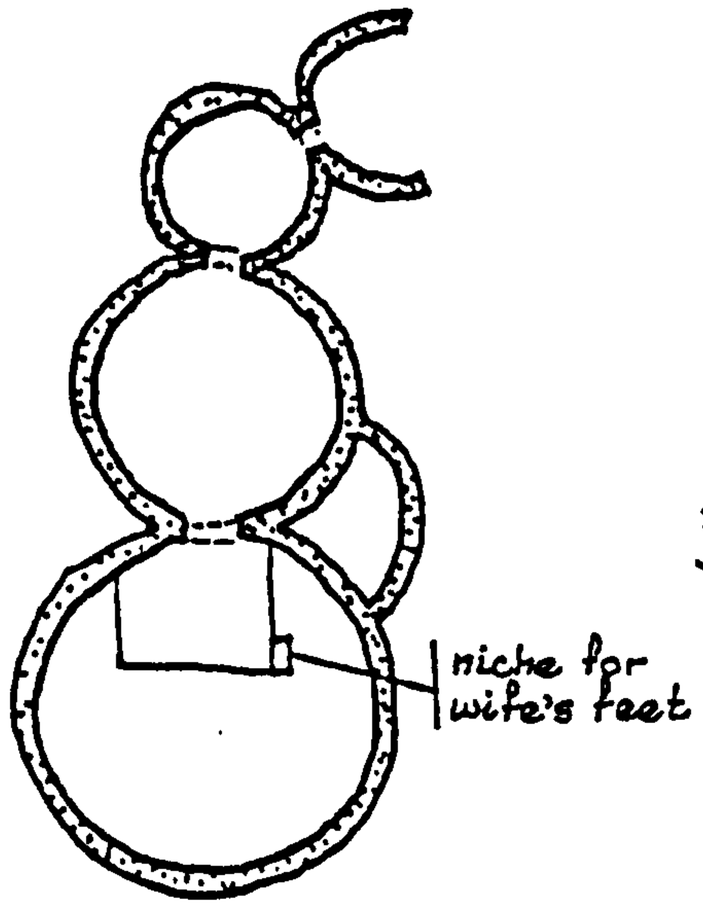


Fig. 46. Single snow house with domed entrance tunnel (Mathiassen, 1928).

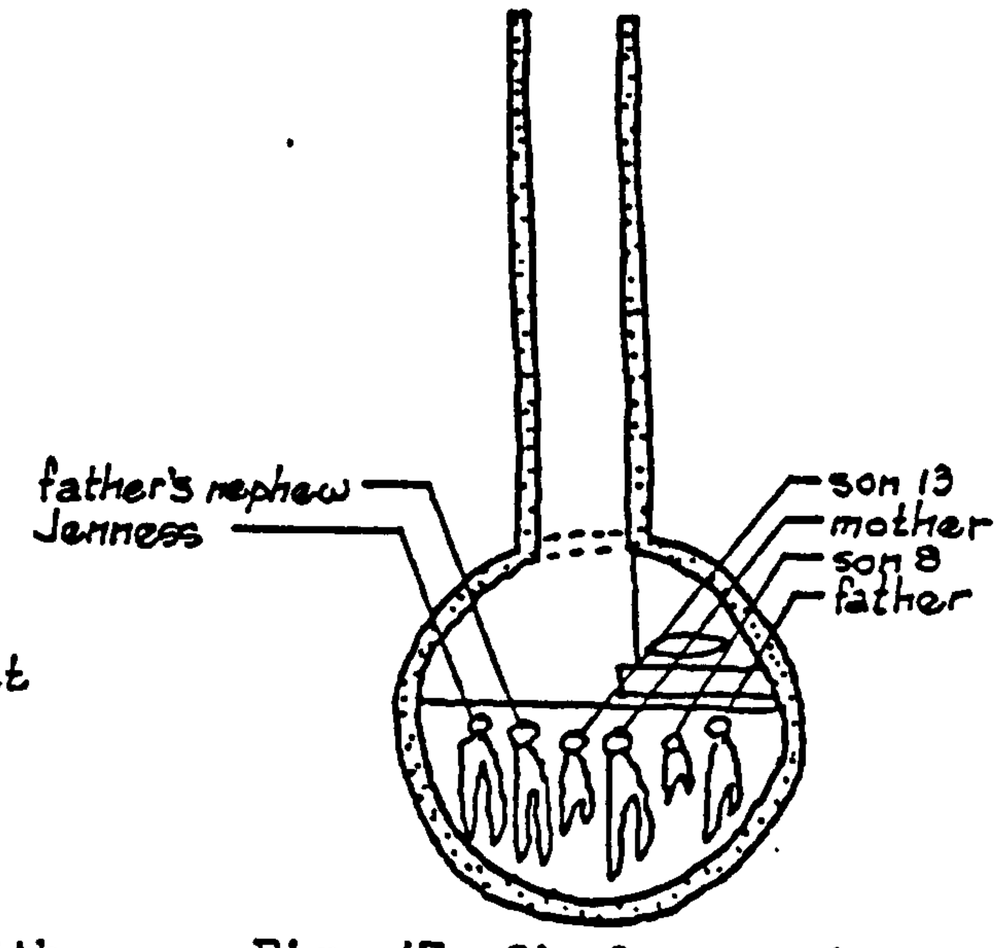


Fig. 47. Single snow house with vaulted entrance tunnel (Jenness, 1922).

spatial organization and the shape of the entrance tunnels. Fig. 43 shows a dome and a vault joined to the main house, whereas Fig. 44 shows three vaults joined together to form the entrance tunnel. Fig. 46 illustrates another variation where two domes were joined together forming the entrance tunnel (Mathiassen, 1928, p. 125). Fig. 47 shows an example in which the entrance tunnel is made of two walls with slabs of snow covering them. In all the examples, the tunnels were relatively straight with a wall protecting the entrance to the tunnel from the changing wind directions.

In Fig. 47, Jenness shows the hierarchy of the interior arrangement of the family members on the platform (Jenness, 1922, p. 65). The place next to the wall and closest to the cooking lamp was normally occupied by the wife, but Fig. 47 indicates that there was some variation allowed in this sleeping order. The second position, next to the wife was normally occupied by either the father or the youngest child, and the third position by an older child followed by other children, nephews, uncles, aunts or grandparents. See Figs. 48 and 49 for two other snowhouse plans with platform positions of the occupants indicated (Baillargeon, 1979, p. 40).

Other variations on the single snow house are related to the dance or singing houses. Fig. 50 is an example of a snow house built for the special purpose of celebrations. The whole village gathered for singing and dancing in this dome-shaped structure which was 15' (4.6m) high and 20' (6.1m) in diameter. In the centre was a snow pillar 5' (1.5m) high supporting a single oil lamp, which would seem sufficient considering the heat generated by the people while sitting or dancing. The interior was unlined indicating its temporary use (Boas, 1974, p. 600).

Fig. 51 illustrates a dance house dome attached to a snow house. The house belonged to a shaman who was responsible for certain activities such as dances that had spiritual and prophetic connotations. The house had two separate cooking areas because the shaman had two wives (Jenness, 1922, p. 66).

Another form of a single snow house was the autumn and spring Quarmat.[1] These structures were used when the weather was too cold for living in a tent, but the snow was not yet of the proper consistency for making the

1 Quarmat is sometimes spelled Qarmat depending on the author and region studied.

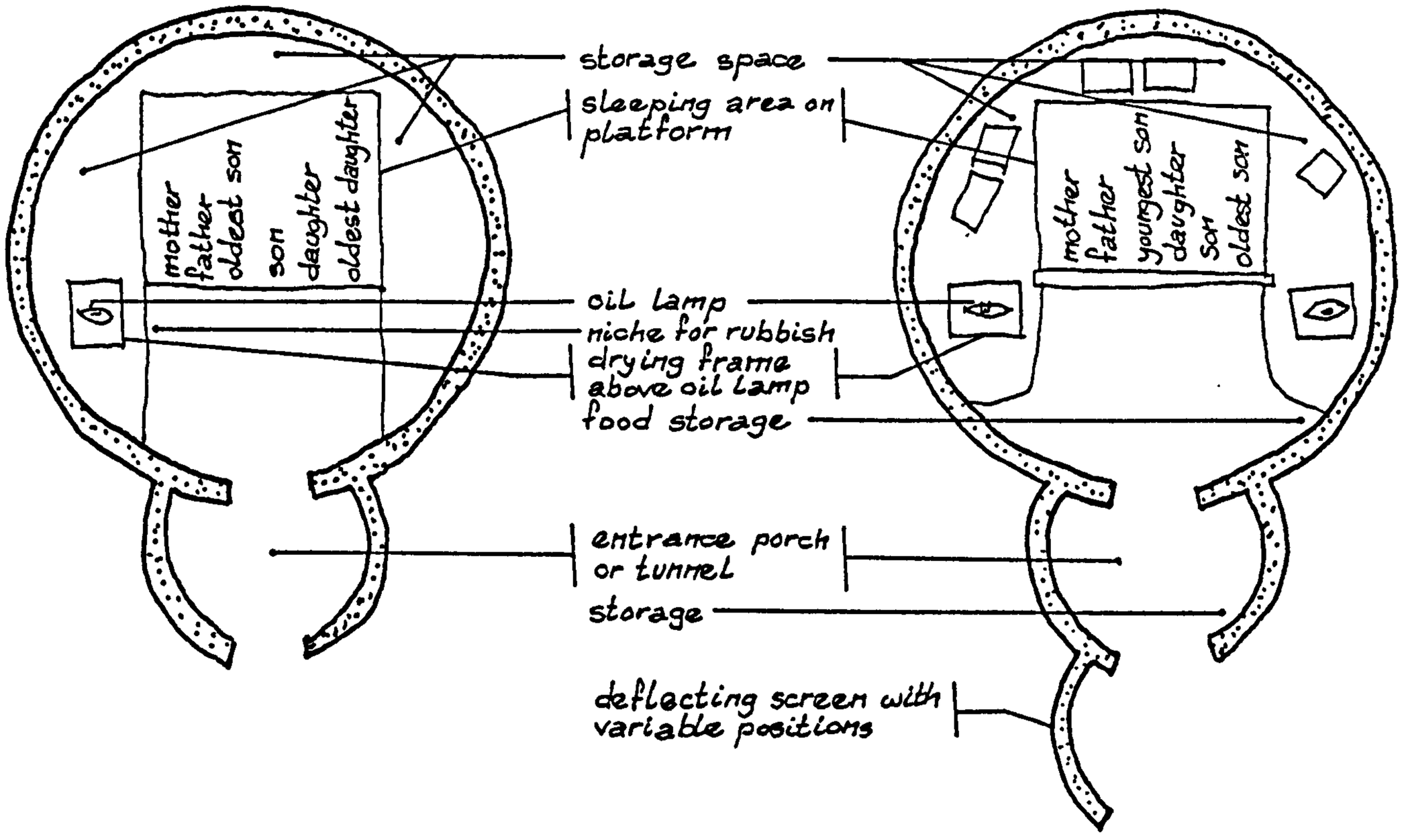


Fig. 48. Single snow house. (Baillargeon, 1979.)

Fig. 49. Single snow house variation (Baillargeon, 1979.)

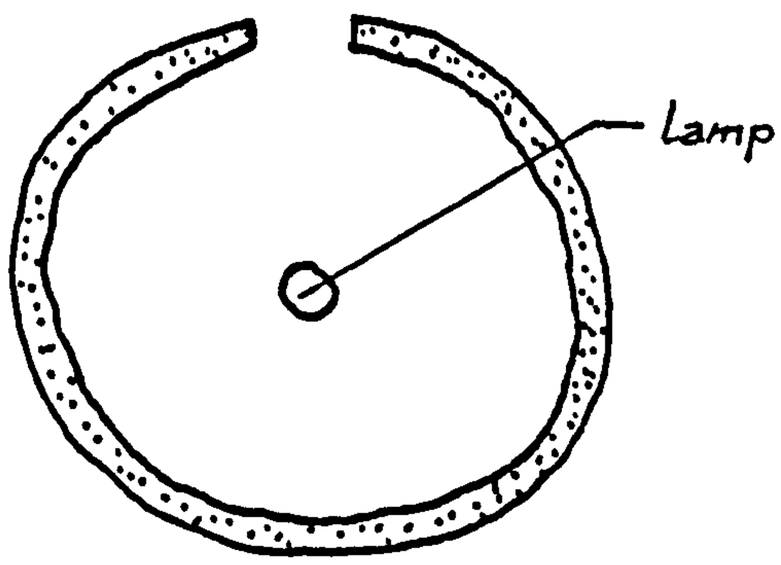


Fig. 50. Snow house for festivals and singing (Boas, 1974.)

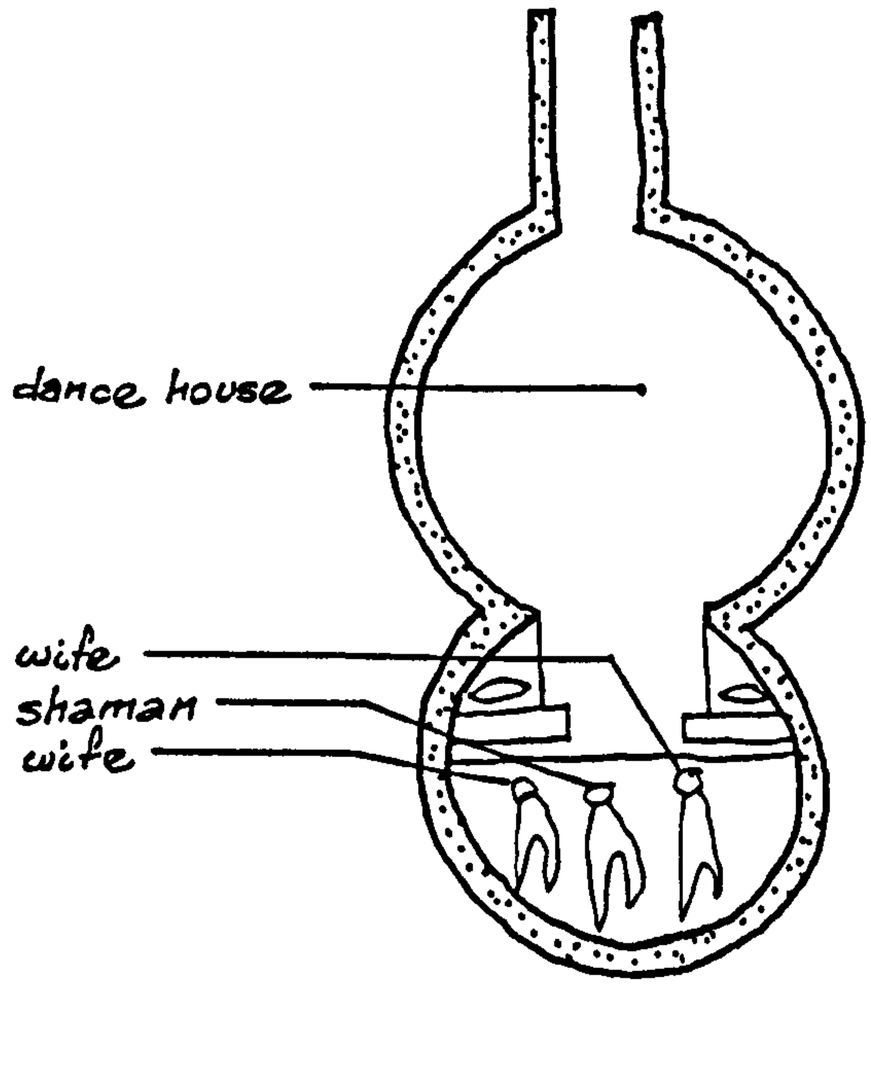


Fig. 51. Shaman's snow house with attached dance house (Jenness, 1922.)

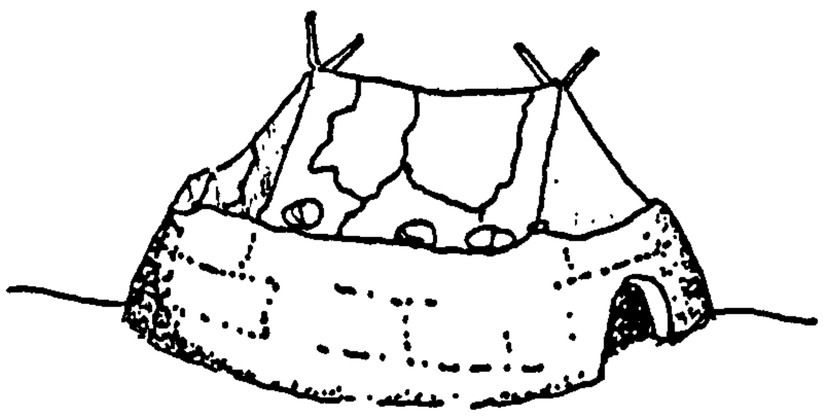


Fig. 52. Qulaalik - snow house with tent roof (Baillargeon, 1979).

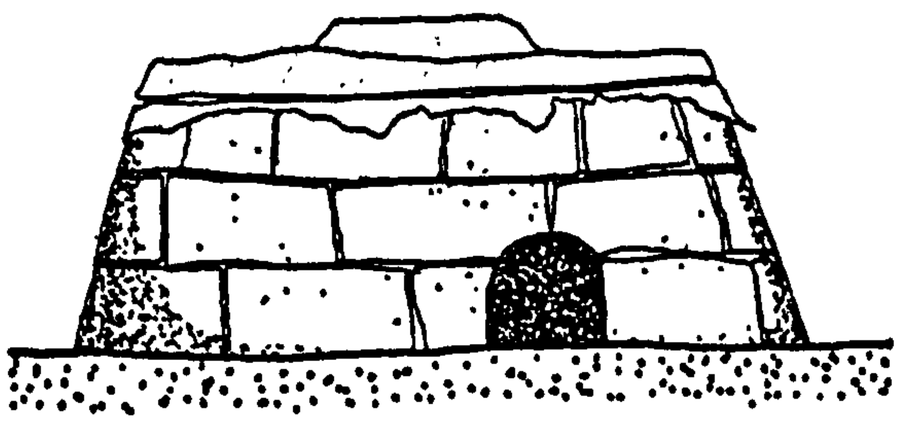


Fig. 53. Ice or snow house with tent roof (Mathiassen, 1928).

parabolic roof. They often used caribou skins from the tent as a roof, supported on the tent poles. In spring, the temperature was still too cold to move into the tent, but the springtime sun was sufficiently strong to weaken the snow dome and therefore it was replaced once again by the tent skins and structure (Baillargeon, 1979, p. 43; Jenness, 1922, p. 77). See Fig. 52 for a sketch of a Quarmat or Qulaalik. Skins were also used to cover the top of snow houses in spring to protect them from the sun until the snow dome lost its structural qualities (Saladin d'Anglure in Baillargeon, 1979, p. 42-43).

Mathiassen describes an ice house which is similar in shape to the snow house, but in which the walls were made of ice 1.5 to 1.7m high and roofed over with a vault of snow. During spring and autumn the roof for the ice house was made of caribou skins supported on tent poles with two salmon spears laid from wall to wall. The flat roof of skins was attached to the circular base by tying the skins down with a thong made of seal intestines set into an angular groove cut into the ice blocks about 50cm from the top of the wall (Mathiassen, 128, p. 139). See Fig. 53.

Mathiassen mentions the existence of a rectangular snow house with a roof of poles and canvas. This snow house was found in Alaska where dome-shaped snow houses were unknown and where the square or rectangular sod and semi-subterranean houses were more common.

Fig. 54 shows two single houses in such close proximity that they almost touch each other. They each had their separate entrance tunnels which face in opposite directions, in this case to keep their dogs from fighting, as the dogs normally slept in the entrance tunnels. Jenness (1922, p. 66) reveals that their proximity was due to the limited amount of suitable snow for snow house construction, especially in late autumn.

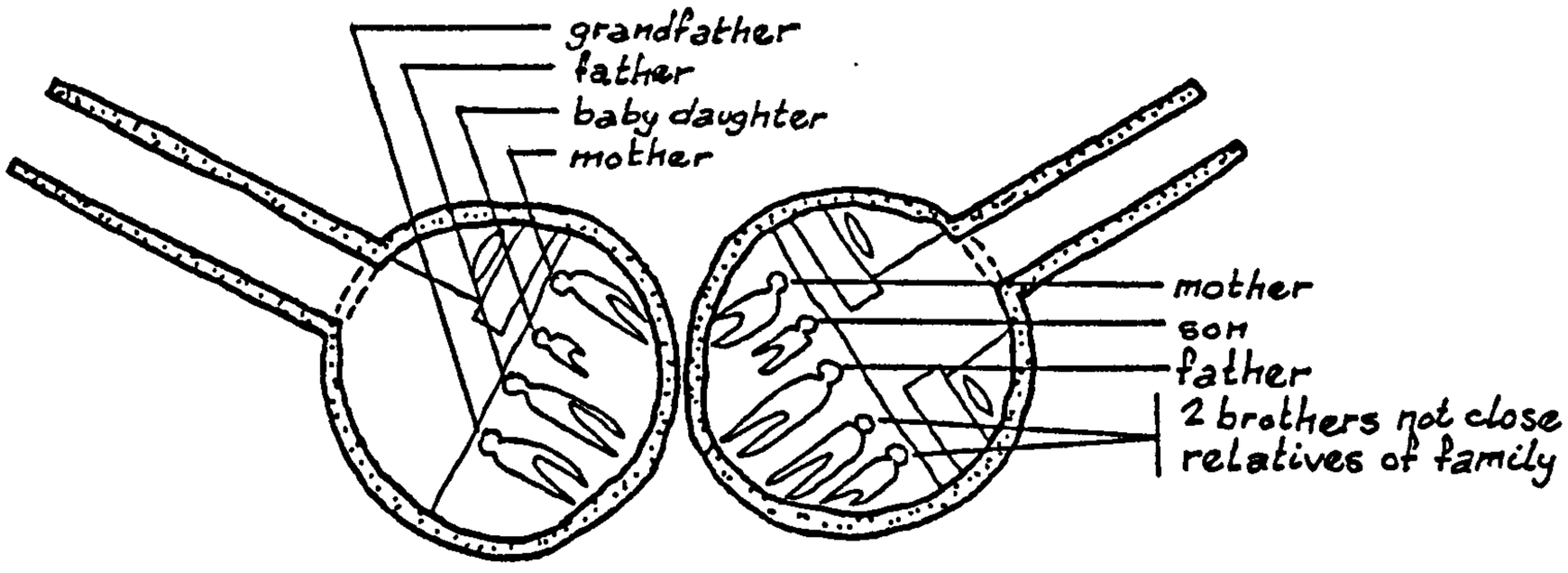


Fig. 54. Two single snow houses approaching double house status (Jenness, 1922).

1.4.1.4.2 Double Snow Houses

The first example would seem, at first glance, less of a double house than the two houses in Fig. 54. Fig. 55 Shows 2 houses that are so far apart that they share only a very small portion of the entrance tunne. According to Jenness, this was often done to minimize the number of entrances to

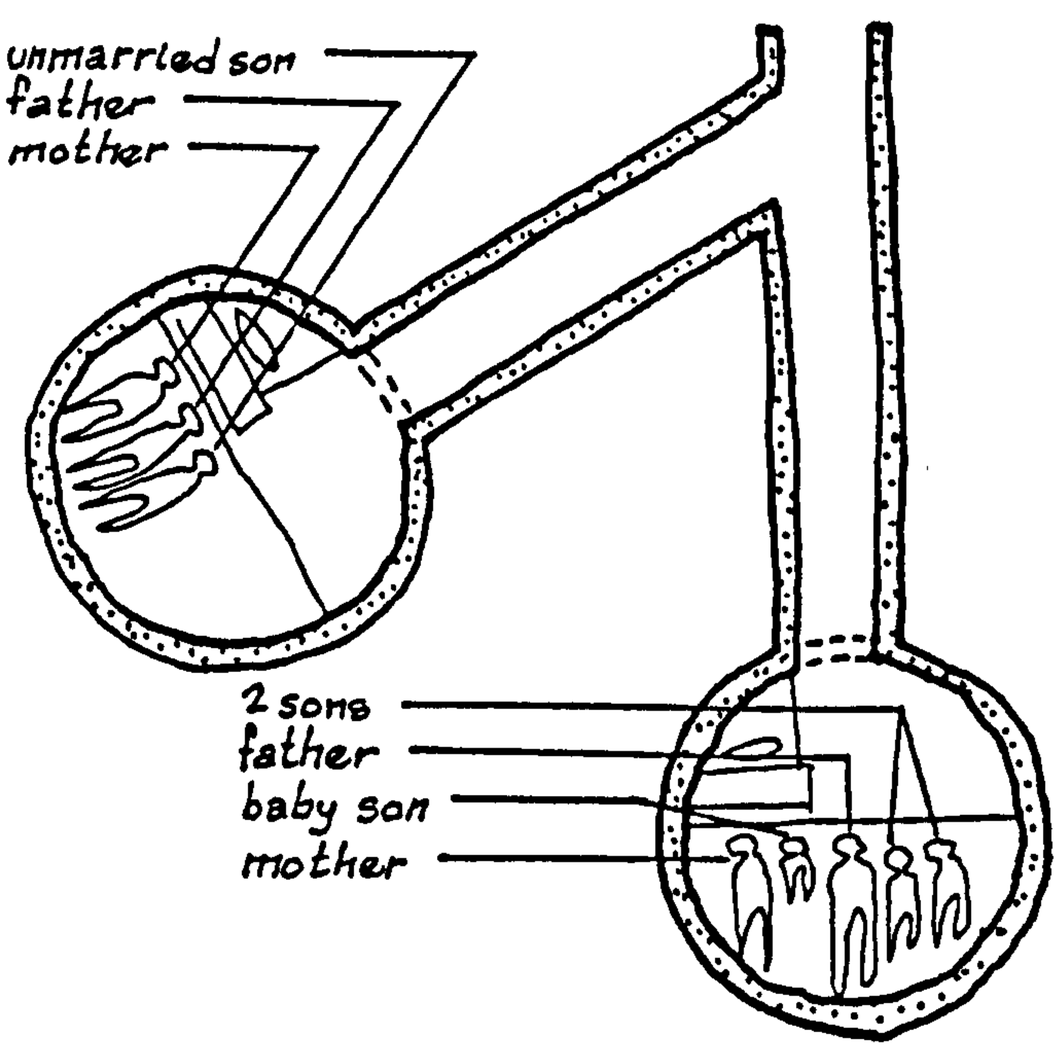


Fig. 55. Double snow house - short common tunnel (Jenness, 1922).

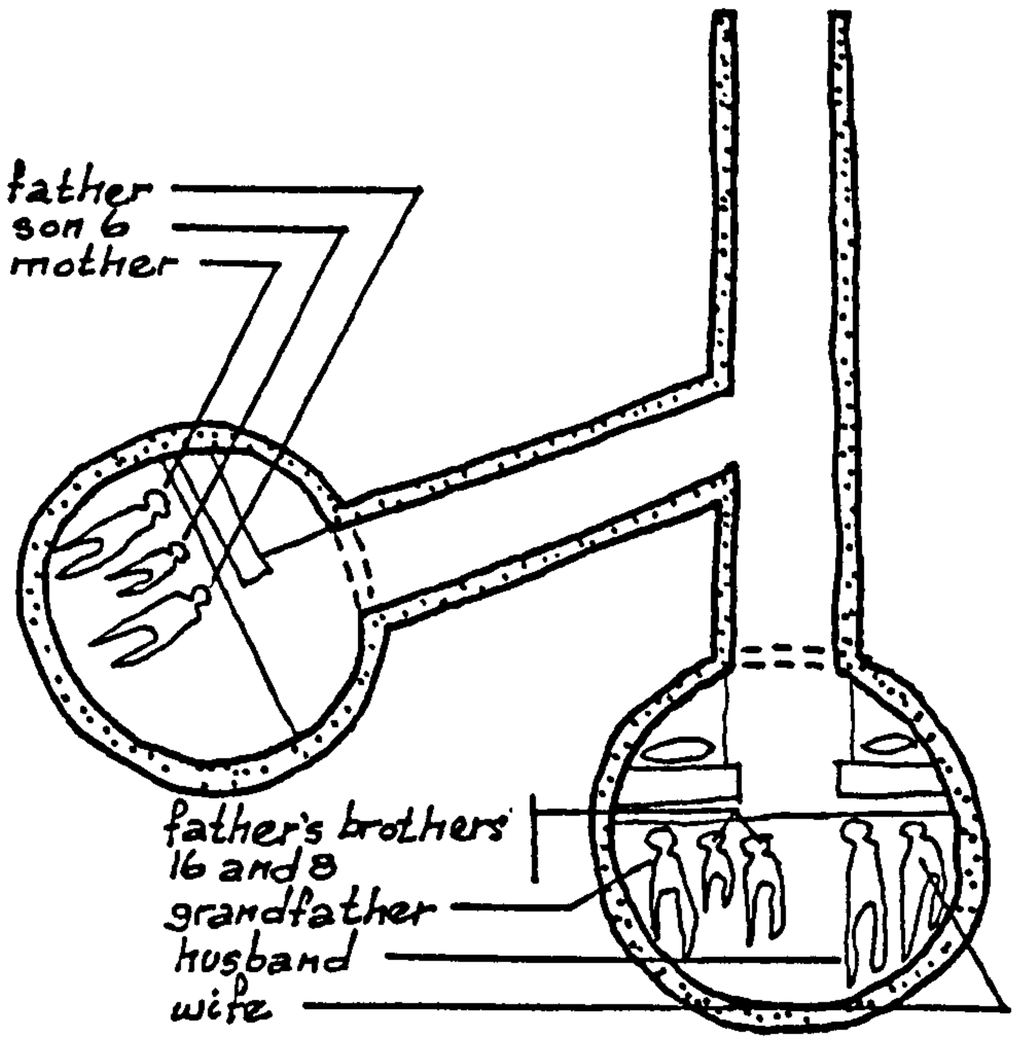


Fig. 56. Double snow house - long common tunnel (Jenness, 1922)

shovel out. The long separate tunnels allowed the families to separate their dogs (Jenness, 1929, p. 69). The second example represents a collaborative effort in which the 2 houses were closer and the shared portion of the tunnel became longer (Jenness, 1922, p. 68). See Fig. 56.

Fig. 57 is a modified version of Fig. 46, but its main difference lies in the construction of the tunnels which are a series of oval and circular vaults joined in alternance. The two houses were separate, but a private portion of the entrance tunnel existed only for the house on the left (Boas, 1974, p. 546). The houses shown in Fig. 58 represent the last example of separate houses. The two houses were joined in a more intimate manner by a miniature tunnel from the smaller house to the main room of

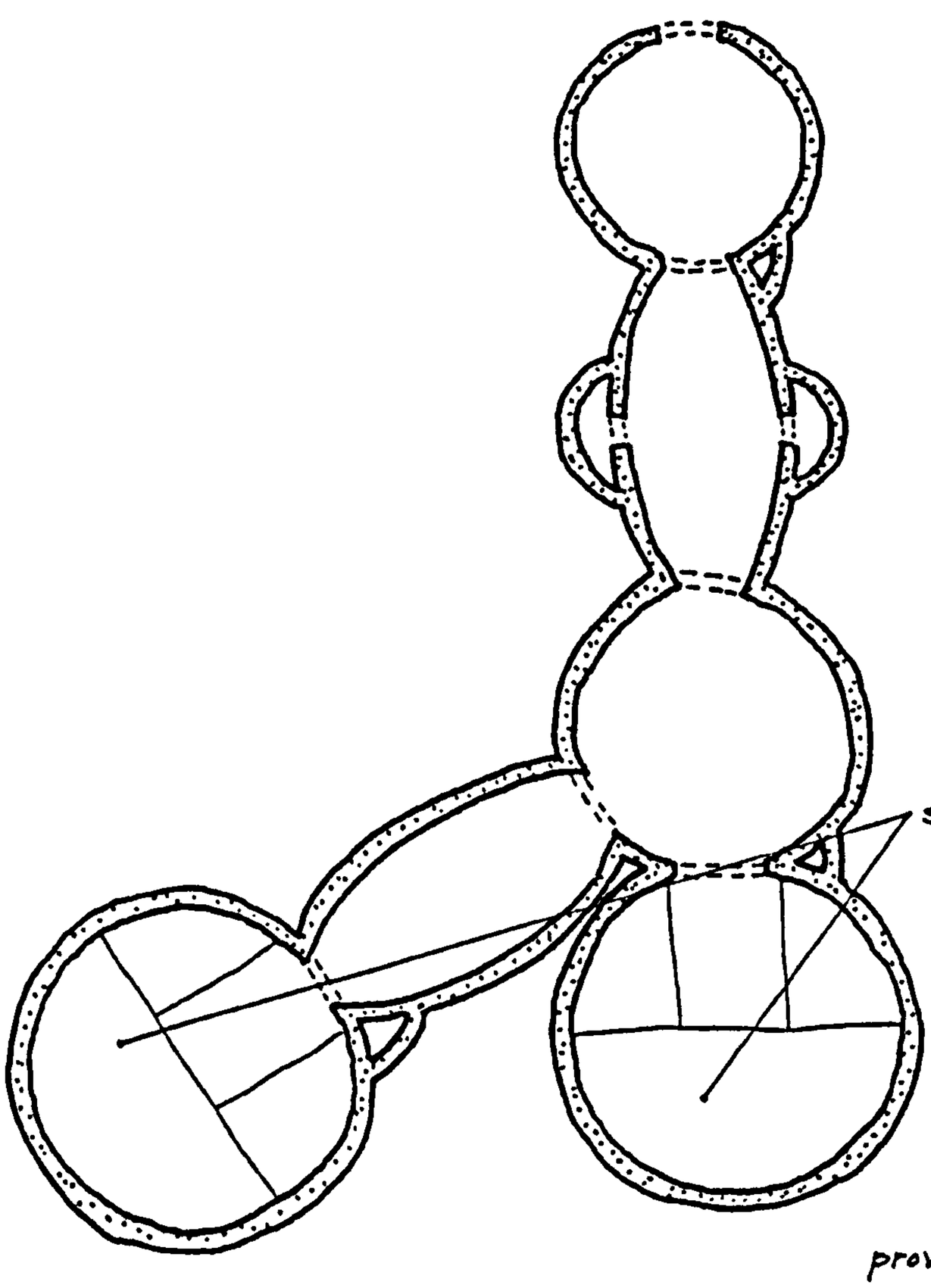


Fig. 57. Double snow house with long common entrance tunnel (Boas, 1974).

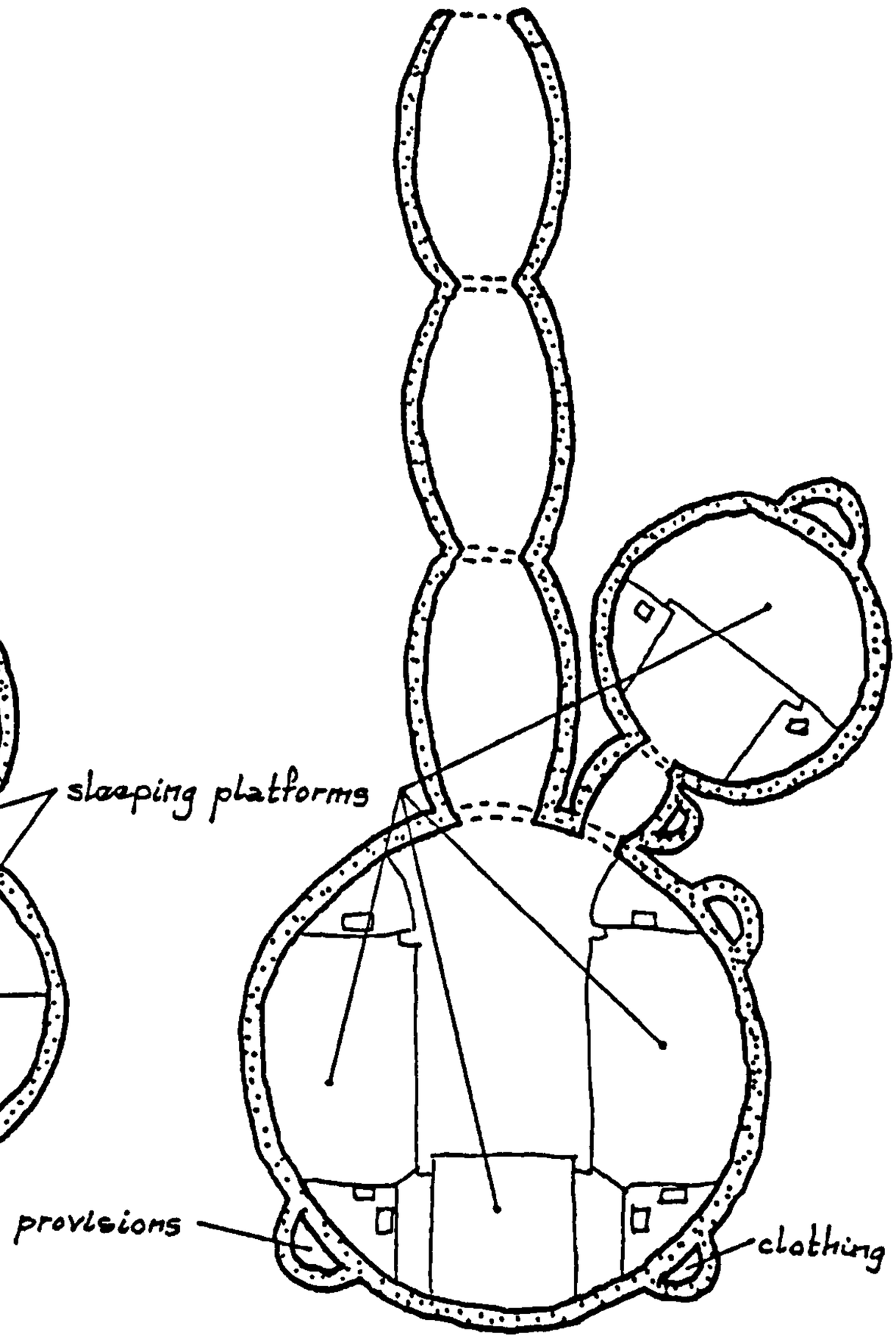


Fig. 58. Double snow house with 2nd house attached to main room of 1st house (Boas, 1901).

the larger house. This group housed 3 families composed of 12 persons. The larger house measured 7m wide by 4m high, and the central floor area 4m by 2m. Three platforms were arranged in a 'U' around the sides and back wall presenting a third variation to the sleeping platform arrangements in Figs. 43 and 44 (Boas, 1901, p. 97).

The double house example in Fig. 59 is composed of two distinct volumes joined together, each with its own short individual tunnel and a longer common tunnel. This house was built by 2 families and was the expression of a desire to be together yet separate. The houses were so close that conversation in one could be heard in the other (Jenness, 1922, p. 69).

The culmination of the proximity of two snow houses into a single two-dwelling house is shown in Fig. 60. This house was formed by 2 main domes covering the 2 living areas and a third covering the forecourt and having the same height as the other domes. The entrance tunnel was enlarged for storing the snow shovel and other items too large to bring into the main snow house. The tunnel curved toward the north so as to allow the dominant

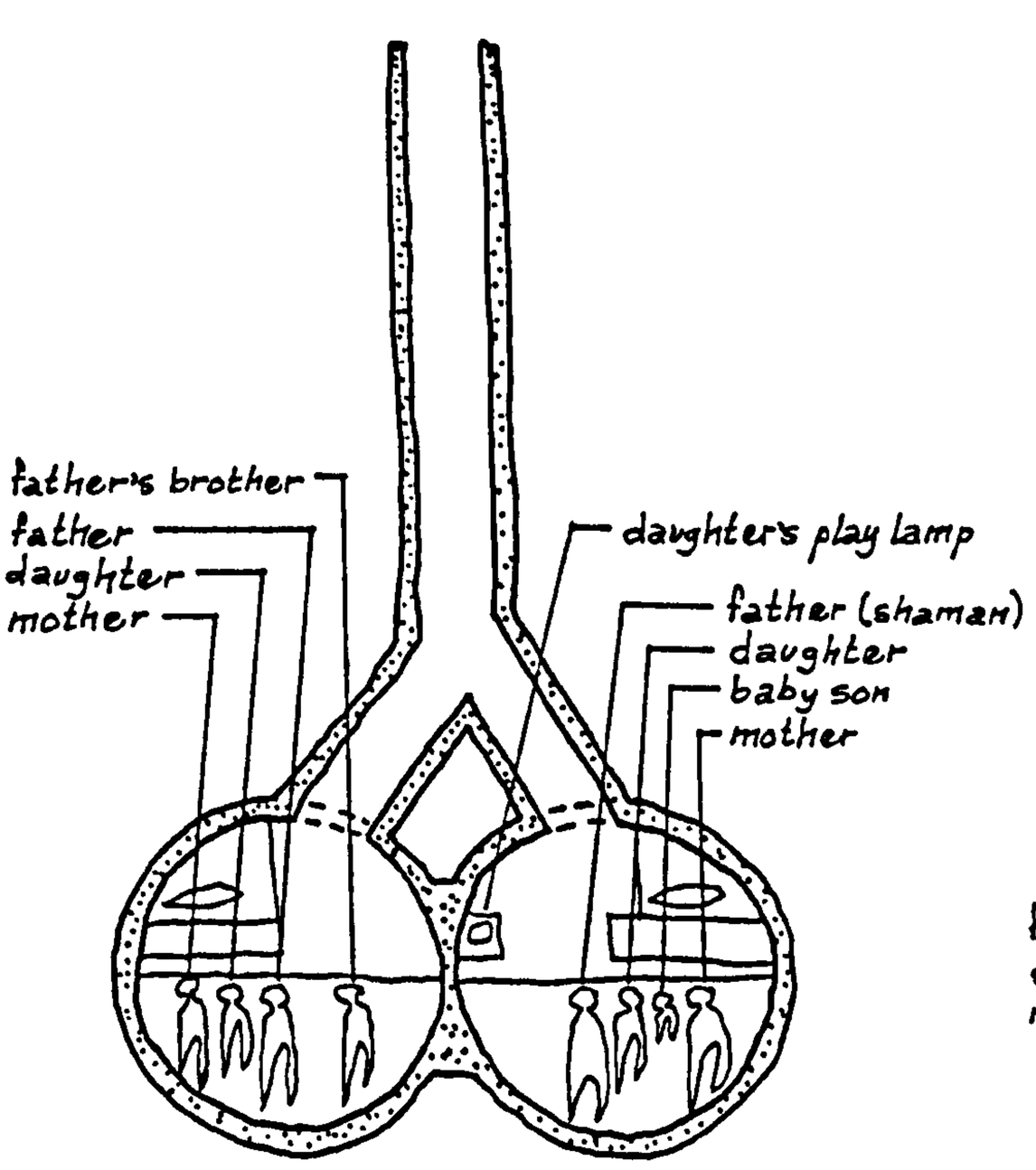


Fig. 59. Double snow house - separate rooms and common entrance tunnel (Jenness, 1922).

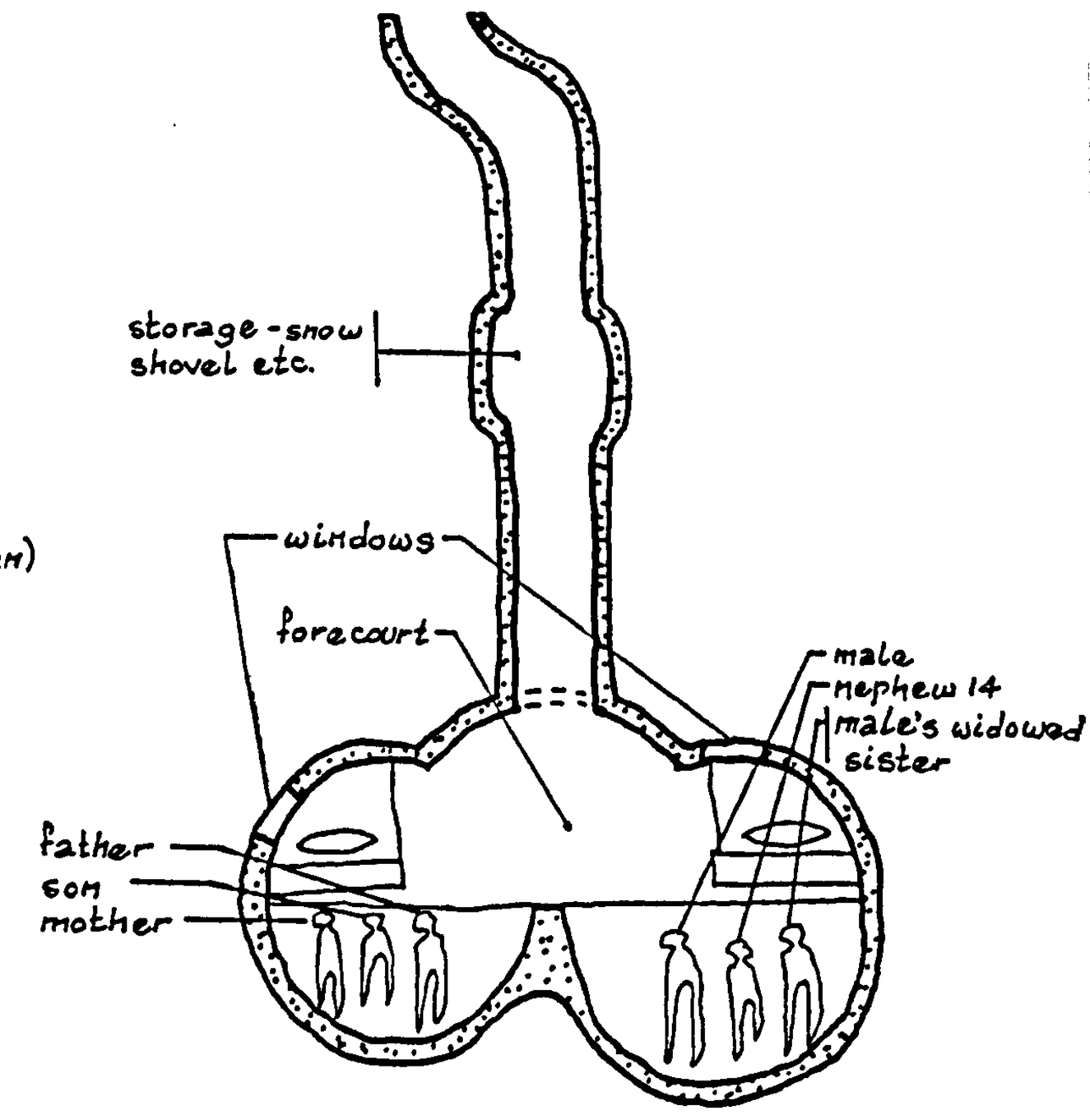


Fig. 60. Double snow house - common forecourt (Jenness, 1922).

east-west winds to blow clear of the entrance. This portion could be changed to another orientation when the wind blew from another direction (Jenness, 1922, p. 70). Fig. 61 shows a house similar to the previous example with a large dance house taking the place of the forecourt. The houses in Fig. 60 were parallel to each other while in this example they were at right angles to one another. These two houses were originally built the same as the house in Fig. 60, but the front walls of the two houses were demolished in order to erect the dance house. The entrance tunnel was T-shaped with one end or the other of the T closed off depending on the wind direction (Jenness, 1922, p. 71).

Another variant in the junction of two houses around a common room is illustrated in Fig. 62. Here we see the two houses separate from each other structurally, but joined by a small common front room. The double house contained a total of 4 families within the large (5.6m wide x 3.2m high) and small (4.1m wide x 2.5m high) houses (Mathiassen, 1928, p. 126).

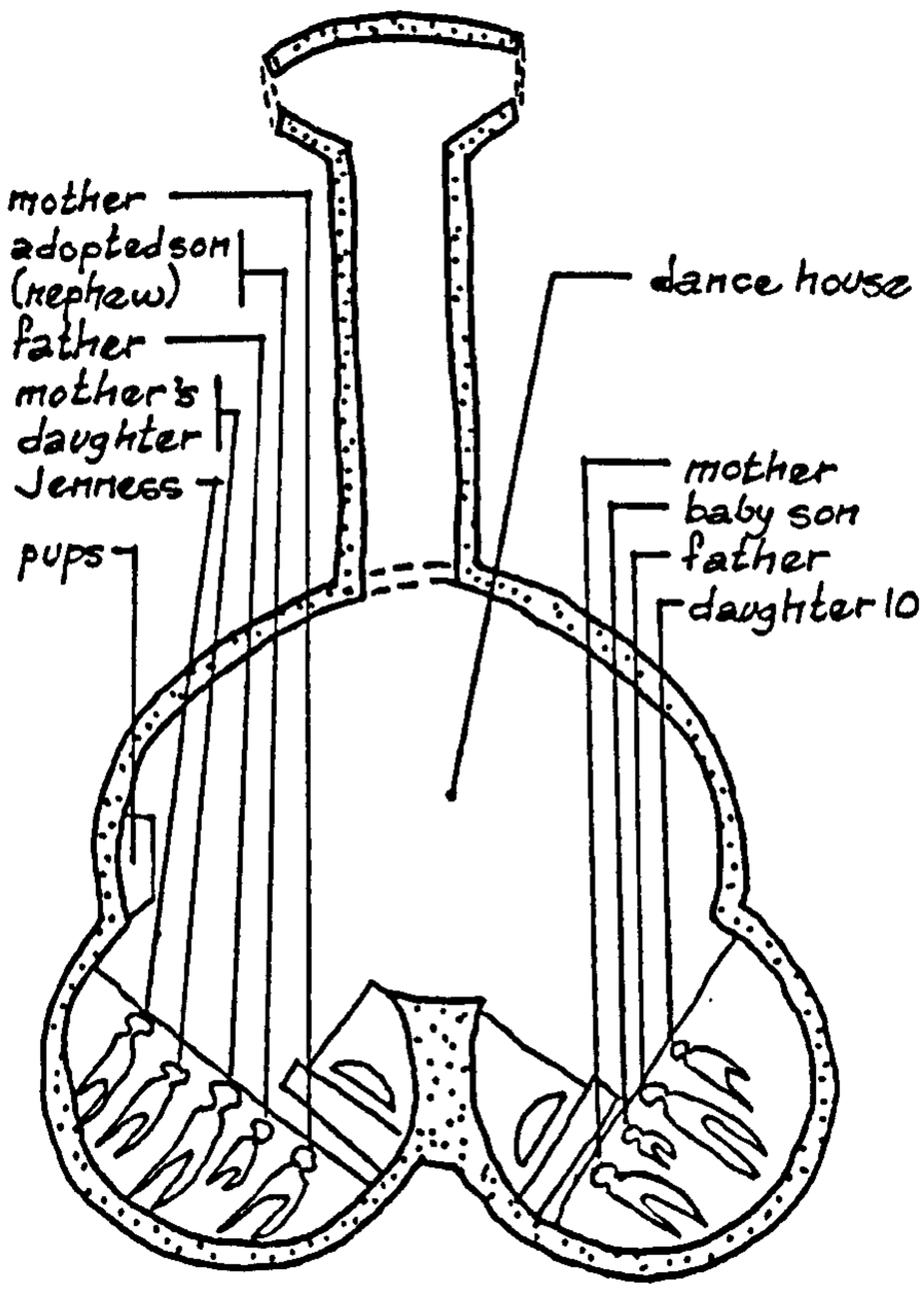


Fig. 61. Double snow house with dance house (Jenness, 1922).

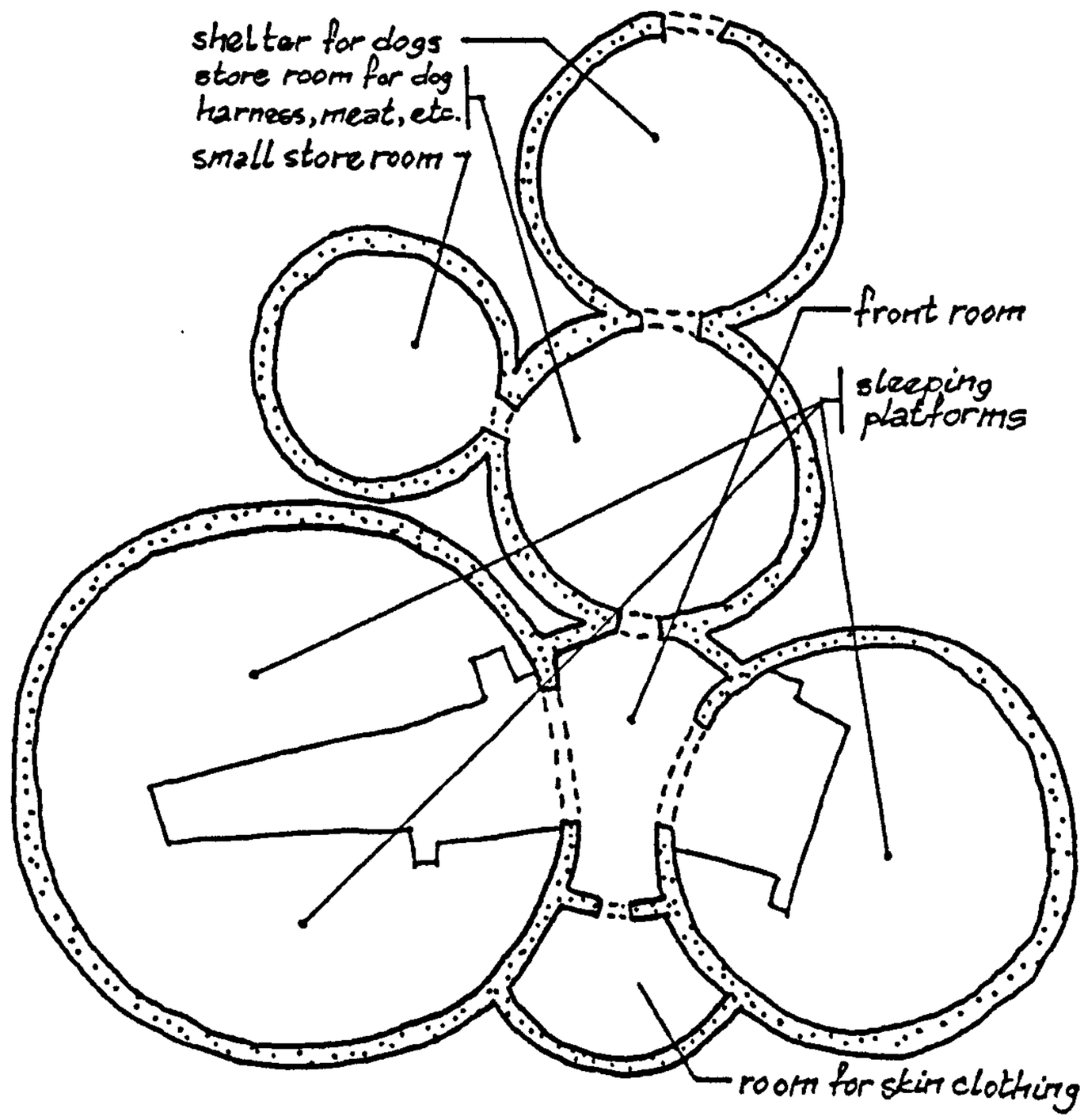


Fig. 62. Double snow house with separate adjoining common room (Mathiassen, 1928).

The last example of a double house is a single house that was expanded to accommodate a larger group of people. See Fig. 63. The Inuit often enlarged a snow house in this manner to accommodate a travelling party, but this was a temporary shelter only. The construction consisted of building an extension to the original house, and then demolishing the interior wall, thereby creating a long platform reminiscent of the communal longhouse (Jenness, 1922, p. 76).

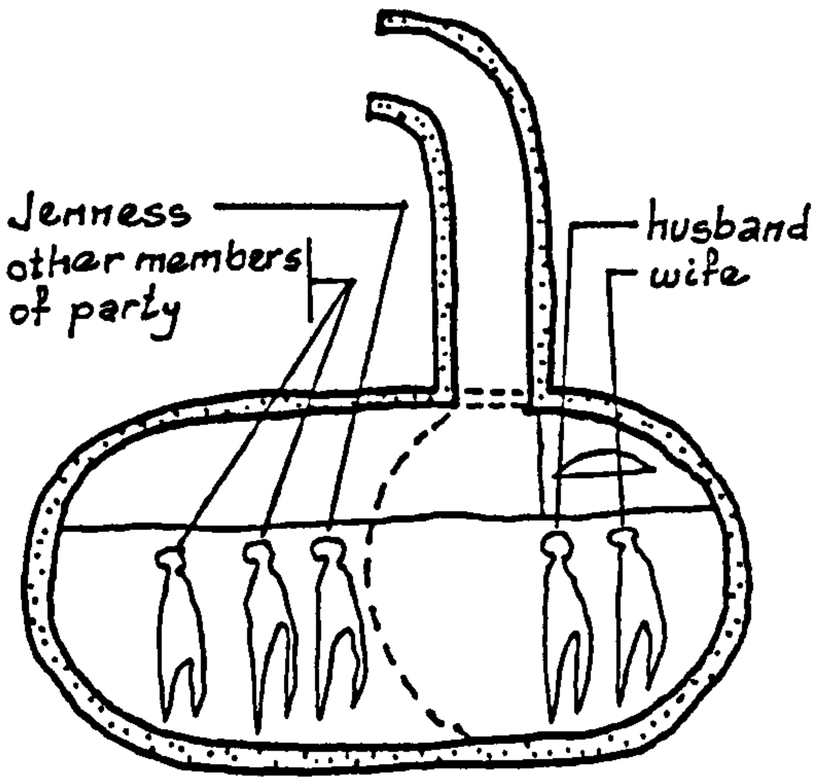


Fig. 63. Single snow house enlarged to double house (Jenness, 1922).

1.4.1.4.3 Triple Snow Houses

The first example is an adaptation of the double houses in Figs. 55 and 56 in which there were two separate houses (in this case not touching each other) with small private tunnels and a long common tunnel. See Fig. 64.

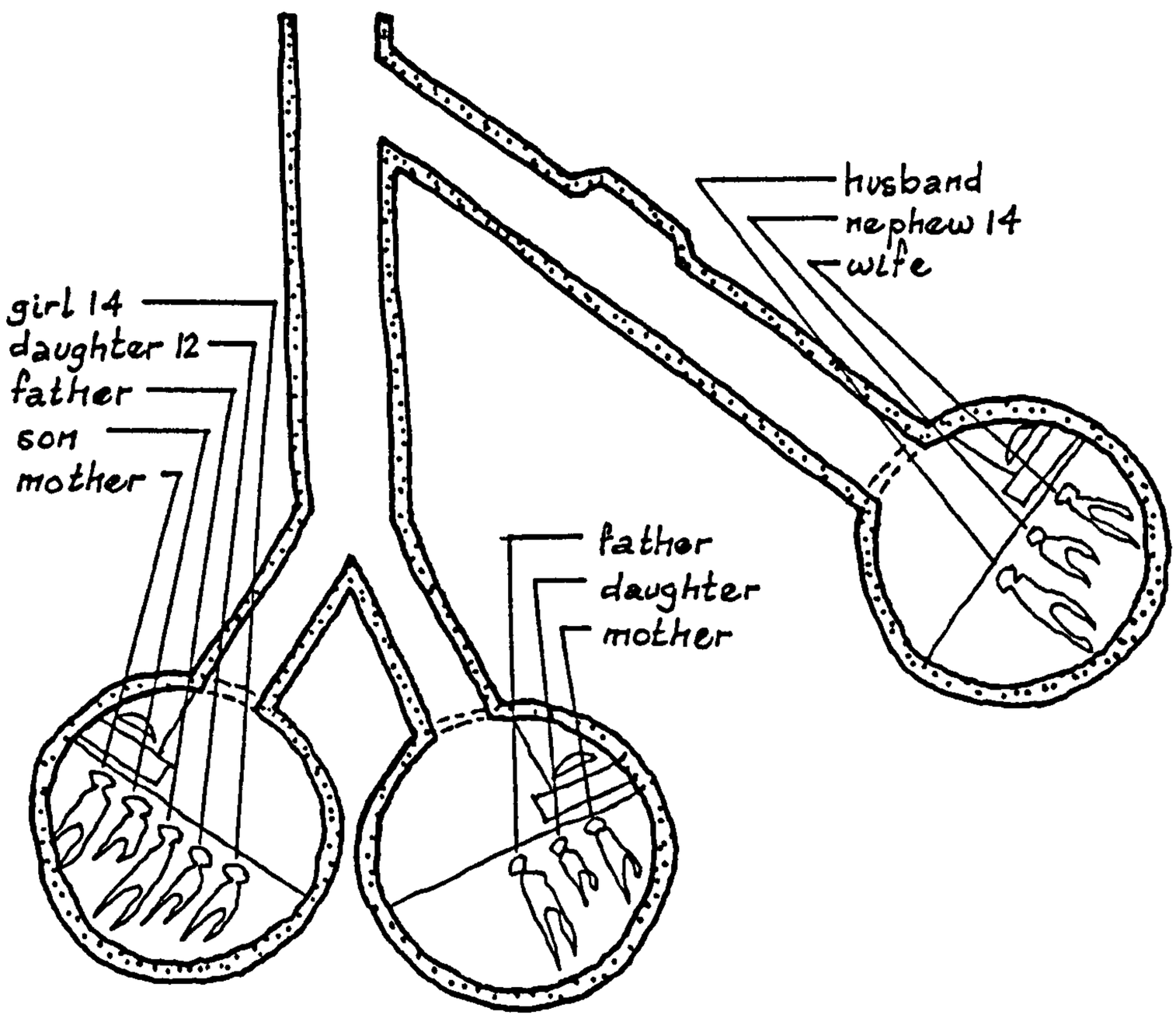


Fig. 64. Triple snow house with 3 entrance tunnels (Jenness, 1922).

The third house in this grouping had a long private tunnel and shared a very small portion of the common tunnel (Jenness, 1922, p. 72).

In Fig. 65 the two closest houses were joined together by a small front room as in the double house in Fig. 60. The third house remained quite separate, being attached by a long private tunnel to a small portion of the common tunnel (Jenness, 1922, p. 73).

In the next example, the three houses are clearly identifiable entities, but were joined together sharing a common space which became the singing house for festive occasions (Boas, 1974, p. 601). See Fig. 66.

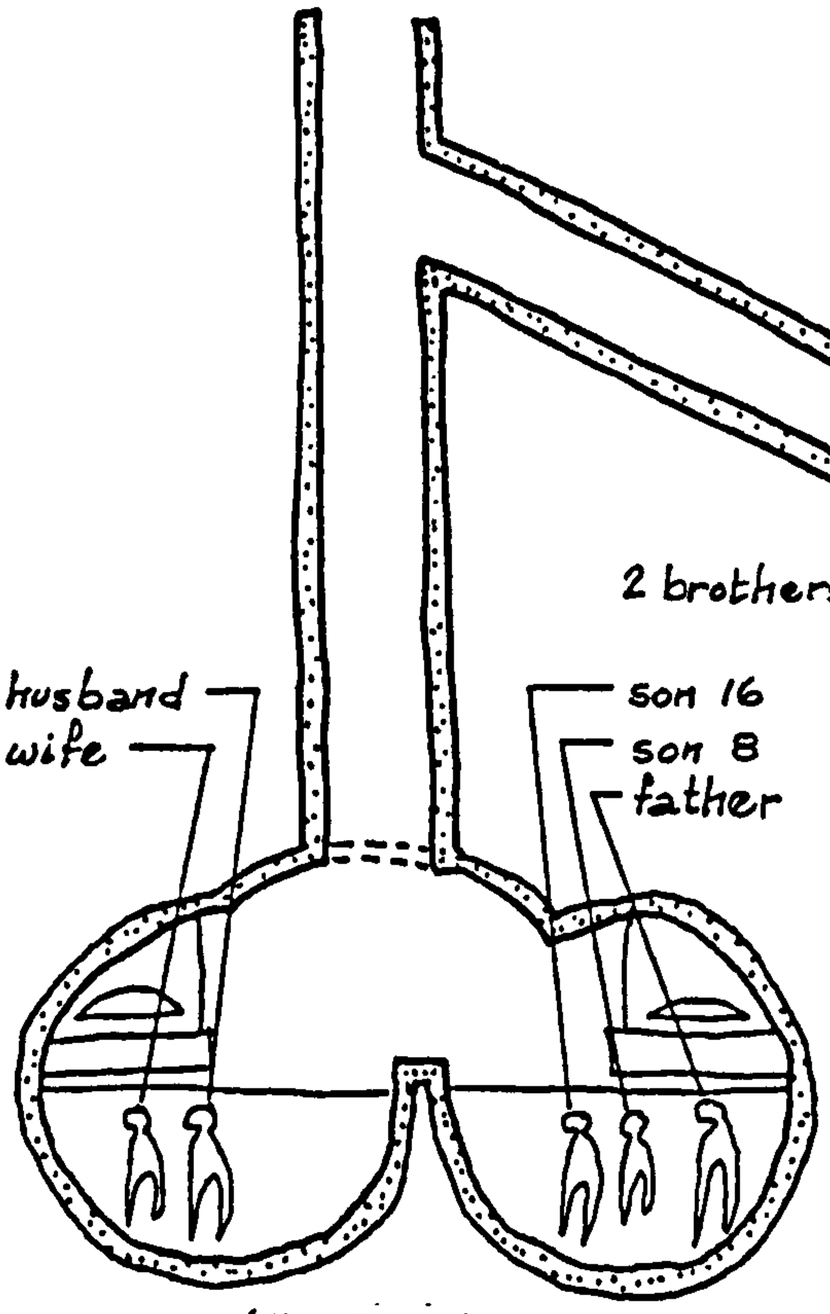


Fig. 65. Triple snow house with 2 entrance tunnels (Jenness, 1922).

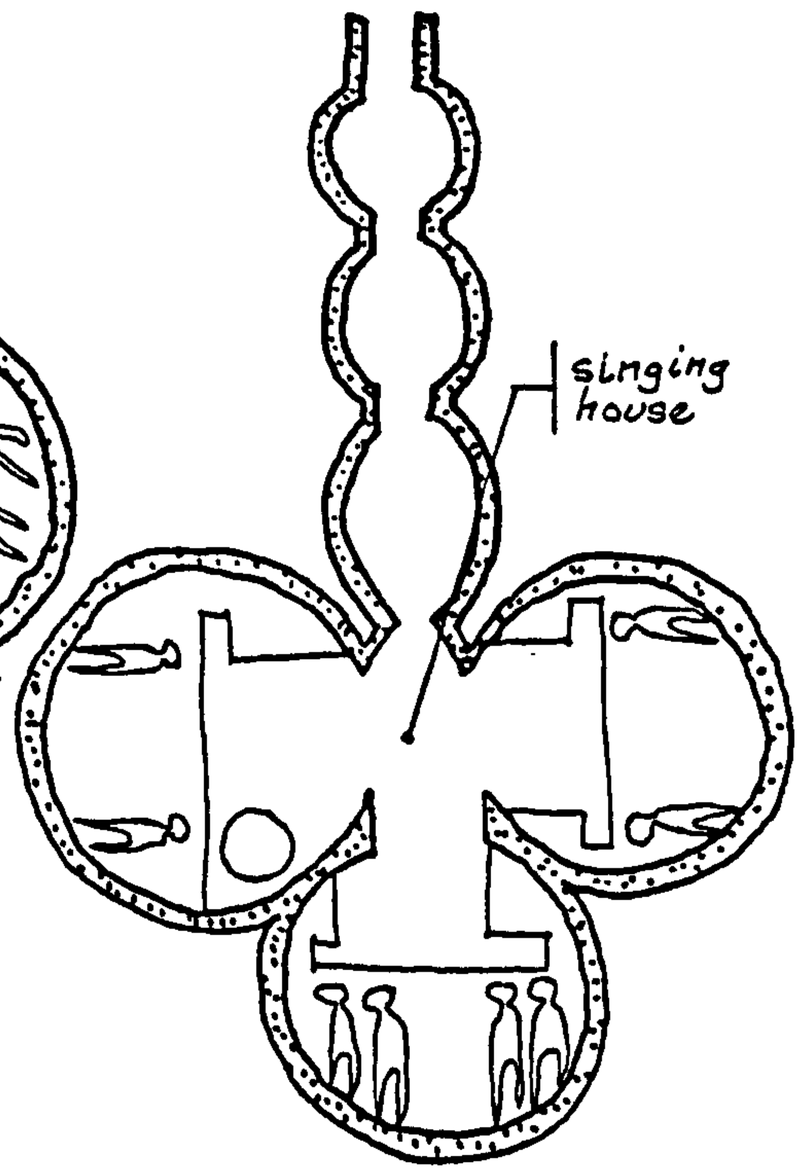


Fig. 66. Triple snow house with 1 entrance tunnel and singing space (Boas, 1974).

In Fig. 67 the three houses are still identifiable entities, but have become appendices to the interior common room which was a distinct separate volume (Boas, 1974, p. 547).

In the last example, the three houses open more generously to a common space. See Fig. 68. In this case the common space dominates the house by eliminating approximately one-third of the wall perimeter. This triple house was originally inhabited by five families, but as the large space was difficult to heat, the single family in the right hand house moved out.

The other four families separated their own houses from the main space in an effort to conserve heat (Jenness, 1922, p. 74).

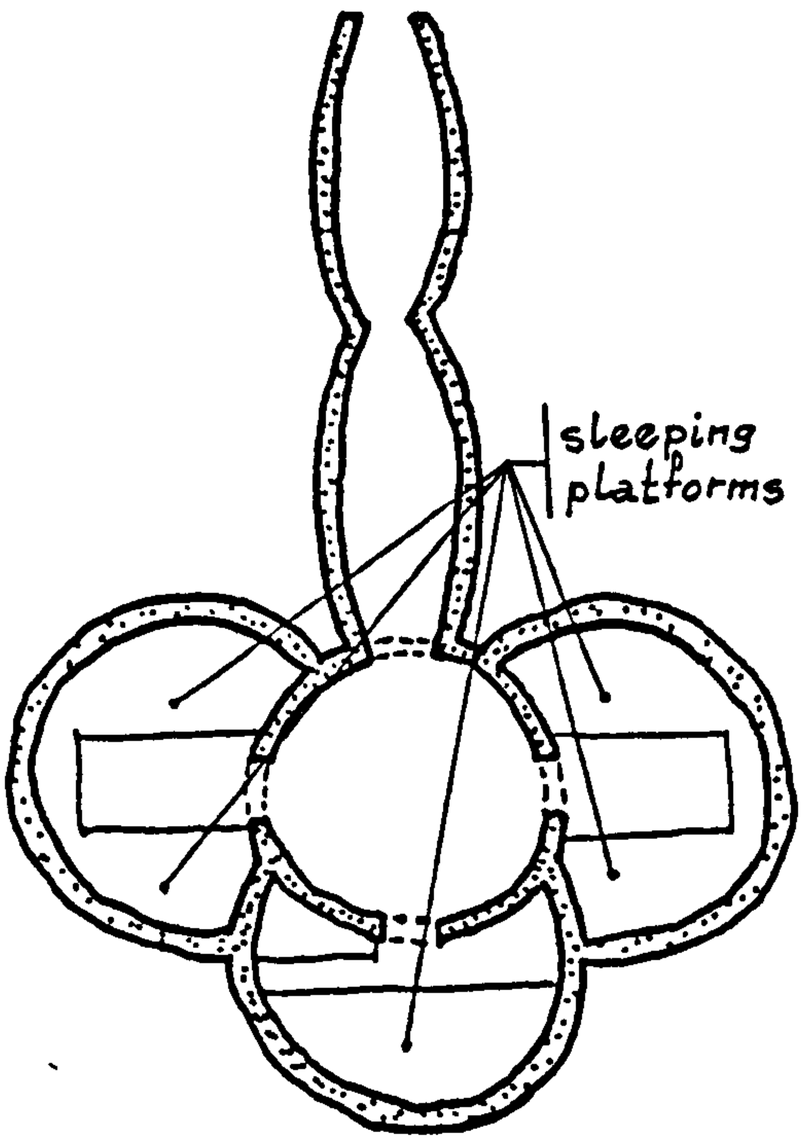


Fig. 67. Triple snow house, with entrance tunnel and separate common room (Boas, 1974).

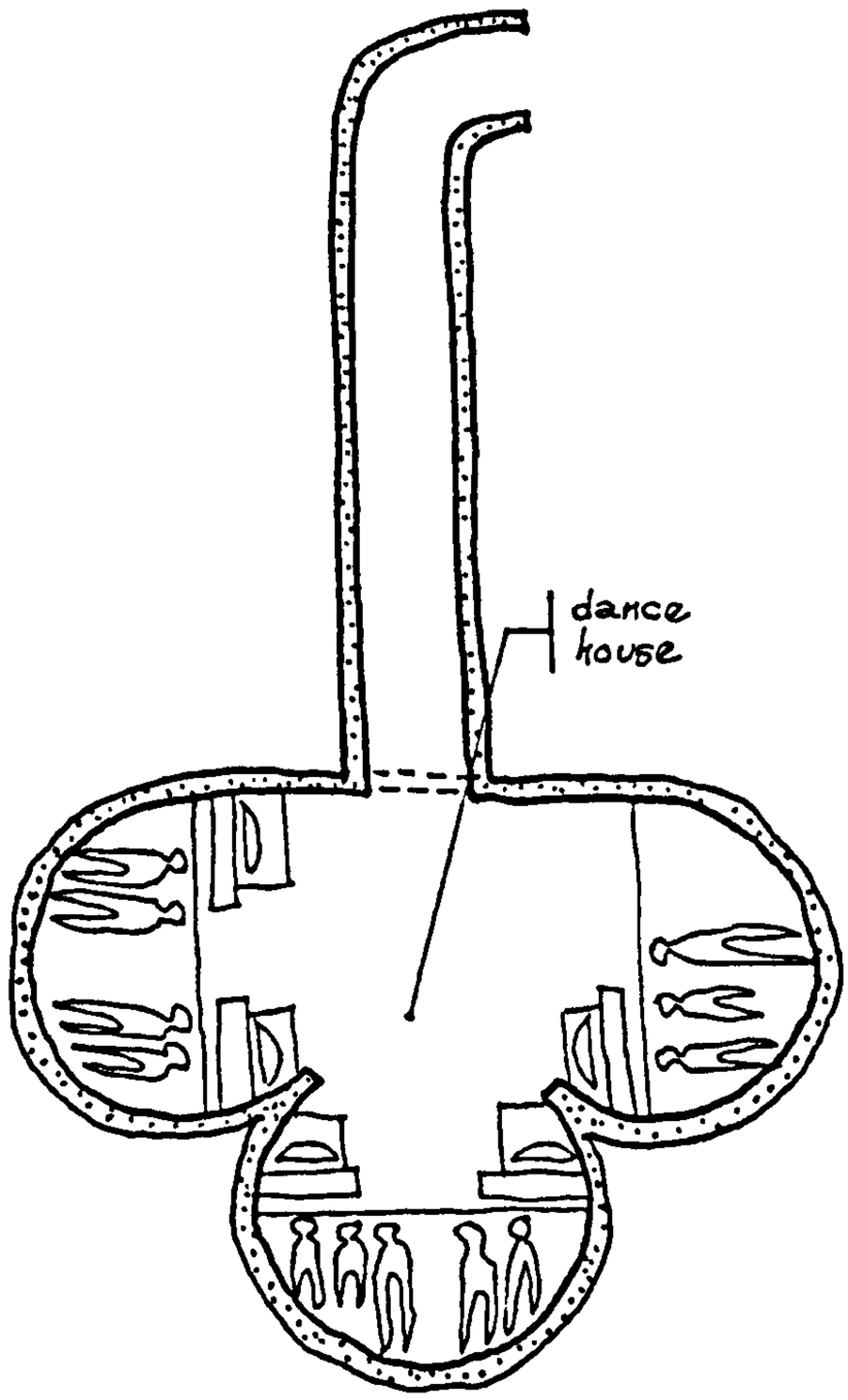


Fig. 68. Triple snow house, 1 entrance tunnel and dance house (Jenness, 1922).

1.4.1.4.4 Quadruple Snow Houses

The first of only two examples found consists of four completely separate snow houses joined to a common front room (which is itself a separate entity) by short tunnels (Boas, 1974, p. 547). See Fig. 69. This model approximates the principle of junction in the double house in Fig. 62 and the triple house in Fig. 67.

Fig. 70 illustrates four houses joined together by a dance house in the manner of Figs. 60, 61, and 68. Two of the houses open directly into the dance house, while the other two open out by a doorway. The two houses which opened directly into the dance house were eventually abandoned, due to the extreme cold and scarcity of blubber, as it was impossible to heat their houses as well as the dance house unless the lamps were burning full.

The other two houses simply closed their doorways and heated their own houses and were thereby able to remain in the house grouping. Jenness reports that the four-house grouping was rare (Jenness, 1922, p. 75).

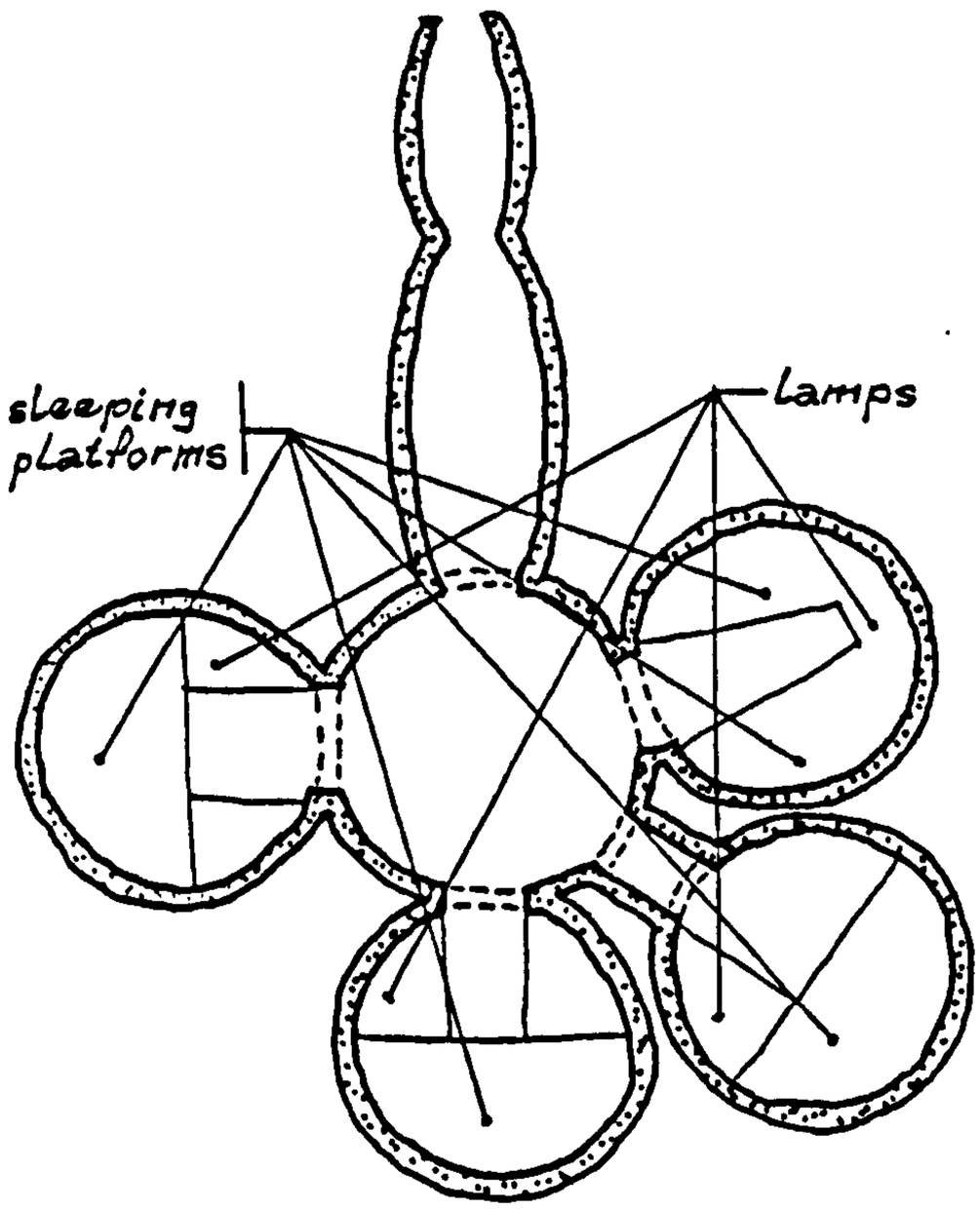


Fig. 69. Quadruple snow house with separate common room (Boas, 1974).

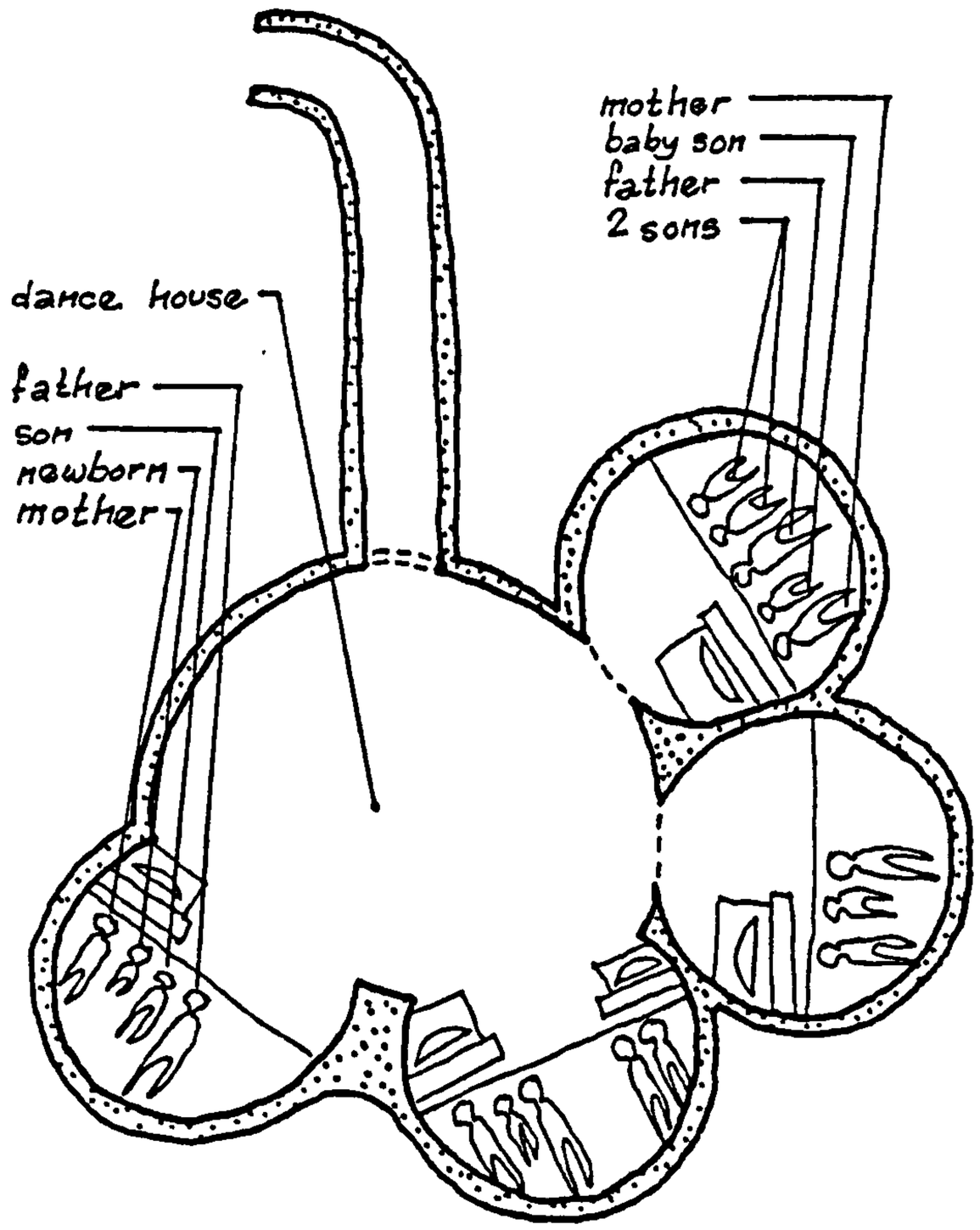


Fig. 70. Quadruple snow house with dance house (Jenness, 1922).

1.4.1.4.5 Quintuple Snow Houses

Mathiassen gives the only example the author found of a five-house group. See Fig. 71. There were seven families living in the five houses, as can be noted from the drawing made during an interview Saladin d'Anglure had with one of the inhabitants. The house group gives the impression that perhaps three houses were built first and that the two other houses were added afterwards (top left and right hand houses) (Mathiassen, 1928, p. 127, and Saladin d'Anglure, 1978).

From this survey of single and multiple snowhouses, it would seem that there are no hard and fast rules or traditions governing the choice of single,

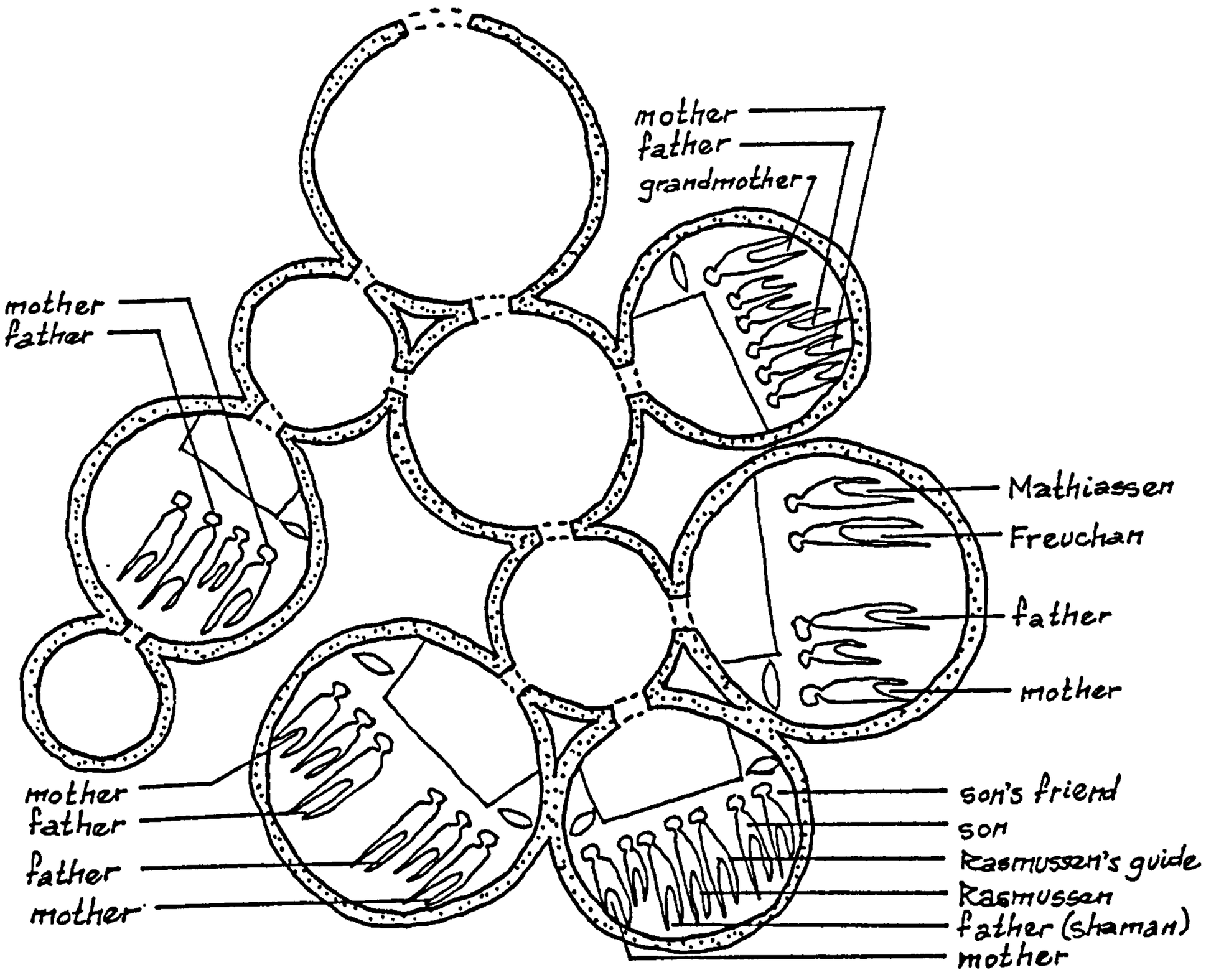


Fig. 71. Quintuple snow house joined by a series of common rooms (Mathiassen, 1928 and Saladin d'Anglure, 1978).

double or triple house (Quadruple and quintuple houses are considered rare cases). Availability of snow, or spontaneous grouping of kin or friends appears to be the main reasons for grouping together in multiple-house groups. It was noted that often houses were added to existing houses when a family arrived later at an established camp. Often two families who were together in one camp or village would build apart in another camp, apparently having tired of one another's company. Jenness noted that the Inuit are individualistic when he observed that two families sharing the same house kept to their own side of the platform, even though there was no line of demarcation (1922. p. 74).

From the preceding inventory of various snow house forms and groupings, it is clear that within the seemingly limited building forms and materials there was a good deal of variance. The house domes are combined side by side (Figs. 59, 66, 68, 70); they interpenetrate other domes (Fig. 61);

they are joined together by part of another dome (Figs. 60, 62, 65); they are appendices to a common-use dome (Figs. 67, 70); they are attached to a common-use dome by a short tunnel or a doorway (Figs. 57, 69, 71); or they simply are extensions of the original houses (Figs. 63, 68). The groupings range from completely detached houses joined loosely by tunnels (Fig. 64) to the single house form made up of several houses (Fig. 70). Judging from the number of variations reported, and Jenness' own observations, the double and triple houses were relatively common.

The snow house was an ideal housing solution for a nomadic people. The Inuit were able to move from one hunting area to another carrying a minimum of materials. They often cached their belongings needed for the summer, but most equipment was useful all year round. Caribou skins used for tent covers, for instance, were used for the interior lining of the snow house, and along with the tent poles were used to replace the snow roof in autumn and spring. The snow blocks provided good insulation, and with a single stone lamp, they were able to keep the house warm. The form of the house concentrated the reflected radiant heat towards the centre and with the inner layer of skin, created a smaller volume to heat as well as adding a layer of insulating air between the snow walls and the occupants.

Snow houses were not permanent houses, because of their sensitivity to temperatures, especially those houses without skin linings. If the temperature was too hot then the snow would melt and droplets of water would fall on the occupants, or, if on the other hand it was too cold, ice crystals would form in the air. In any case, the interior of the dome would become dirty after a certain time, so that the inhabitants would have to build another snow house. According to Saladin d'Anglure, they had to build at least three or four houses during a winter (in Baillargeon, 1979, p. 42). The Inuit, however, also changed sites when game in an area was hunted out or became scarce. Stefansson mentions that they hunted in a 5-mile radius around the village, so that when the area was hunted out they moved on to another site 10 miles further on (Stefansson, 1913, p. 168).

The interior arrangement of the snow house was quite simple. See Figs. 48 and 49. The platform was U-shaped around the periphery of the snow house. The rear portion of the platform was used for sleeping, but it was also used

as a work area, as a living room for entertaining friends, as a game room, as a resting area, etc. This was the space for all activities related to the Inuit domestic, social, intellectual, and spiritual life. Around the perimeter of the actual area occupied by the people were places for storage, thereby maximizing the use of the circular plan. The cooking platform on either side of the entranceway had a stone lamp on it with a drying rack above as in the semi-subterranean houses. Below the cooking platforms were storage spaces, one of which was for rubbish and the other for meat. The entrance tunnel was used for storing outdoor equipment, certain food and skins, and also as a shelter for the dogs in stormy conditions. The women spent most of their time indoors in winter, going outside to other houses for brief visits. The men were outside much of the time hunting, but spent some time indoors repairing equipment, etc. (Baillargeon, 1979, pp. 37-42).

From this description it is quite clear that the snow house was an excellent dwelling form from the point of view of comfort, culture, economics, and structure.

1.4.1.5 Tents

Tents are a product of a different ecological system. Snow houses were constructed of abundant indigeneous materials as were, to a certain degree, the stone, sod and semi-subterranean houses. Tents were made from wood supports and the skins of animals that had to be hunted. The skins were a by-product of the main activity of finding food, and therefore were a sub-system of the larger subsistence economy. The snow house could be easily abandoned because it was a material that was readily available and required little effort to transform into a housing form. The same was not true of the tent, which required effort in hunting, skinning and drying, and finally the sewing together of the skins (Baillargeon, 1979, pp. 43, 44). Tents were transportable and therefore were the major housing form in late spring, summer and early autumn when the Inuit moved frequently seeking a variety of game and following their migration.

The stone rings left by tents have been found in many locations in the Arctic, and their forms varied from circular, oval, rectangular to square (Jenness, 1922, p. 82). See Fig. 72. Tent rings were found dating from 200 B.C.,

the Early Dorset period (ovel-shaped rings); 500 to 800 A.D., Late Dorset (rectangular rings); 1200 A.D., Thule period (round and oval rings); and more recently from the present century (Helmer, 1980, pp. 436, 439; Maxwell, 1980, p. 509; Mathiassen, 1927, p. 102; Jenness, 1922, p. 82).

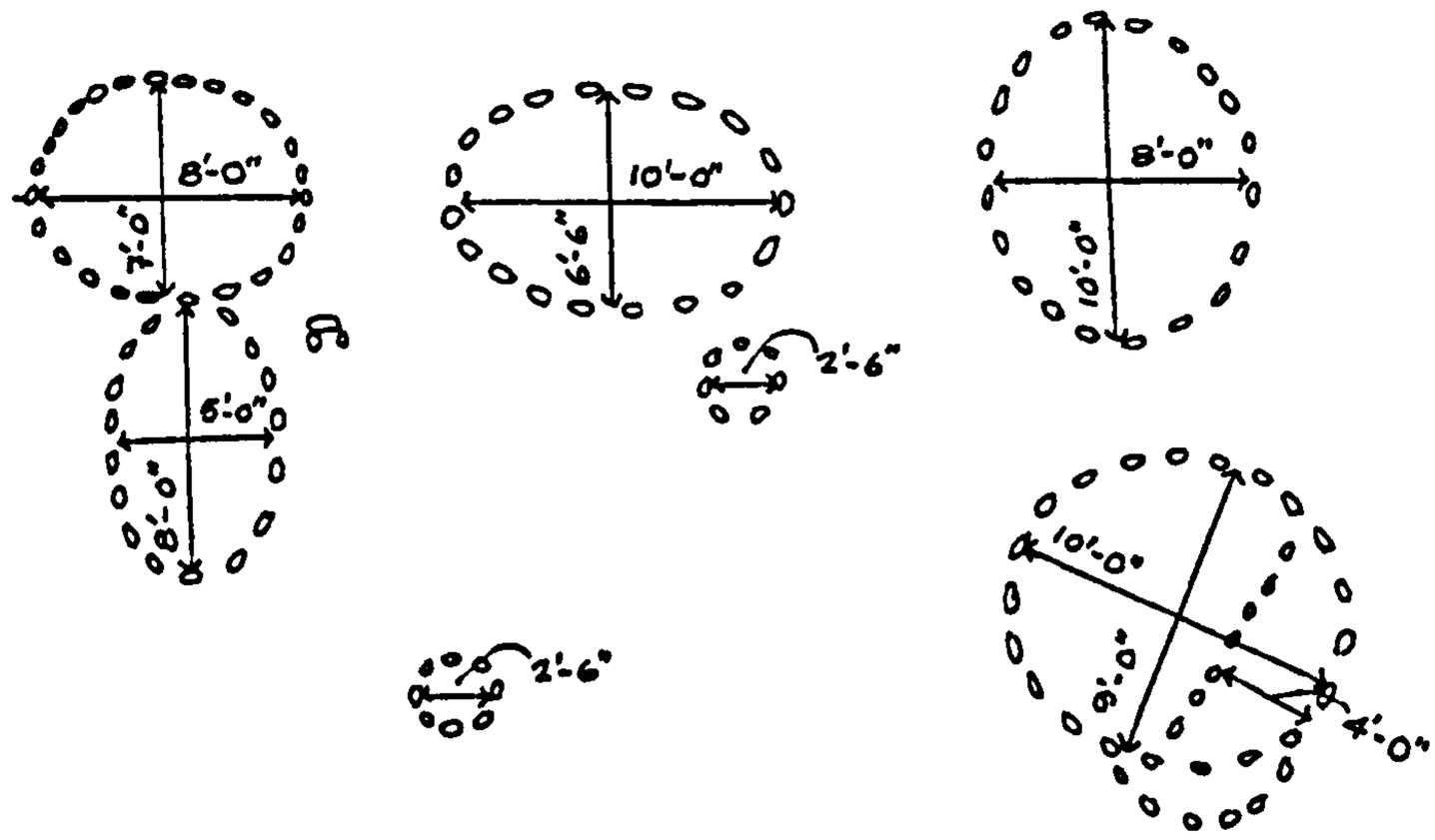


Fig. 72. Oval stone tent rings (Jenness, 1922).

1.4.1.5.1 Single Tents

Tents were made of either deerskin or sealskins, and occasionally of musk-ox skins. When made of sealskins the bearded seal was usually used (scarcer than the smaller seals), requiring between 10 to 15 skins to make a tent. Once the skins were dried, the inner layer or membrane was detached from the skins thus doubling the usable area. The opaque portion of the skins was used for the apse end or rounded section of the tent where the platform was situated, and the translucent section of the skins was used on the forward portion of the tent allowing light to enter. The skins were stretched over the wood structure and anchored on the ground by rocks. The sites chosen were slightly sloping for good drainage, and the tents were situated such that the sleeping platforms were higher than the entrance. The interior arrangement was similar to that of the snow house with a platform taking up approximately half of the space and in one corner a place to store food. Note the use of the rounded space at the back of the platform for storage as in the snow house. The lamp was used in the tent, but its use was greatly reduced as most of the food was cooked outside on fires made from

driftwood (Baillargeon, 1979, pp. 44, 45). See Figs. 73 and 74 for a plan and a sketch of a tent used in arctic Québec. Jenness describes a rectangular tent rounded at both ends that is similar to the Québec tent (1922, p. 79). Jenness also describes the tents used by the Coppermine

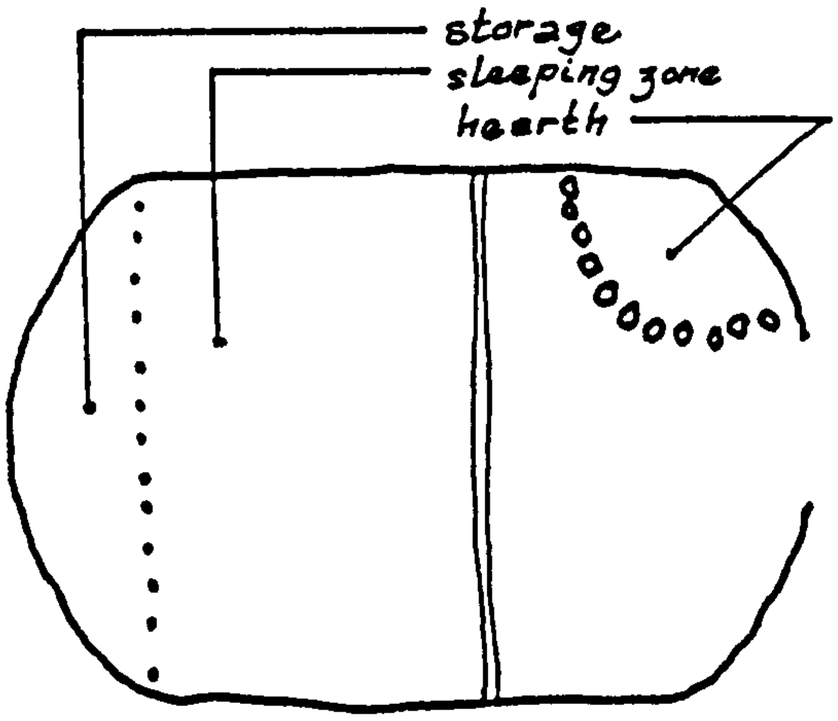


Fig. 73. Typical tent plan (Baillargeon, 1979).

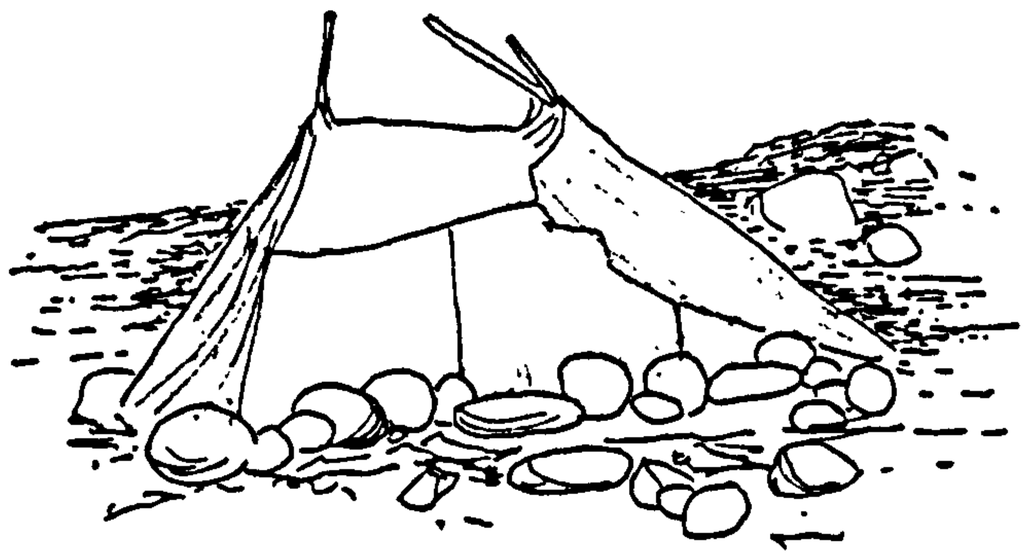


Fig. 74. Arctic Québec skin tent (Baillargeon, 1979).

Inuit which were made from deerskins and weighed approximately 70 lbs. (31.8) and measured 15' (4.6m) long by 11' (3.4m) wide and 7' (2.1m) high. The framework was composed of 10 to 12 poles suppporting a ridge piece. Some of these poles were also used as snowbeaters and walking sticks, indicating the importance attached to wood in the Arctic. The construction was similar to the rctic Québec tent with a slight difference in the shape at the entrance which was straight rather than round (Jenness, 1922, p. 78).

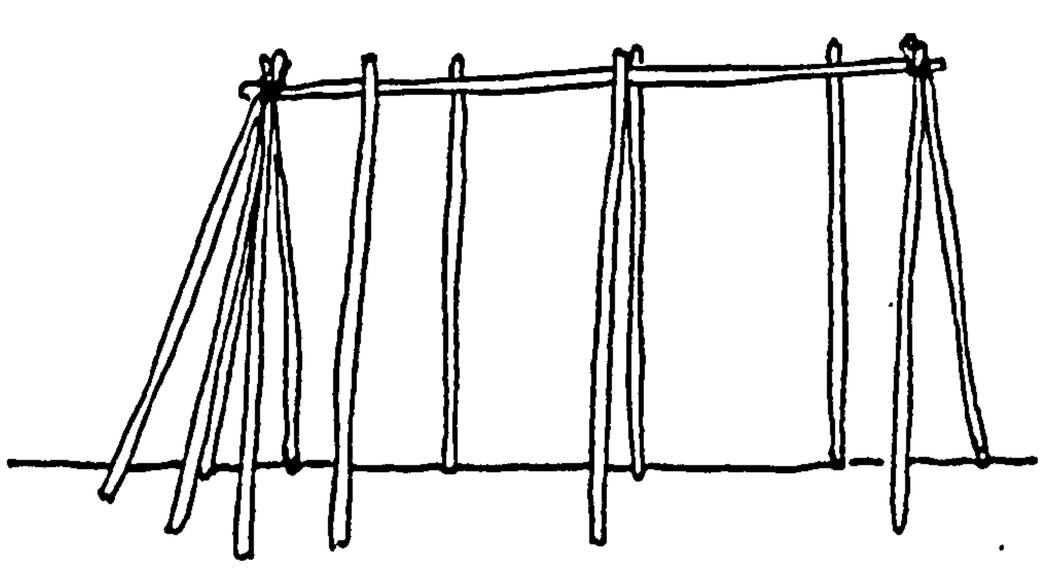


Fig. 75. Wood frame for spring tent (Jenness, 1922).

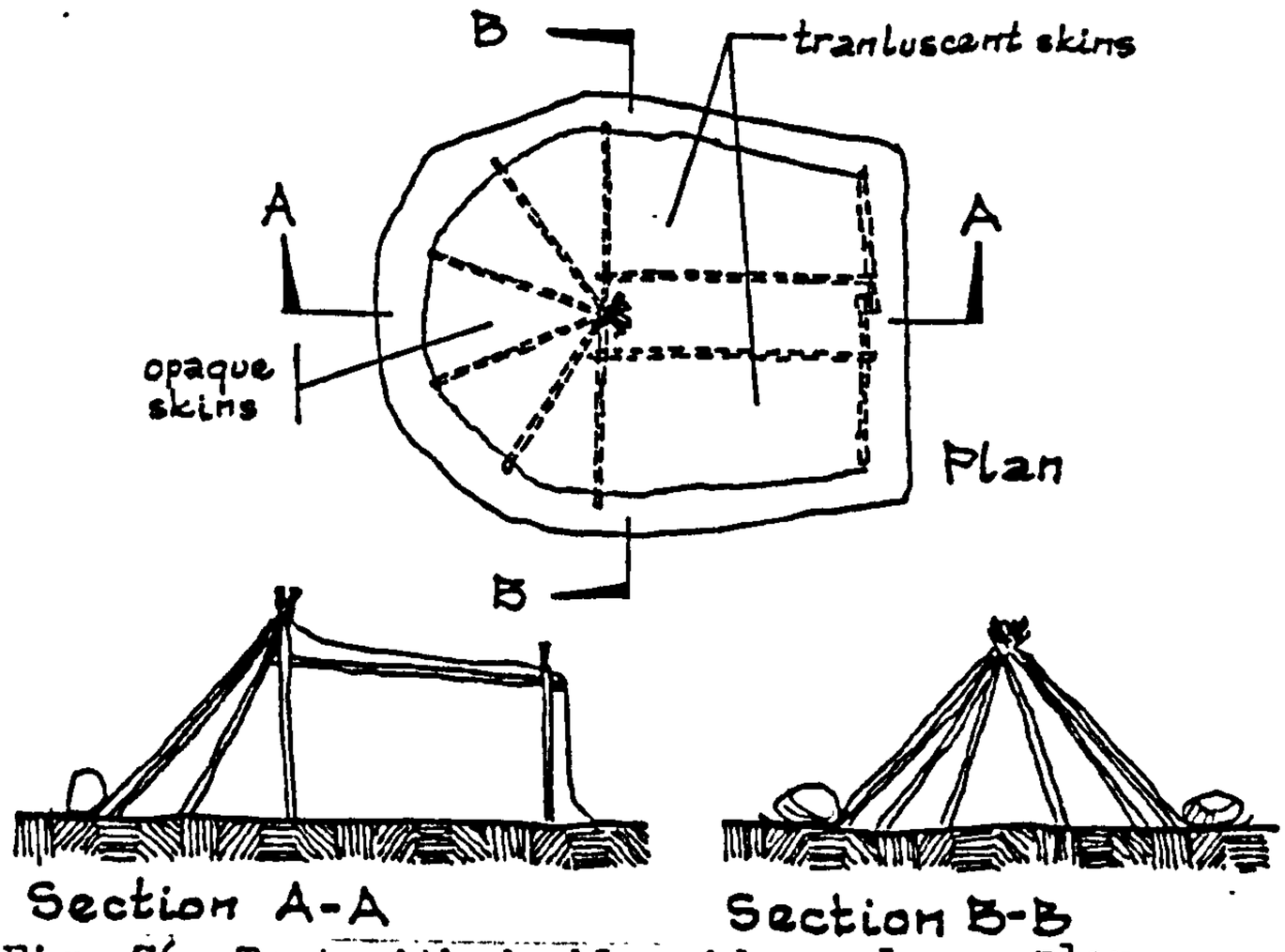


Fig. 76. Tent with double ridge poles - plan and sections (Boas, 1974).

See Fig. 75. Boas describes a tent that was similar in all respects to these tents, but which had a double ridge pole. In some areas of the Arctic the slope at the rear of the tent was 45°, while in other areas the slope was 60°, indicating perhaps a difference in wind velocities (Boas, 1974, p. 551). See Fig. 76.

If there was still snow on the ground when the tents were put up, the poles were set up on the top of a low snow wall. At approximately 1' (31cm) away from this wall another surrounding snow wall was erected and the space between the two walls was filled with loose snow. The tent skins were pegged into this space and covered with more loose snow to keep out the cold air. A short entrance tunnel was made of snow blocks and was attached by tying or jamming the tent into the top of the snow tunnel and covering the junction at the bottom with snow.

The seam at the ridge pole was stuffed with mittens, scraps of skins, etc., to keep out wind, snow and rain. The caribou skins used for tents were usually those not suitable for clothing; that is, they were spring caribou whose coats have long, loose hairs. The skins were laid on the supports with the hairs facing out. It took approximately an hour to set up a tent with its entrance tunnel and outer snow wall. In stormy weather a windbreak wall was set up on the windward side of the tent. These windbreaks were sometimes used in summer to sleep behind when en route to other camps (Jenness, 1922, p. 259). See Fig. 77.

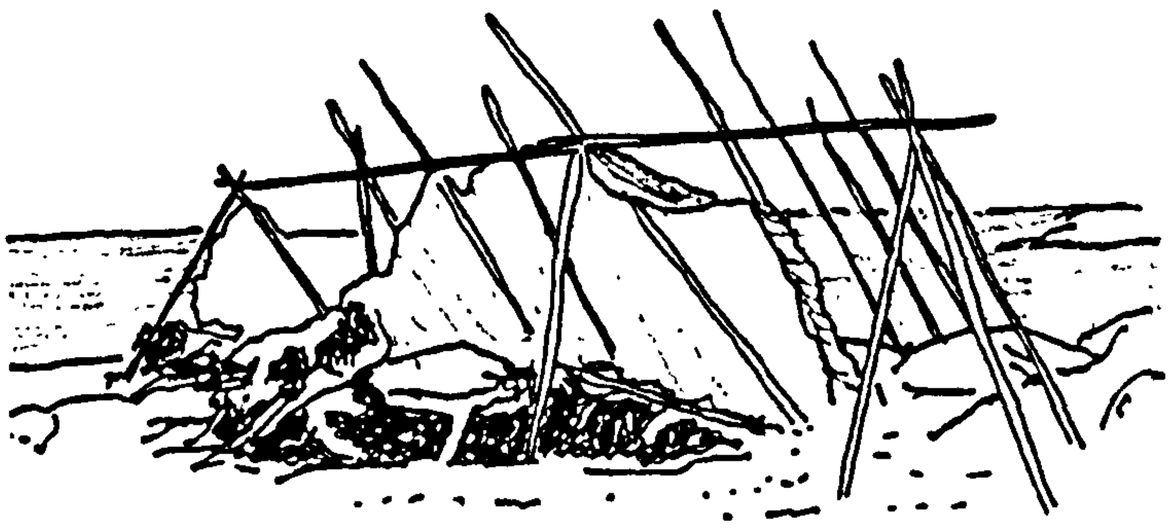


Fig. 77. Windbreak of skins and poles (Jenness, 1922).

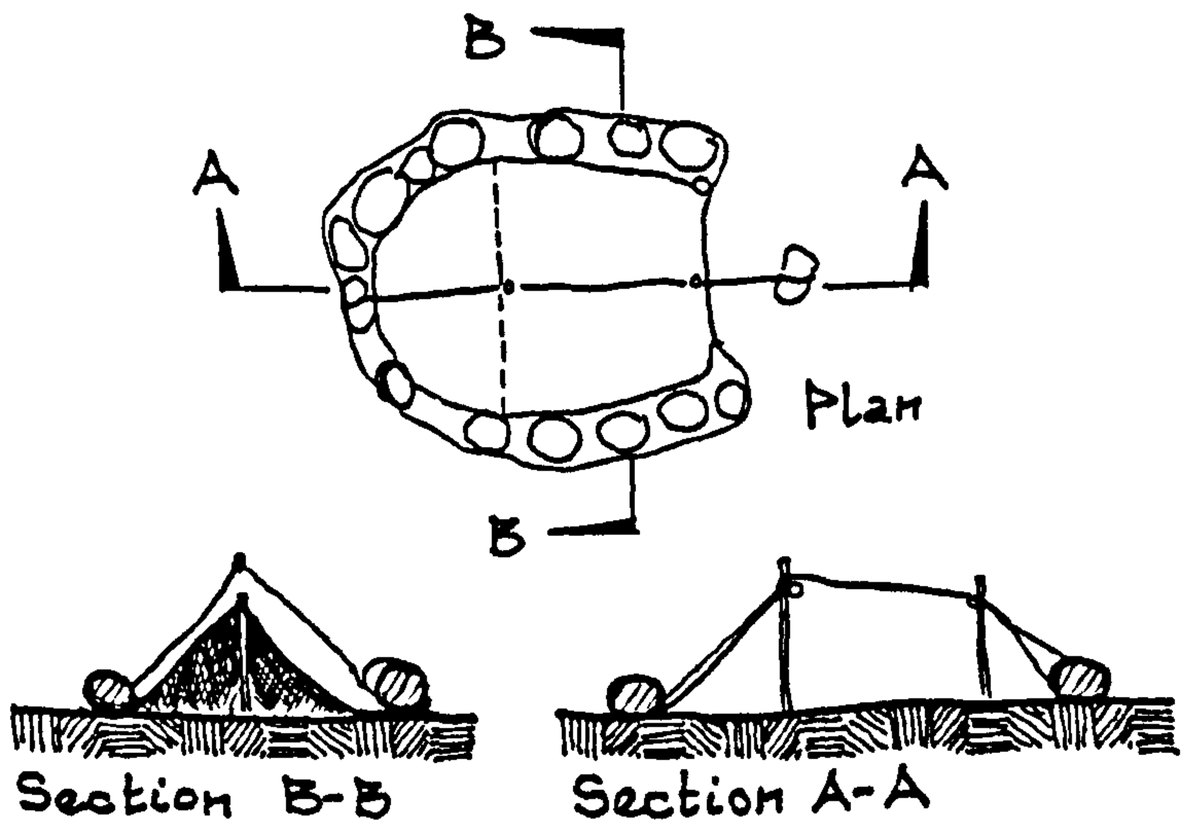


Fig. 78. Tent with minimum wood supports (Boas, 1974).

The interior, as mentioned, was arranged in much the same way as the snow house except that when the tent was set up on the snow, a platform was built, but when set up on bare ground, a platform was not constructed. In inclement weather, a fire was made just inside the entrance, and with an outside temperature at 0°F (-17.8°C) the interior temperature would be 43°F (6.1°C). If the smoke found its way to the back of the tent, the occupant simply lifted the skins at the back creating an air inlet which would drive the smoke out the front. These tents were dark, but because of the dazzling light outside and the extended length of daylight, the darkness was appreciated for sleeping (Jenness, 1922, pp. 78, 79).

A slight variation of this tent existed further north and west where wood was scarce. This resulted in the use of only 3 pieces of wood, 2 used vertically, and 1 at an angle to form the entrance. A thong ran between the tops of the poles and their ends were anchored on the ground by a large rock. The skins were spread over the tent poles in the same fashion as the other tents and weighted with rocks. See Fig. 78. These tents were sometimes supported on whale bones and were 9' to 10' (2.7 - 3.1m) high, 17' (5.2m) long, 9' (2.7m) at the widest part in the sleeping platform zone, and 7' (2.1m) wide at the entrance. The door which faced southwest was usually formed of 2 pieces of bone. In some cases, curved pieces of whale bone were used to anchor the tent skins (Boas, 1974, pp. 552, 553).

Another tent type used mainly in the spring was similar to the Indian 'tipi'. It had converging poles, giving it a conical shape, and was smaller than the normal tents (Boas, 1974, p. 553). Jenness, however, points out that the conical tents he saw 18' (5.5m) high and 20' (6.1m) in diameter were uncommon (1922, pp. 79, 80). He also describes a slight variation of this tent in which only 4 or 5 members meet at the top, while others rest on a hoop attached to these main members about 6' (1.8) above the ground. Sometimes as with other tents, a snow tunnel was added to the entrance (Jenness, 1922, p. 80). See Fig. 79.

Fig. 80 is a sketch of a tent that was known to the inland Inuit in northern Alaska and McKenzie natives, but unknown to the Copper Inuit. The tent was formed by bending willow sticks in pairs and tying them together to form a series of arches. The resulting beehive-shaped tent was covered with deerskin, but later on was covered with cloth (Jenness, 1922, p. 80).

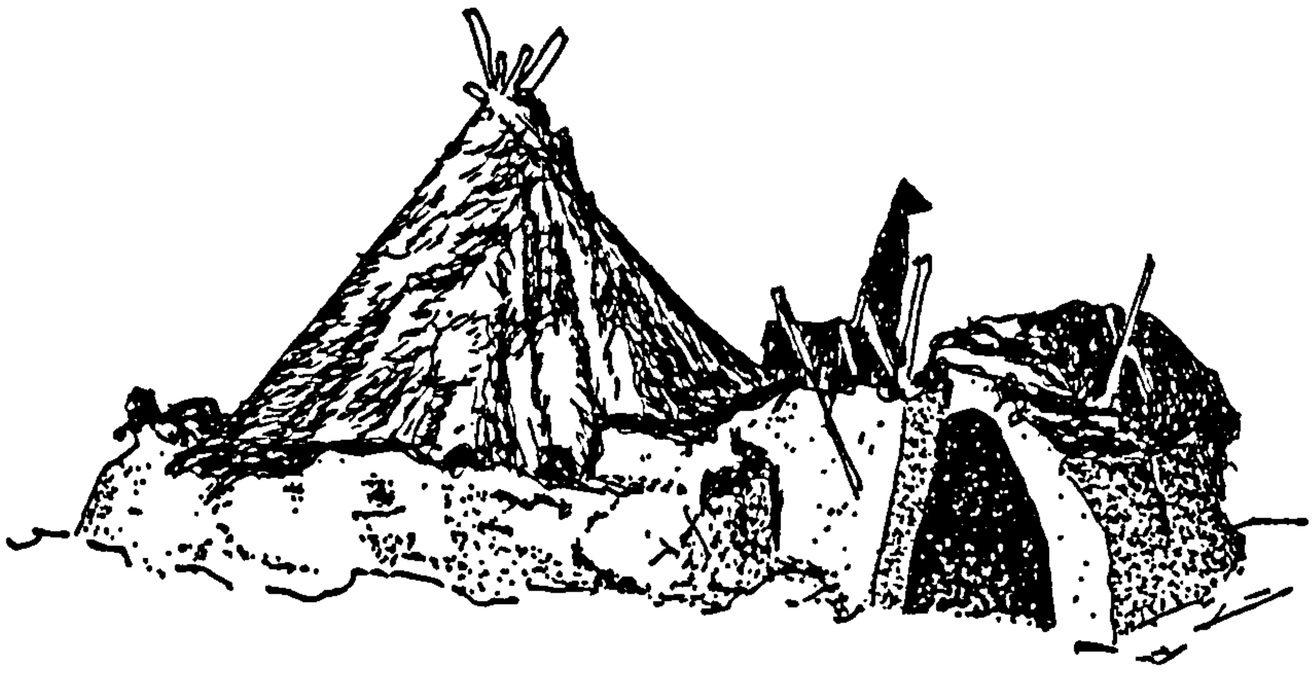


Fig. 79. Conical tent with snow wall and entrance tunnel (Jenness, 1922).

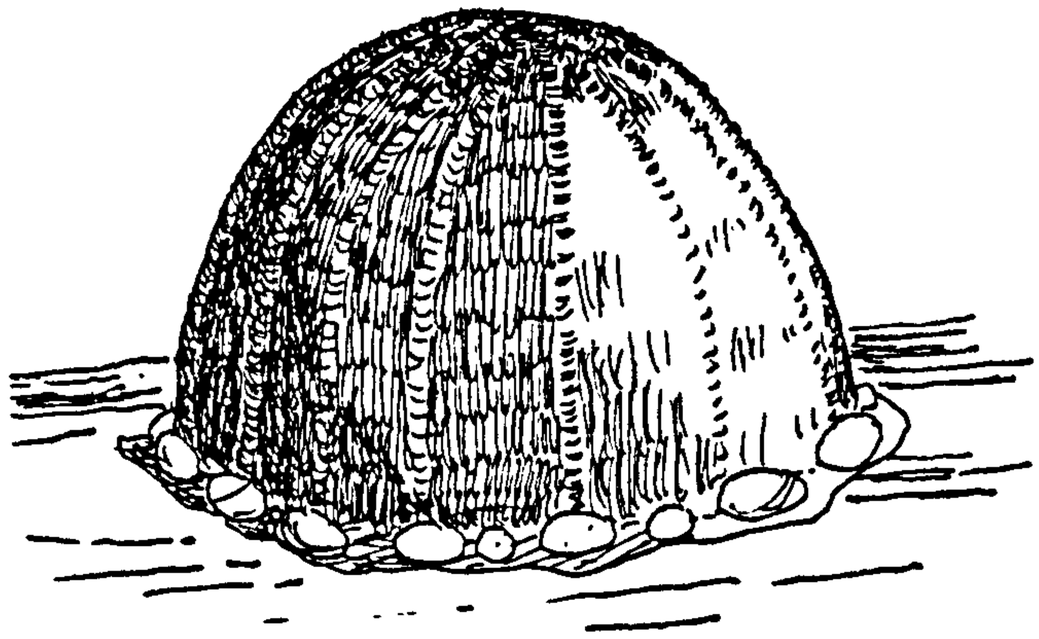


Fig. 80. Beehive-shaped tent (From a description in Jenness, 1922).

The East Greenland Inuit had a different tent form which was fan-shaped. The structure was made of 2 vertical wood poles carrying a horizontal bar which in turn supported long poles stretching from the bar to the ground or a wall of earth placed in a semi-circle. The tent was 8' (2.4m) high at the front, and had a diameter of 10' to 15' (3.1 - 4.6m). As can be seen from Figs. 81, 82, and 83, the major portion of the tent is quite low in comparison to the front of the tent. The tent was covered with 2 layers of sealskins, the first layer with the hair facing inwards and the second layer without hair (rendered waterproof by smearing blubber on it) was laid in 3 breadths with large portions of the upper skins overlapping the lower ones. The portion of the skins spread on the ground was held down with stones. A skin hung from the horizontal member at the entrance closing off the interior from the entrance.

The interior of the tent was arranged much like semi-subterranean houses except that there were no partitions separating the families, as each tent was normally occupied by one family, although occasionally closely related families shared a tent. The platform was at the back and measured approximately 5' (1.5m) wide. In front of the platform stood the lamps and water tubs with boxes placed along the tent walls. In the entry were situated the urine tubs for treatment of the skins. The entrance, as in the semi-subterranean houses, faced the sea. In West Greenland the Inuit sometimes added a short wall in front of the entrance to shelter it from the winds. It was noted that these double skin tents with lamps burning were quite pleasant. These tents were employed from late April to the end of

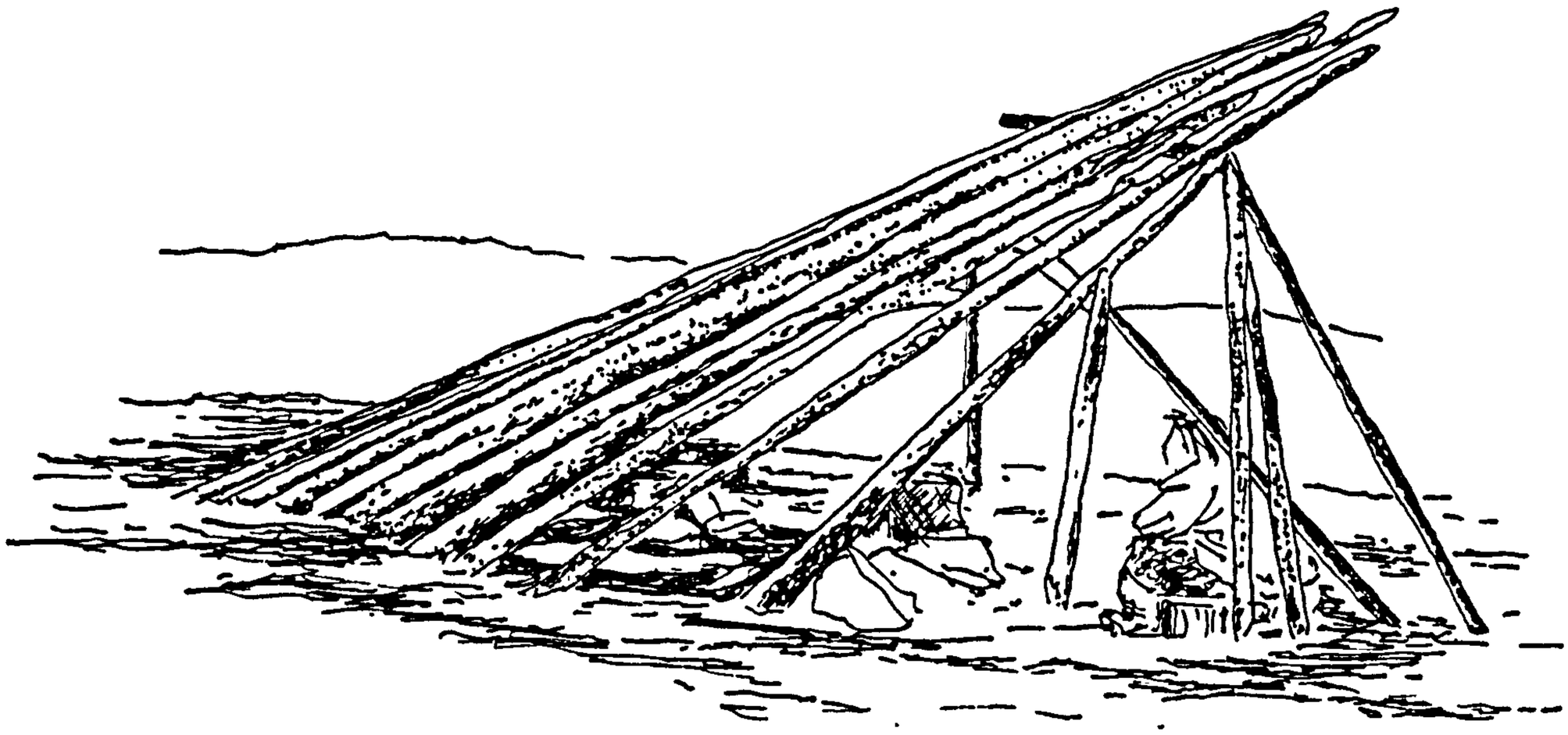


Fig. 81. Fan-shaped East Greenland Inuit tent frame - side view (Thalbitzer, 1914).

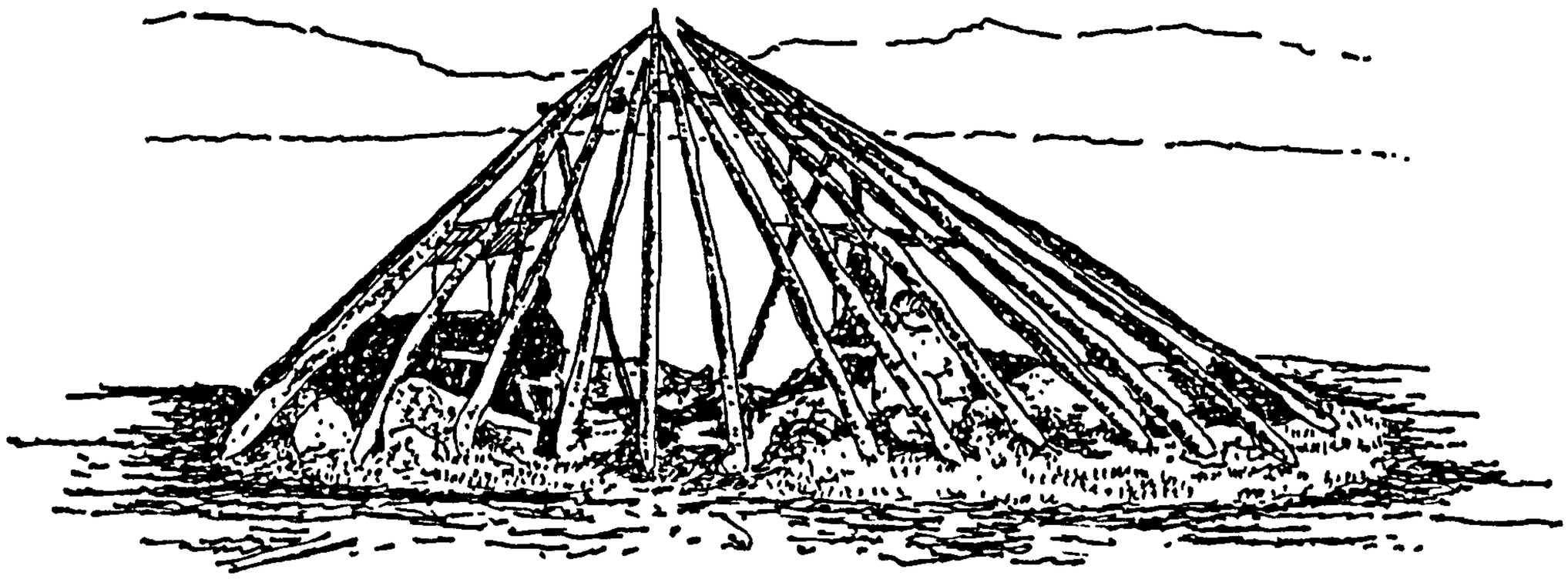


Fig. 82. Fan-shaped tent - rear view (Thalbitzer, 1914).

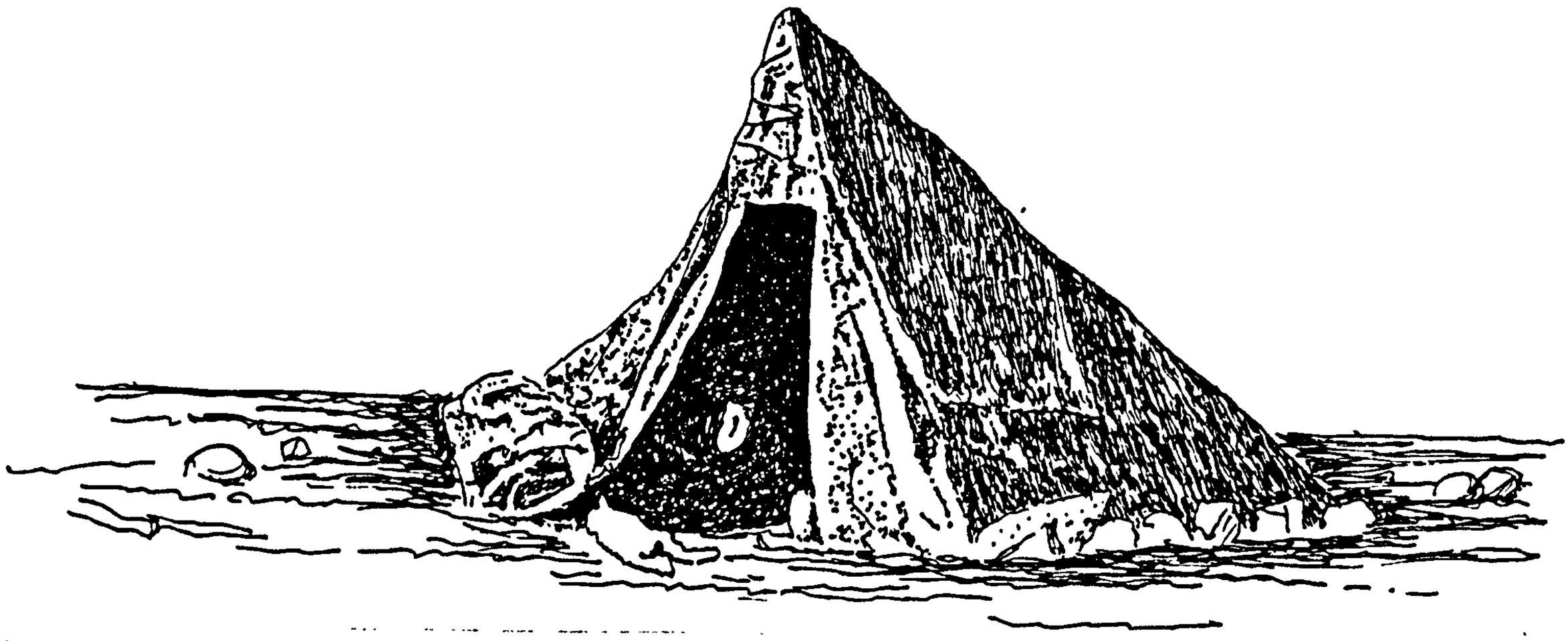


Fig. 83. Fan-shaped tent with skins in place (Thalbitzer, 1914).

September (Thalbitzer, 1979, pp. 42, 364 - 366).

Although the introduction of the cloth or calico tents occurred at the turn of this century, it is included in this section on traditional housing, because cloth was used to cover traditional tent structures. Tents were used as summer dwellings up until the replacement of the snow houses by wood houses. Baillargeon in his interviews with Inuit in Puvirnituuq (also known as Povungnituk) in Arctic Québec noted that snow houses were still in use as late as 1962 (see Fig. 48) and therefore tents were still being used as a summer dwelling at this time.

With the introduction of calico tents the Inuit summer habitation became easier to transport because they were lighter. They also had the added advantages of being more translucent and airy while providing the same protection as the heavier skin tents. Other advantages were their compactness when folded (thus taking up less space on the sled or boat), and their exemption from being chewed up by the dogs who found caribou skins more tasty (Hutton, 1912, pp. 255, 256). See Fig. 84 for a typical skin tent and Fig. 85 for a cloth tent.

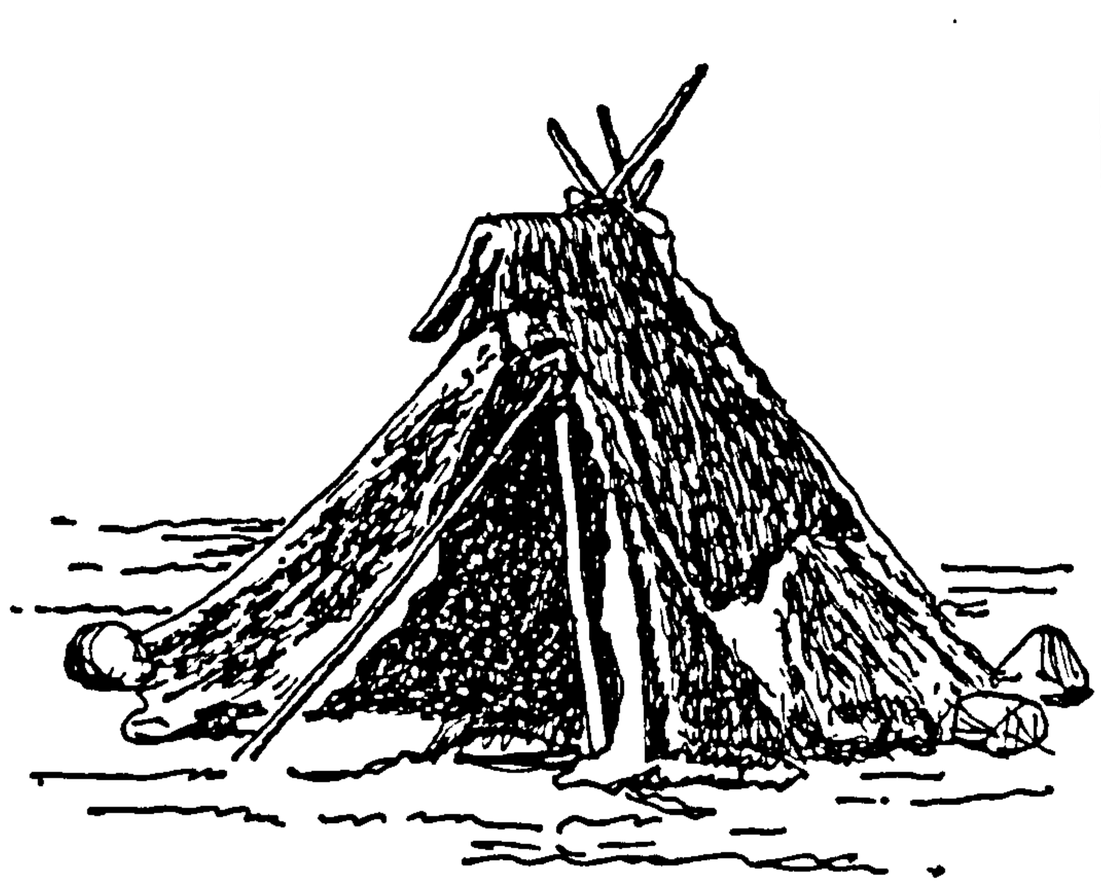


Fig. 84. Small summer skin tent (Jenness, 1922).

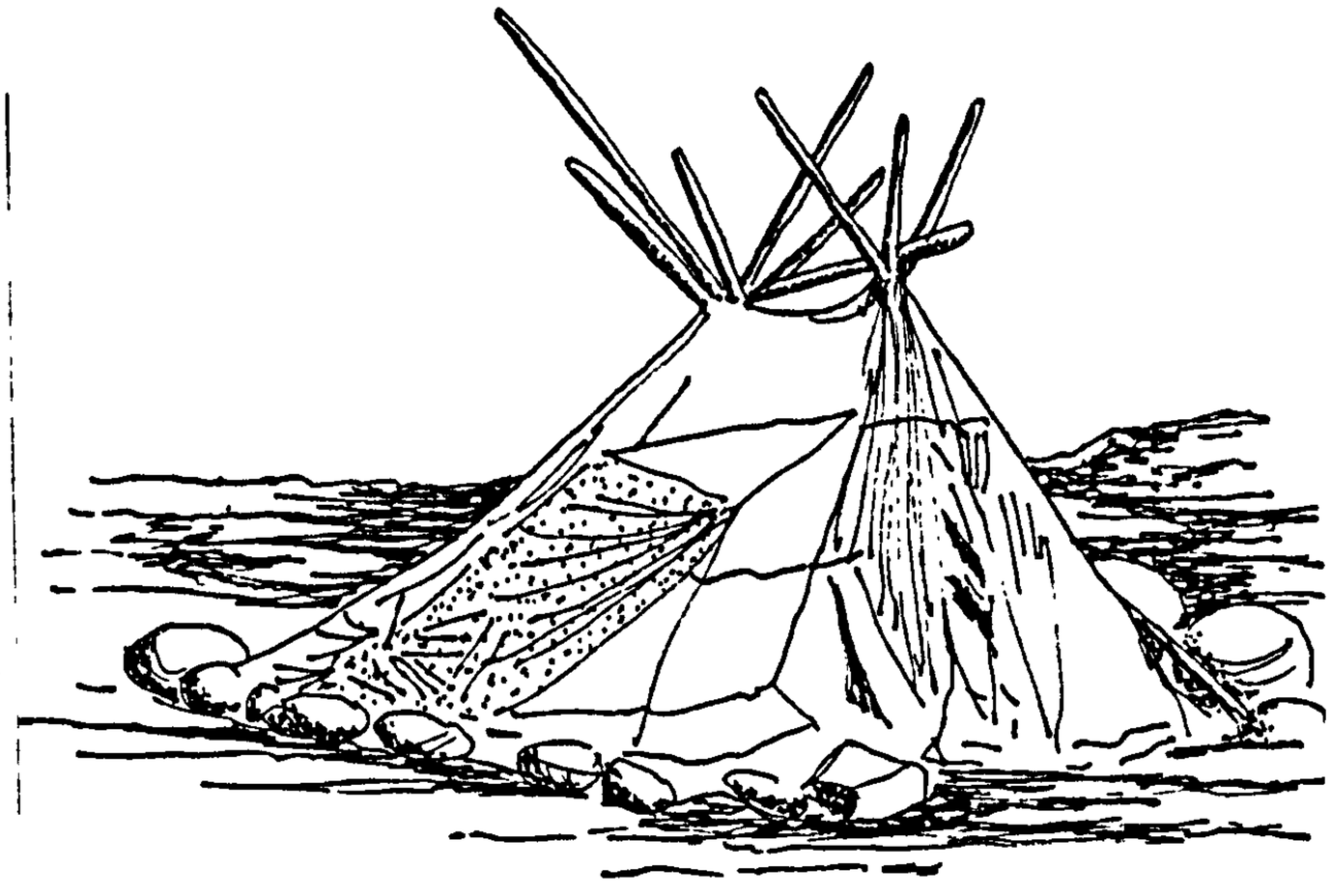


Fig. 85. Calico or cloth tent (Hutton, 1912).

Since the cloth for tents had to be purchased from the trading post, a family with a cloth tent was regarded as wealthy because only a productive hunter and trapper could affort to buy tent cloth. Eventually cloth tents became more common, and between 1910 - 1920 skin tents disappeared altogether.

At first as can be seen in Fig. 85, the use of cloth did not modify the form of the tent (Baillargeon, 1979, p. 70, 71). Eventually, however, either through imitation of white men's commercially fabricated tents, or by gradual modification of the structure and acquisition of more objects from the white man's culture (beds, stoves, etc.) more vertical space was required and the form of the cloth tents changed. See Fig. 86. (Baillargeon, p. 72). Note the vertical walls and the wood door.

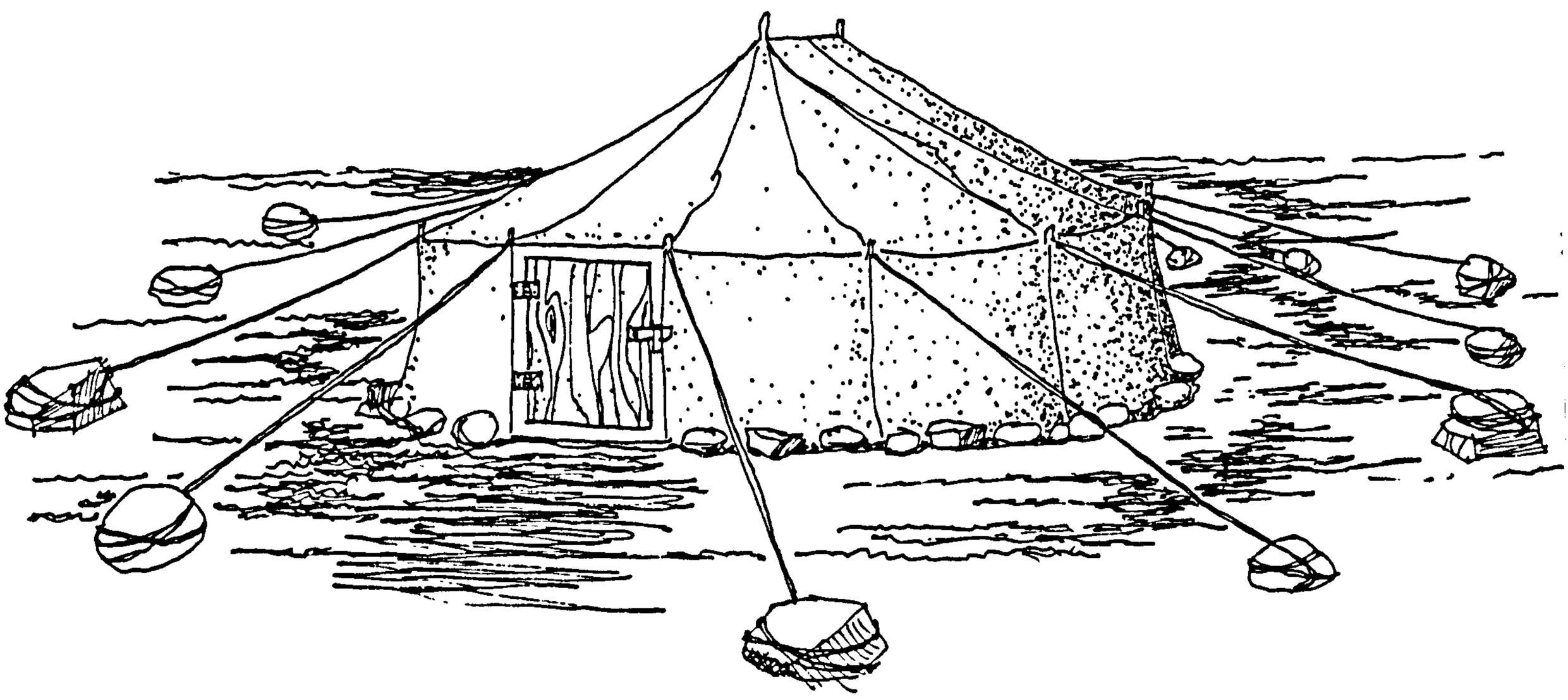


Fig. 86. Contemporary cloth tent (Baillargeon, 1979).

1.4.1.5.2 Double Tents

Normally each family had its own tent, but upon occasion two families would share a tent, dividing the space with an invisible line so that each family would have its own portion of the tent (Jenness, 1022, p. 85). In some cases two tents were joined together with a single common entrance with an opening between the two formed by a whale rib arch. The two tents were placed at a slight angle so that the sleeping platforms would be more distant from one another. See Fig. 87. Fig. 88 shows a double tent with two entrances (Boas, 1974, p. 553). Sometimes these tents had a common entrance tunnel by which both families entered much as in the snow or stone houses (Jenness, 1922, p. 81). Occasionally the tents were covered with shrubs

and then a second layer of skins was added. The double tent is the only example of multi-tent forms the author was able to uncover, unlike the stone, semi-subterranean and snow houses which exist in triple-house types and other multi-family forms.

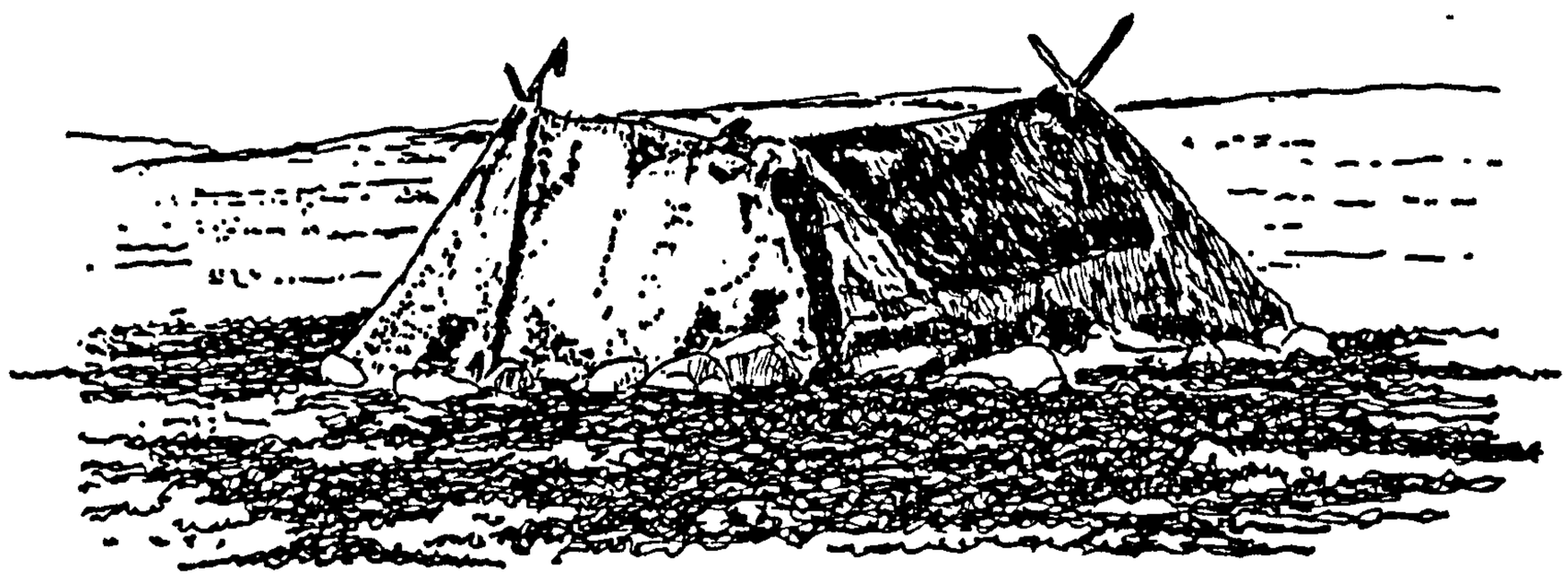


Fig. 87. Double summer tents made of skins (Jenness, 1922).

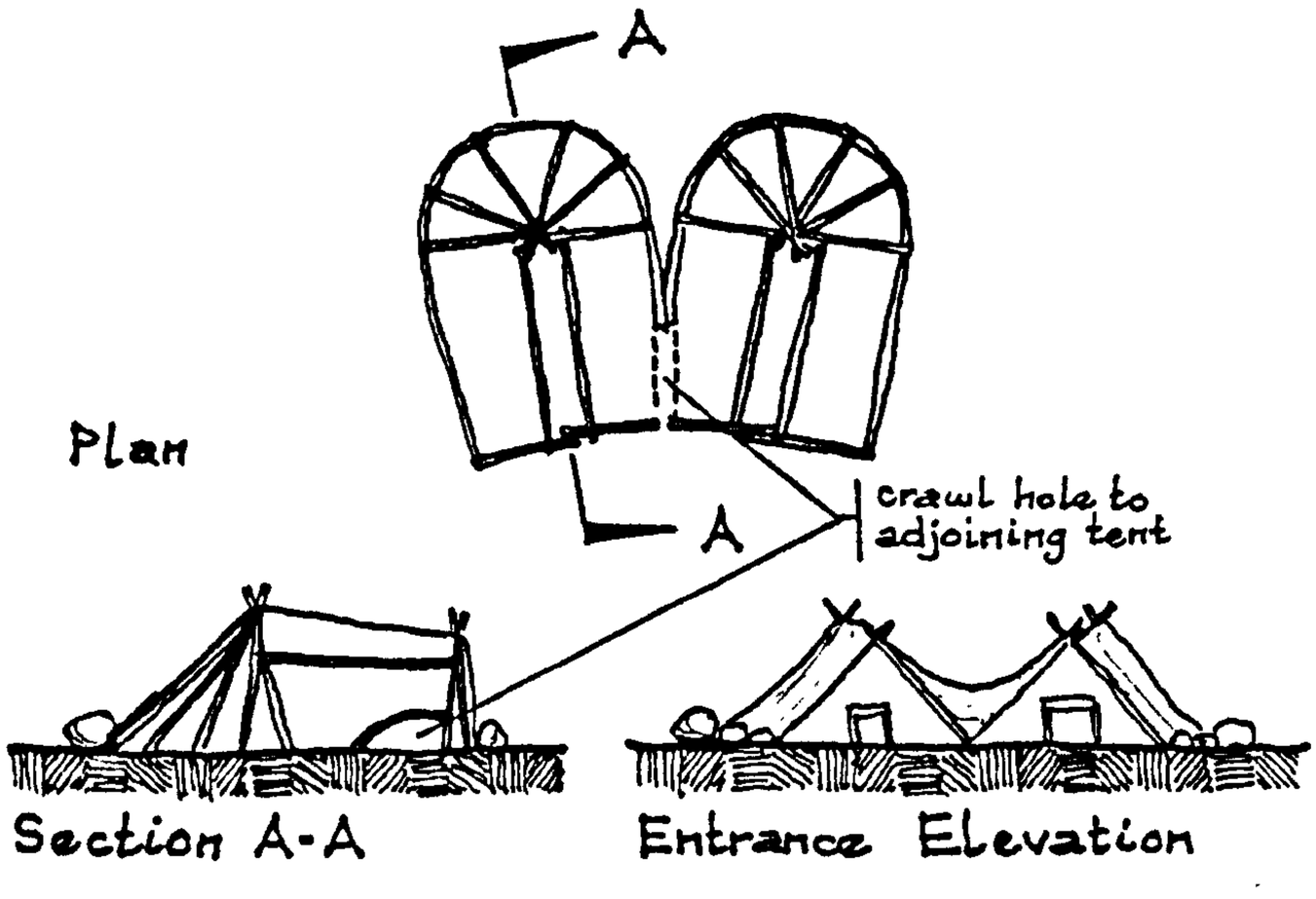


Fig. 88. Double tent - plan, section and elevation (Boas, 1974).

1.4.2 CONTEMPORARY HOUSING FORMS

Even though the white man's influence on housing form and construction was felt as early as 1910 in some parts of the central Arctic and even earlier in Alaska, it wasn't until 1950 in Alaska and 1959 in Canada that the respective U.S. and Canadian governments embarked on a policy of providing housing for the Inuit (Stefansson, 1913, pp. 86-87; Jorgensen, 1968 (a), p. 11; and Thompson, 1969, p. 111). One of the main reasons for this concern with better housing by the governments was the great number of Inuit with respiratory diseases (Dicks and Platts, 1960, p. 224) and the generally very low level of hygiene in Inuit housing (Jorgensen, 1968 (a), p. 11).

The housing prior to 1959 was a mixture of traditional and self-built houses. In a survey carried out in 1964-65, of 11,416 Inuit surveyed, 1,966 were living in 386 snow houses or tents; 2,041 were living in 390 unacceptable self-built houses; and the remaining 7,409 were living in 1,156 government houses of which few were more than one room (Yates, 1970, p. 46). This gives an indication of how recently the Inuit have transferred from snow houses to permanent wood houses.

1.4.2.1 Self-Built Housing

The self-built houses were generally a rather poor form of shelter fabricated from discarded materials such as packing cases, scraps of metal, tar paper and lumber. These shelters were an imitation of the white man's more spacious frame dwellings. Unfortunately they were very difficult to heat compared to their traditional dwellings because the walls were either poorly insulated, or completely lacking in insulation. The houses required so much wood to heat them that in Alaska, the driftwood accumulated over the centuries was burned up in a period of 30 years. To save heat they tried to seal their houses as tightly as possible, thereby creating the unhygienic conditions that were partly responsible for the high incidence of pulmonary diseases and high death rates (Stefansson, 1913, p. 87).

1.4.1.1.1 Scavenged Wood Houses

Hutton describes several scavenged wood houses built with double-slope roofs, some of which were covered with sod, and others with wood shingles (1912, p. 248). Mathiassen also describes wood houses which were rectangular with double-slope roofs, found in the central Arctic (1928, pp. 140, 141). The houses described by Hutton were found in Labrador, while those mentioned by Stefansson were found in Alaska, indicating the widespread use of wood houses by the Inuit. See Figs. 89 and 90.

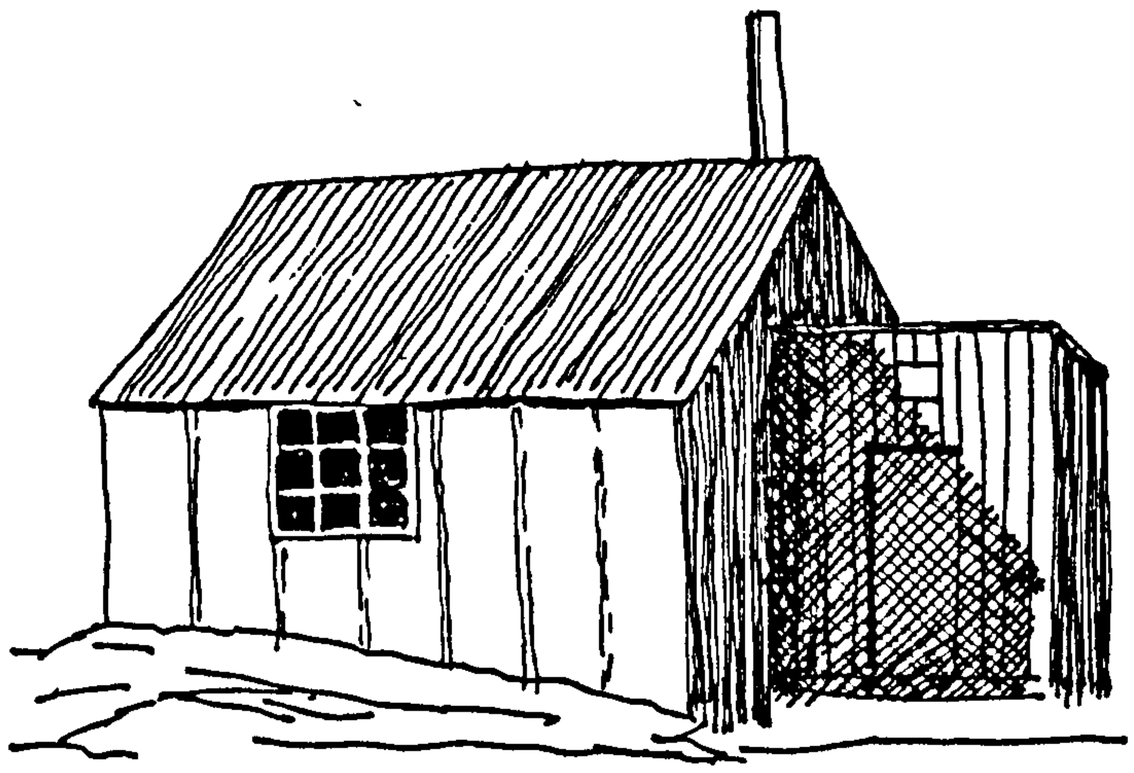


Fig. 89. Wood house - Alaska (Jorgensen, 1968).

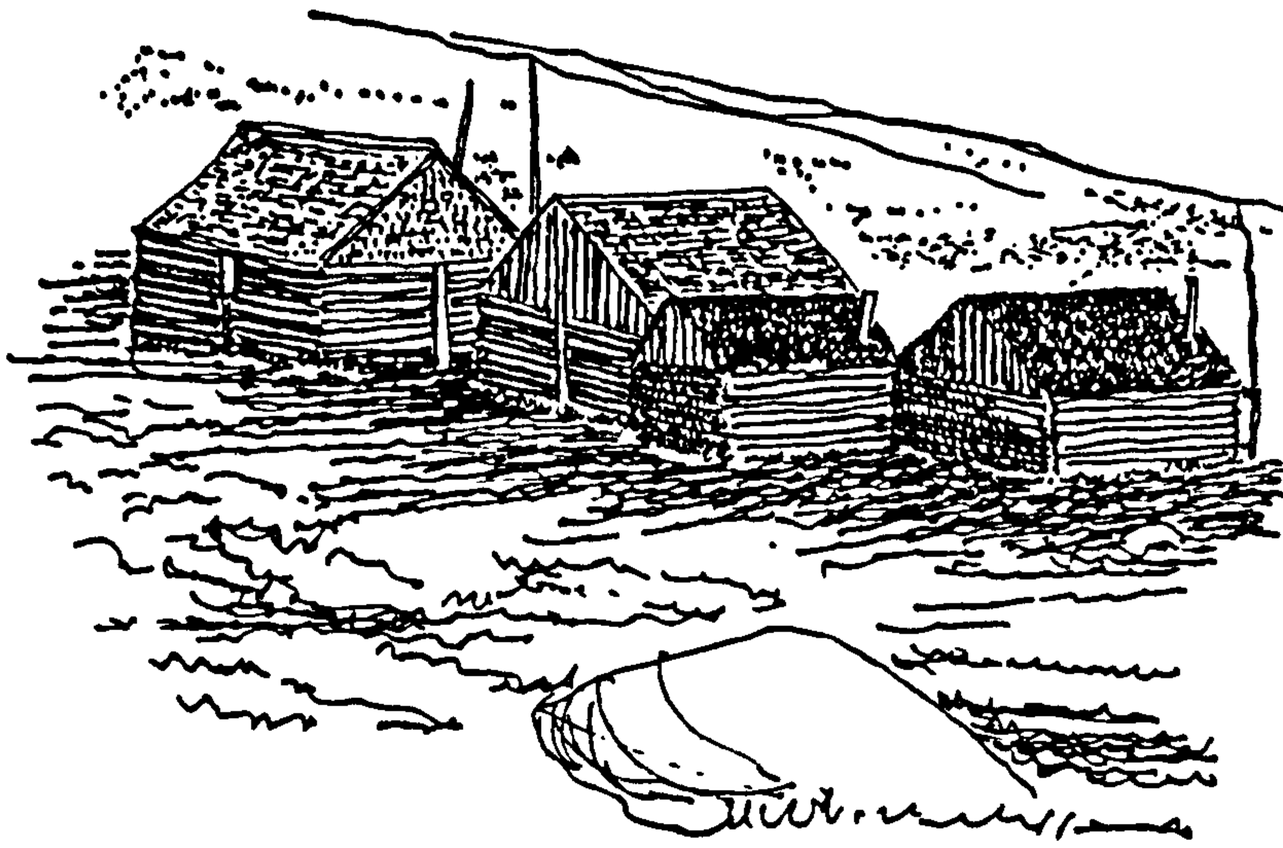


Fig. 90. Wood houses - Labrador (Hutton, 1912).

1.4.2.1.2 Stone Houses

In 1957 in the village of Povungnituk, arctic Québec, Father Steinman, a catholic missionary, constructed a few stone houses with the Inuit. The experiment was an attempt to use local materials in the construction of the walls which were built by piling field stones on top of one another directly on the ground without any foundation. No mortar was used, but rather sod and earth were packed in between the stones to close the gaps and help hold the stones together. On top of this structural wall were laid the rafters for the roof. A bed of sand was laid on the ground and a wood floor was built on top. An internal wall was built from the floor to the roof rafters leaving an air space between the two walls for insulation. Later on mineral wool insulation was added in the floor and wall spaces. The roof had a

quadruple slope in order to keep the stone walls at the same height all around.

Another example of the stone house is a modified version of one of the Father Steinman houses which had a second storey in wood construction built above the one storey stone walls. This is the only example of an Inuit two storey house in the entire village. The modification was made when the family found the space too small for their needs (Nunaturliq, 1973, pp. 93-94). See Figs. 91 and 92.

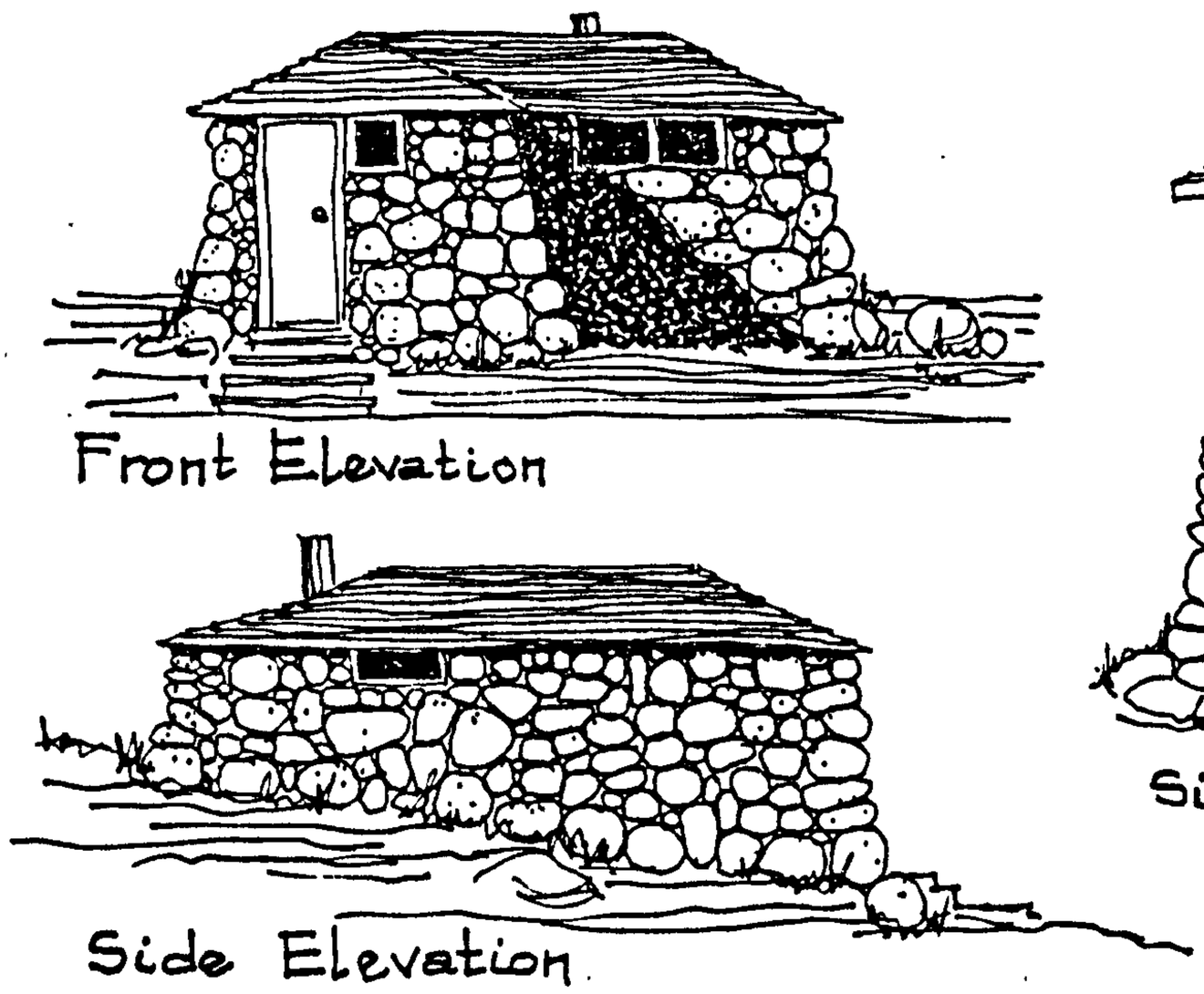


Fig. 91. One storey self-built stone house (Nunaturliz, 1974).

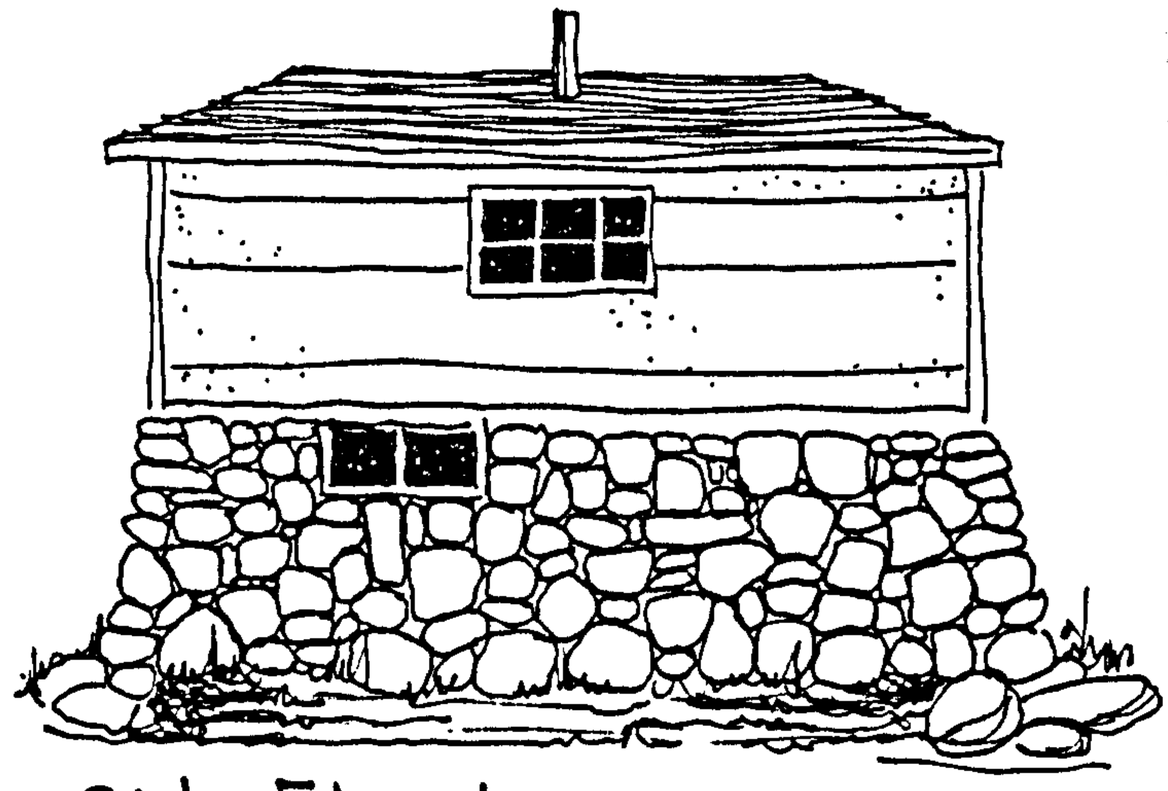


Fig. 92. Two storey self-built house (Nunaturliq, 1974).

1.4.2.1.3 Wood Frame and Sod Houses

This was a house type developed by the National Research Council of Canada and draws heavily on the example of the traditional Inuit sod houses. This house was built of standard 2" by 4" (5 x 10cm) structural members. The structural wall members supported a thick wall of peat sod and the roof and floor were covered with plywood. The walls, floor and roof were all insulated with 4" (10cm) of caribou moss with the addition of a polyethylene vapour barrier which served as an interior finish for the walls and ceiling

and a ground cover for the floor (Dickens and Platts, 1960, pp. 224-225). See Fig. 93.

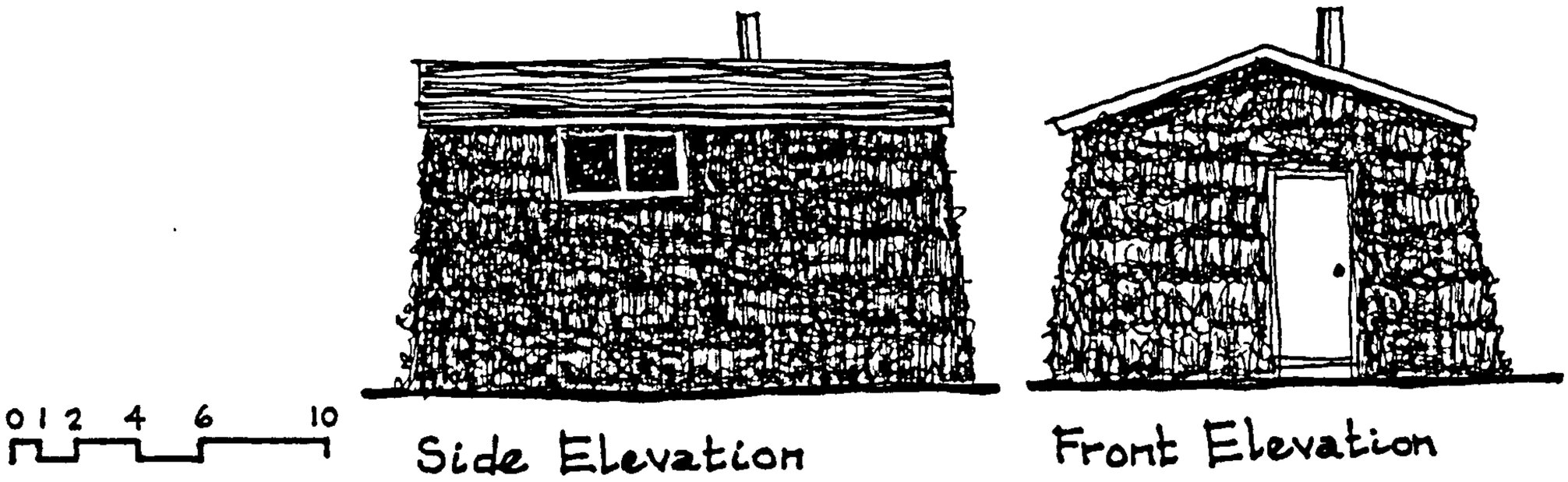


Fig. 93. Wood frame sod house (From a description in Dickens and Platts, 1960).

1.4.2.1.4 Wood Frame Houses

This was another attempt to use local materials and labour as much as possible. These houses built in 1958 used 2" x 4" (5 x 10cm) structural members covered with plywood and insulated with brushwood or moss. The interior of the roof was metal with the exterior covered in tar paper as were the walls.

This house was introduced by Peter Murdock of the Inuit Co-operative who helped the Inuit in Povungnituk build the first houses of this type. The houses unfortunately developed condensation problems caused by the metal ceiling, the roof leaked and the insulation settled to the bottom of the walls and became quite useless. The houses were 12' by 20' (3.7 x 6.0m) in plan with a double-slope roof. The roofs were changed to a quadruple-

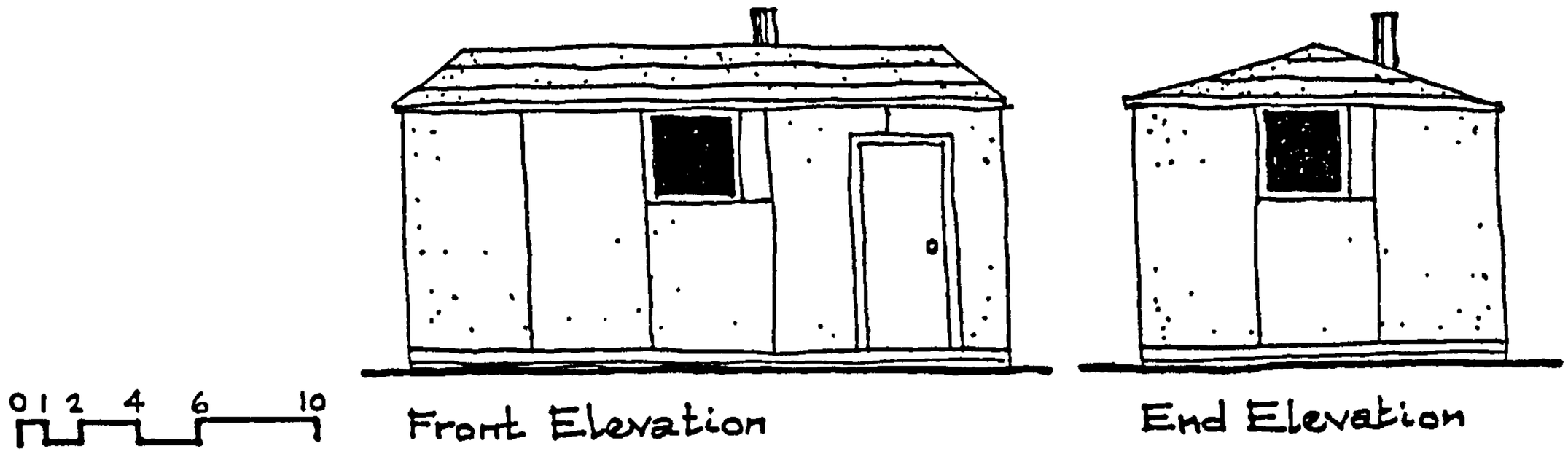


Fig. 94. Wood frame self-built house (Nunaturliq, 1974).

slope when the houses were modified to rectify the above problems. None of the original Murdock houses exist today, and at the time of the Nunaturliq study in 1973, only 8 of the modified houses remained (Nunaturliq, Phase 1, 1973, pp. 95-96). See Fig. 94.

1.4.2.1.5 Wood House

In 1965 an Inuk in the village of Povungnituk decided to build his own house from materials available in the village. This house is one of the rare examples of a house conceived and built entirely by an Inuk. The plan is a classic 'H' plan with a central kitchen-living-dining room, 3 bedrooms (2 on one side of the central space and 1 on the other), as well as a storage area. The house has one large exterior porch which serves as the entrance, summer kitchen, storage and room for the toilet. The floor plan is 16' by 32' (4.9 x 9.8m) and the house has a double-slope roof over the main house and a single-slope roof over the entrance porch. The entrance porch floor is approximately 2' (0.6m) lower than the floor of the house. In front of the entrance porch is a wood platform which serves as an exterior terrace in sunny weather (Nunaturliq, 1974, p. 101) See Fig. 95.

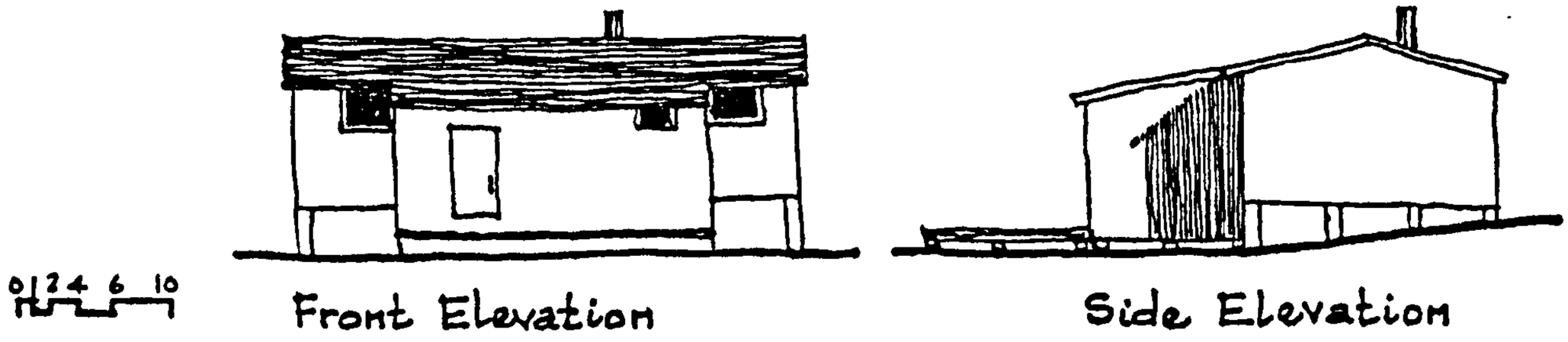


Fig. 95. Self-built wood house (Nunaturliq, 1974).

1.4.2.2 Government Built Housing

1.4.2.2.1 Rigid Frame Prefabricated Wood Panel House Model 319

This type of house is noteworthy because of its unusual concave-shaped walls which gave it structural rigidity. This was the first house supplied by the Canadian government and was made completely of prefabricated wood panels with no local materials in its construction. This house, built in 1959, was soon modified by the Inuit, transforming it into a house with vertical walls and in one case joining 2 houses together to form a duplex.

The original plan was a 16' x 16' (4.9 x 4.9m) square with a double-slope roof (Nunaturliq, Phase 1, page 47).

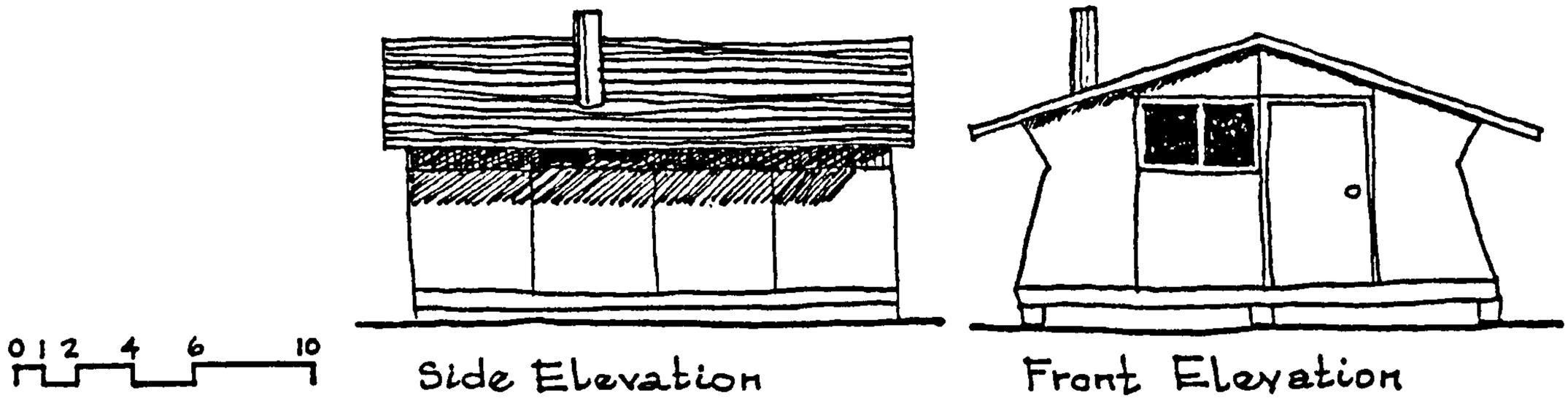


Fig. 96. Rigid-frame, prefabricated wood panel house (Thompson, 1969).

1.4.2.2.2 Prefabricated Wood Panel House Model 370

This particular model, called the "matchbox", for obvious reasons, was built from 1961 to 1965. It consisted of a 12' by 24' (3.7 x 6.6m) rectangular single room plan with an exterior entrance porch and a toilet room. The roof was almost flat having a very slight double-slope roof which is necessary for the rain. The whole construction was of prefabricated wood panels fabricated in the south. This house, like many others was modified by attaching an exterior porch. In many cases the toilet room and the interior porch were eliminated to gain more space (Nunaturliq, Phase 1, page 98).

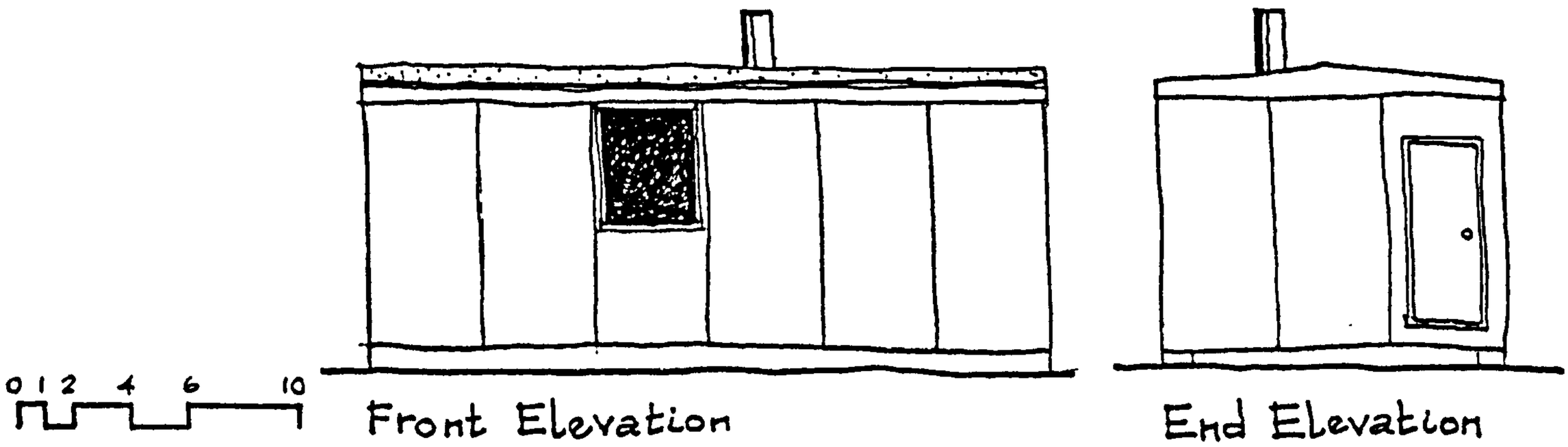


Fig. 97. Prefabricated wood panel house - "matchbox" (Thompson, 1969).

1.4.2.2.3 Prefabricated Wood Panel House - Model "Angirraq"

This house was the outcome of a study by the National Research Council of Canada and was built in many villages in 1965. Its main feature was its sloping walls and single-slope roof. The plan was rectangular measuring 16' by 28' (4.9 x 8.5m), but its roof span was 13' (4m) which is the optimum span for stressed skin panels. Thus the walls were sloped inwards to achieve optimum span while enclosing a larger floor area. This was also an attempt to relieve the box-like quality of most northern houses. This house had two main rooms, one for cooking, eating and entertaining and another for sleeping. It also had an open porch set into an end wall leading into an interior porch (Platts, 1966, pp. 192-193; Thompson, 1969, p. 42; Nunaturliq, 1974, p. 103). See Fig. 98.

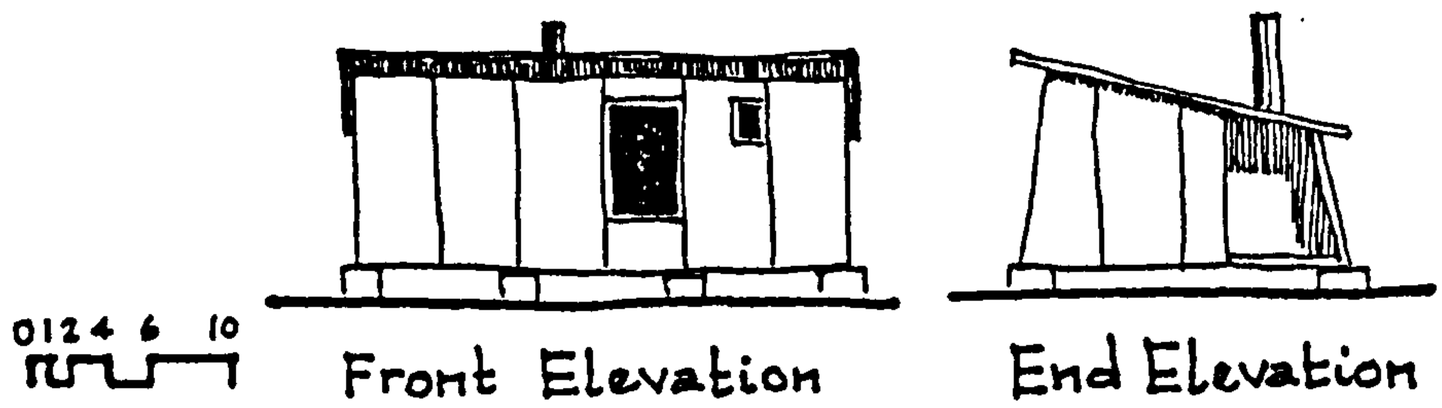


Fig. 98. Prefabricated wood panel house - model Angirraq (Platts, 1966).

1.4.2.2.4 Prefabricated Wood Panel - 2 Storey House

This house is identical in its structural conception to the Angirraq except that the walls are vertical and an interior supporting wall breaks up the roof into 14' (4.3m) spans. The plan is rectangular, 28' by 36' (8.6 x 11m) with a shallow incline to the single-slope roof (Platts, 1966, p. 200). Although this house was originally intended for the imported administrative

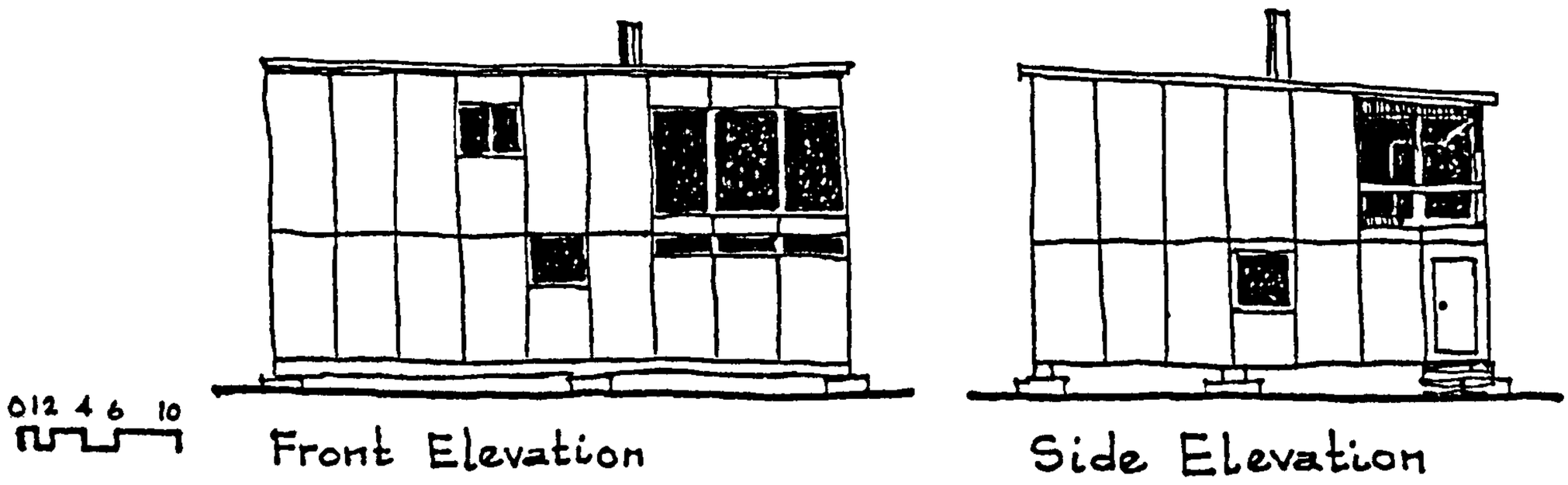


Fig. 99. Prefabricated wood panel two-storey house (Platts, 1966).

staff in the arctic, in some areas they are being turned over to the Inuit who are replacing the white administrative staff.

1.4.2.2.5 Prefabricated Wood Panel Single-Storey House

In 1965 the first of the multi-room prefabricated houses arrived in the north. These houses had 5 rooms consisting of 2 bedrooms, a central living-dining-kitchen area, a storage area, and a bathroom. The plan was rectangular measuring 18' by 29' (5.5 x 8.8m) and having a standard double-slope roof. In fact all the houses provided for the Inuit from 1965 to the present time (with the exception of a few experimental houses) were all the same basic form and varied only in the dimensions of the floor plan and number of rooms. For example, the standard Model 455 house is a 4 bedroom, 24' by 30' (7.4 x 9.2m) house with a 6' by 12' (1.8 x 3.7m) porch added on one end (Nunaturliq, 1974, p. 107). See Fig. 100.

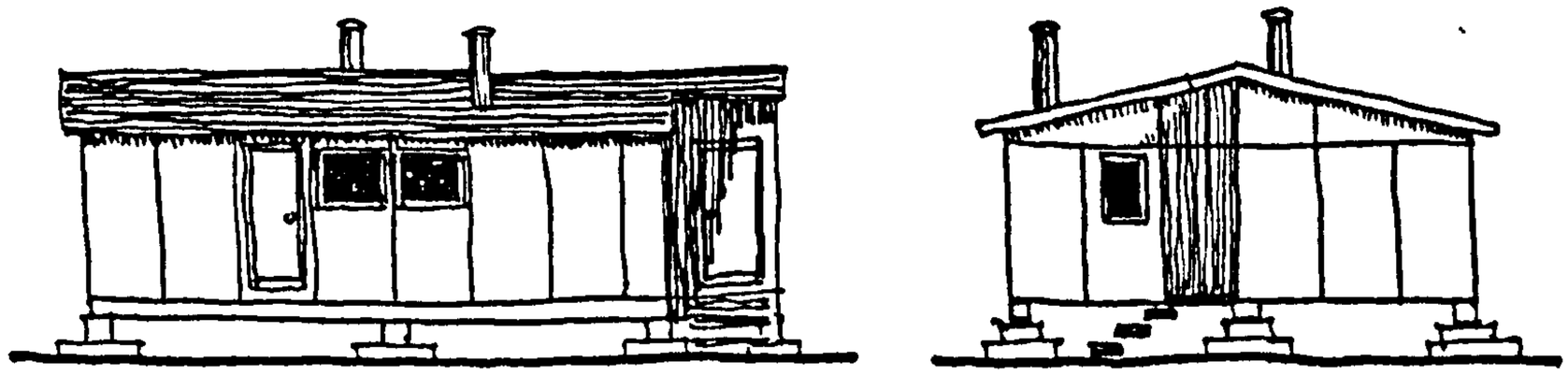


Fig. 100. Prefabricated wood panel one-storey house - Model 455 (Dept. of Indian Affairs and Northern Development, 1978).

1.4.2.2.6 Stick-Built Wood House

This house built in 1964 by the Province of Québec with Inuit labour and a white foreman, is an example of a very ordinary house but one which was cited often by the Inuit as being one of the best houses in the village of Povungnituk because it its warmth and stability in high winds. The house

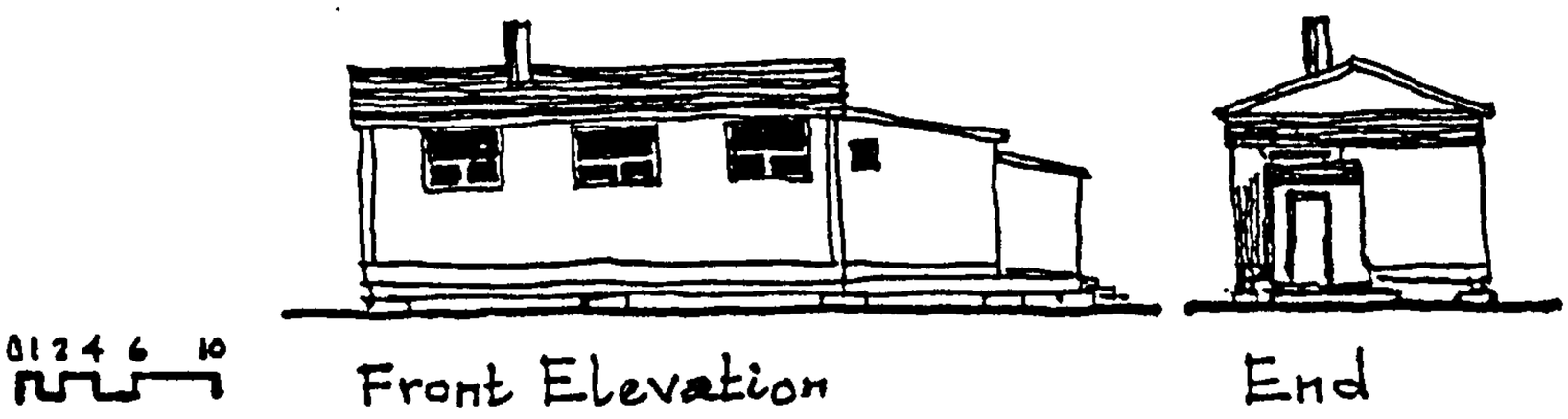


Fig. 101. Wood frame house with two porches (Nunaturliq, 1974).

was "stick-built" and therefore did not have the problems of infiltration through joints as did most of the prefabricated houses. This house has a rectangular plan 12' by 24' (3.7 x 6.6m) and a double-slope roof. It has 4 rooms and an unusual feature in that it had 2 exterior porches and 1 interior porch. The 2 exterior porches were added on one of the gable ends and were both single-slope roofs (Nunaturliq, 1974, p. 99).

1.4.2.3 Summer Housing - Tents

Although the Inuit were living in permanent wood houses in the settlement, during the summer many would leave the village for periods of 1 to 2 months to be close to hunting and fishing grounds (Nunaturliq, 1974, p. 84). The housing form which allowed this mobility was the tent, but due to the acquisition of frame beds and stoves, the traditional skin tent form was changed to canvas vertical-wall tents.

In Fig. 102, oval and rectangular tent plans are shown. As can be seen,

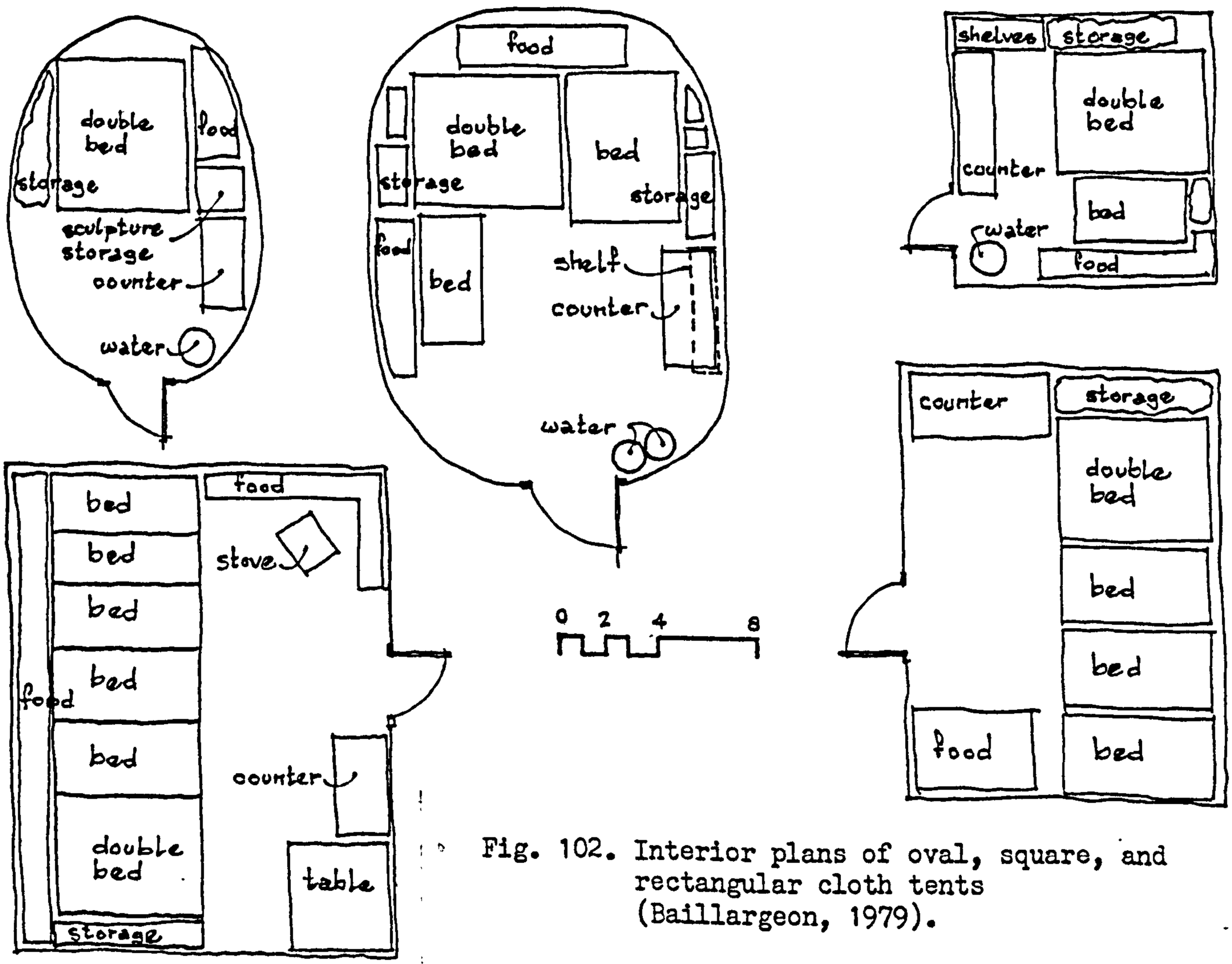


Fig. 102. Interior plans of oval, square, and rectangular cloth tents (Baillargeon, 1979).

the interior arrangement is very similar to the traditional snow house and tent arrangements. The sleeping area occupies almost the entire rear portion of the tent, with beds being pushed together forming the equivalent of a platform. The space in the oval tents was more difficult to use efficiently, and the area between the rectangular beds and the curved portion of the tent are filled with boxes and small articles to permit maximum use of space. This is similar to the way space was used in the snow house.

More recent tents are square or rectangular in plan with double-slope or pyramidal-shaped roofs. See Fig. 103. It should also be noted that these tents have wood doors hung on a wood frame attached to the fabric of the tent. The entrance has evolved to the point where the tent has become more airtight and easier to heat. With the use of a stove, the tents can now be used in the colder periods of the year.

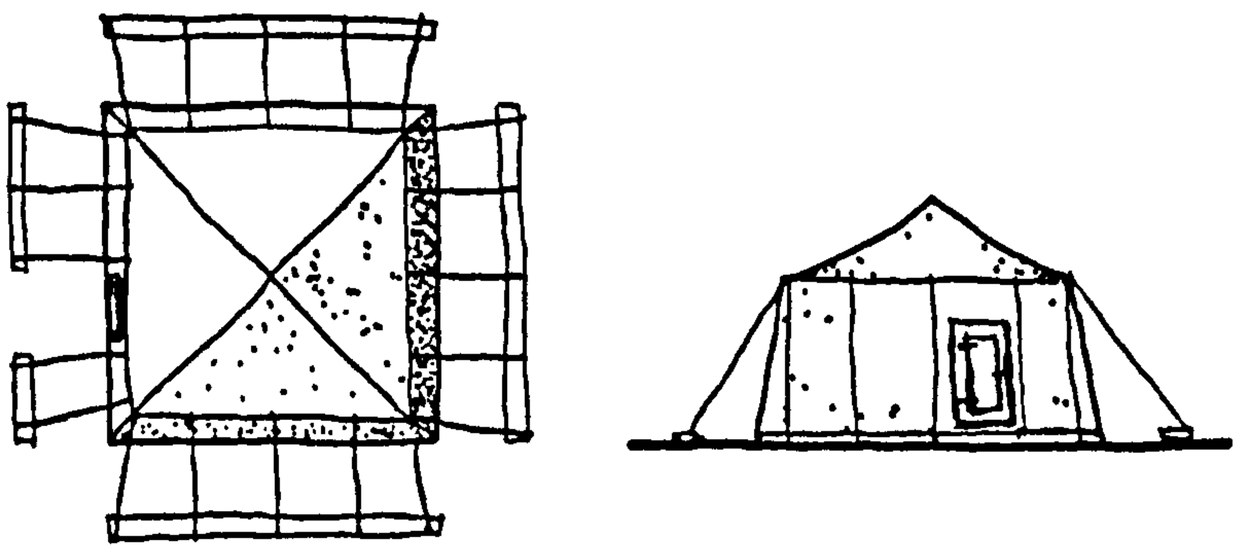


Fig. 103. Roof plans and elevations of square and rectangular cloth tents (Nunaturliq, 1974).

1.4.2.3 Experimental Houses

1.4.2.3.1 Two-Storey Wood and Stucco Igloo

In 1968 an experimental wood and stucco dome-shaped house, imitating the igloo, was built in Povungnituk. This house was unusual not only for its form, but also because it was the second two-storey house built for the Inuit in the village. It is 20' (6.1m) in diameter and is divided into 2 rooms, a central living and cooking space on the ground floor and a sleeping area on the first floor. This house has proven to be structurally stable and very warm. The house is now used as a bank (Nunaturliq, 1974, p. 106).

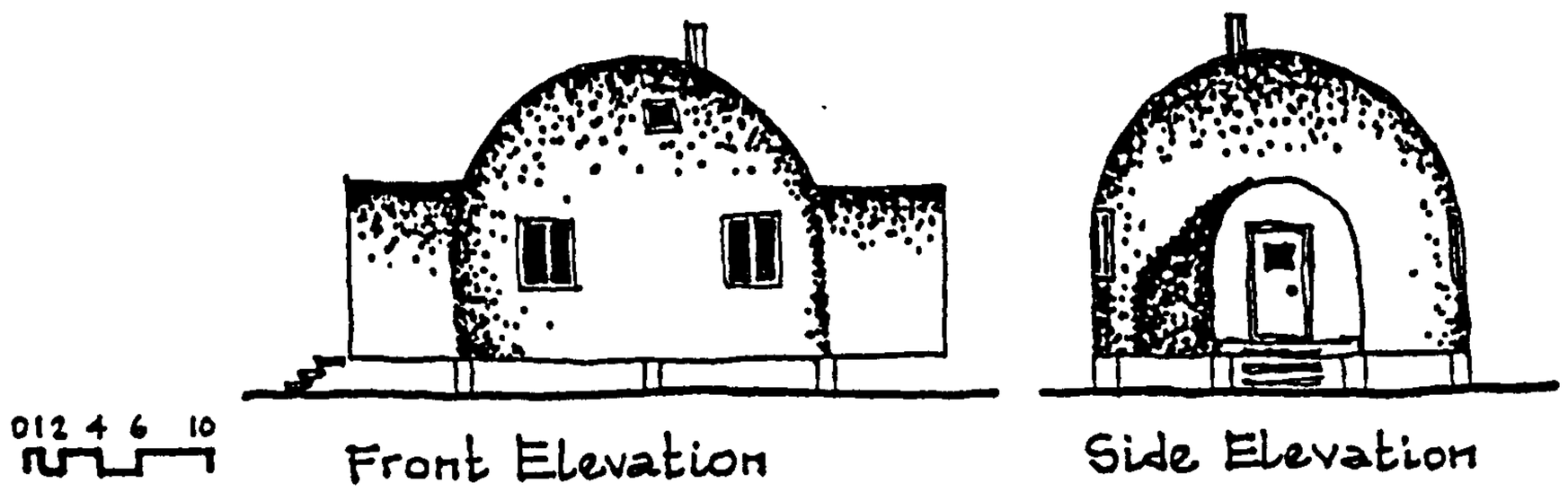


Fig. 104. Wood frame and stucco two-storey igloo (Nunaturliq, 1974).

1.4.2.3.2 Cylindrical Wood Houses

In Alaska in 1955, four experimental houses were built as an attempt to find a new construction method and materials that would be suitable to the Alaskan Arctic conditions. All of these houses had double-slope roofs and were more or less rectangular with the exception of one. This exceptional house was adapted from a cylindrical water tank made of wood staves covered

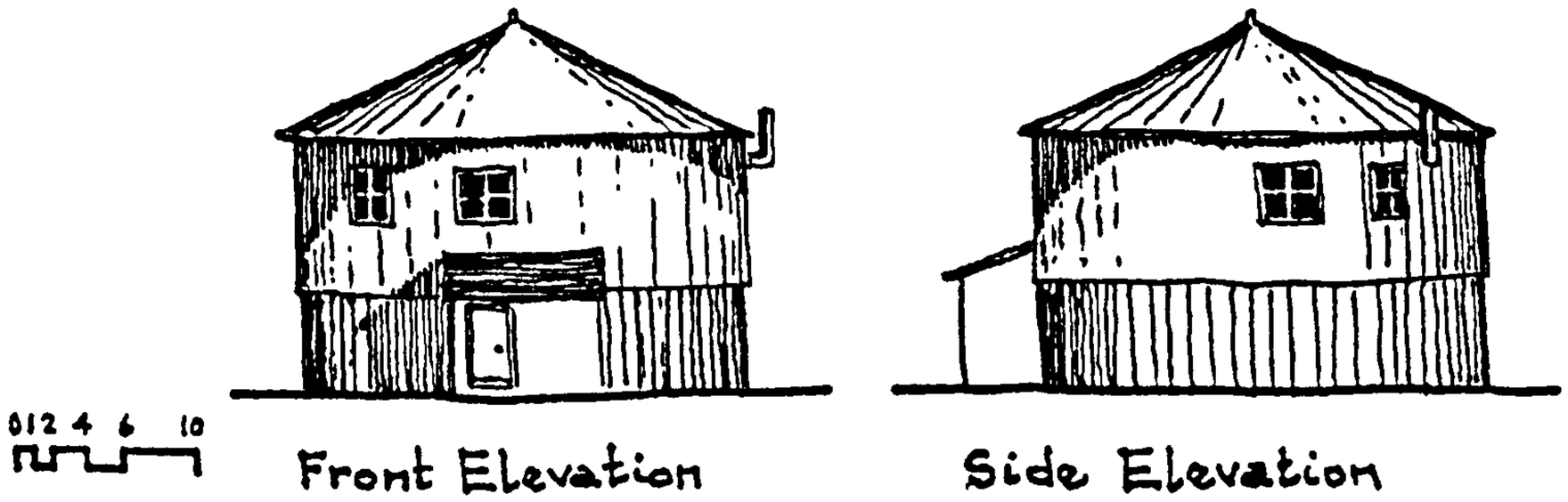


Fig. 105. Cylindrical wood house (Wik, Page and Shank, 1965).

with a conical roof. This single-storey house was 24' (6.6m) in diameter enclosing 4 rooms separated by curtains. Another novel feature of the house was the entry from underneath creating a cold air trap in the 6' (1.8m) space under the first floor (Jorgensen, 1968 (a) pp. 11-13; Wik, Page and Shonk, 1965, pp. 72-88).

1.4.2.3.3 Rammed Earth and Wood House

This demonstration house was built in Alaska in 1968, and is a slight variation of the rectangular plan houses with a double-slope roof. The plan is 30' (9.2m) square and is enclosed by sloping walls of rammed earth 3' (0.92m) thick. The roof is the normal double-slope and the windows and doors are cut into the walls at the junction of the roof so that wood lintels can be used over these openings (Jorgensen, 1968 (a), pp. 10, 22; Jorgensen, 1968 (b), pp. 14, 25, 31, 39).

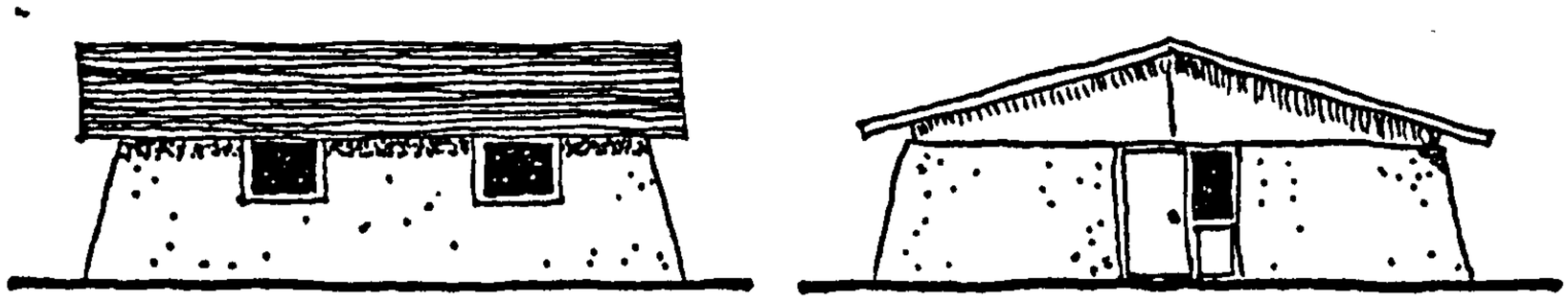


Fig. 106. Rammed earth and wood house (Jorgensen, 1965).

1.4.2.3.4 Three-Level Wood House

In 1974, two three-level wood houses were built in the village of Povungnituk. These houses were unusual because they were designed through a user-participation process and the resulting plan created a separation of living and sleeping areas on three levels.

The house has the main entrance at the first level which not only serves as a cold air trap, but contains the mechanical equipment, the storage area, and one bedroom. On the second level was the bathroom-kitchen-living-dining area, while the third level contains the remaining bedrooms (Nanaturliq, 1974, pp. 486-492; Zrudlo, 1975 a), pp. 40-44). See Fig. 107.

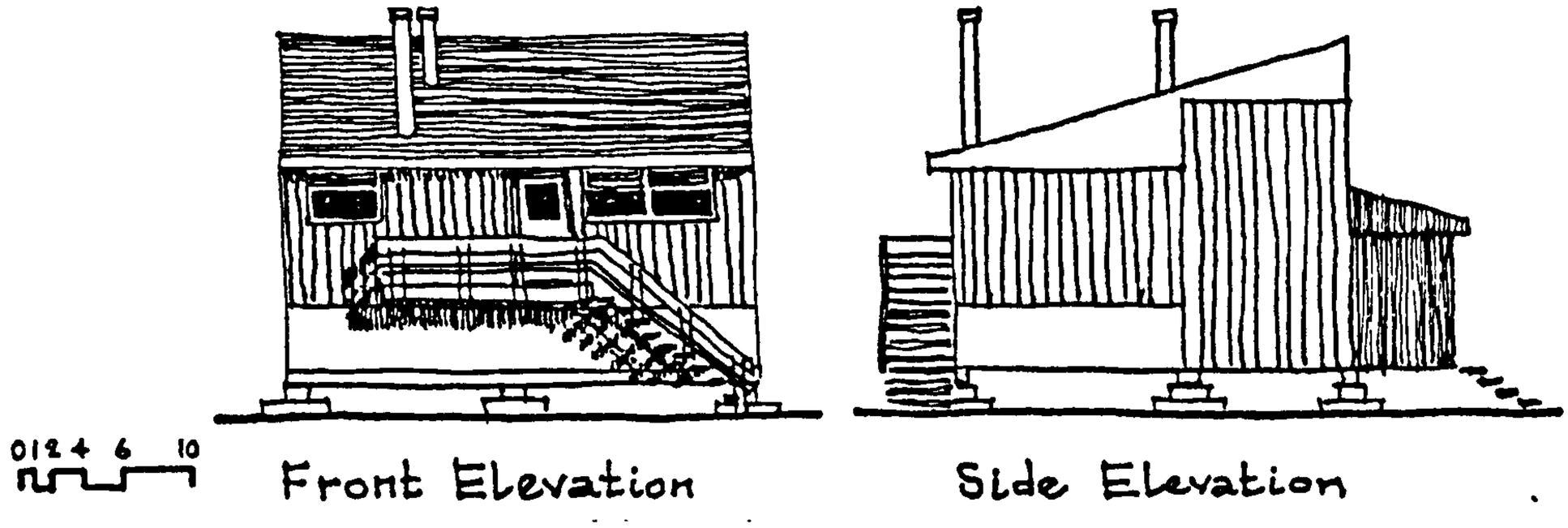


Fig. 107. Three-level wood frame house (Nunaturliq, 1974).

1.4.2.3.5 Prefabricated Fibre-Glass-Panel House

In 1974 in Povungnituk, at the same time as the construction of the three-level house a single-storey prefabricated fibre-glass-panel house was begun. Due to many problems the house was not completed until 1977. The interest of this house lies in its unusual shape created by the angular corners and curved roof. The house is low in profile due to the house's concrete slab foundation that sits directly on the ground in contrast to all other houses which have elevated foundations. The plan is a classic 'H', 21' by 29' (6.4 x 8.8m) with a roof sloping in 4 directions from a central flat area (Nunaturliq, 1974, pp. 479-495).

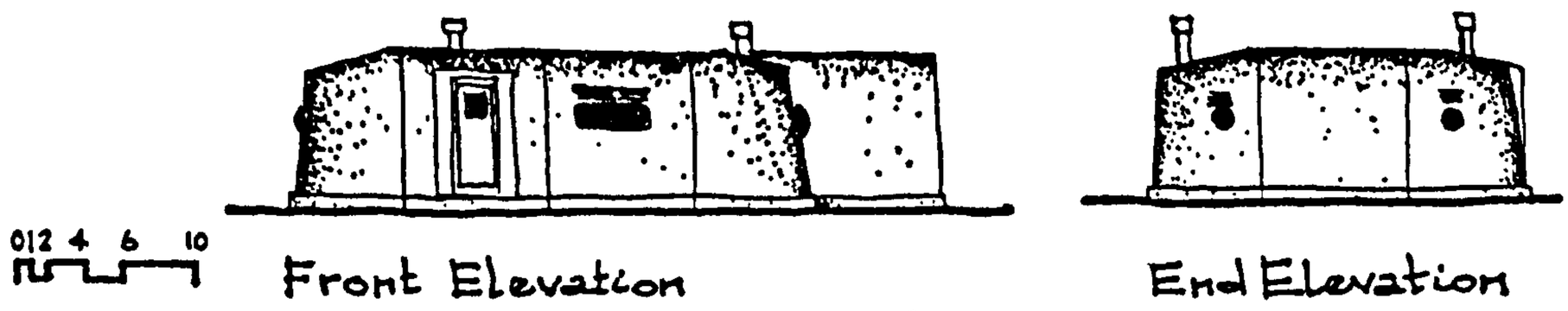


Fig. 108. Prefabricated fibreglass panel house (Nunaturliq, 1974).

1.4.2.3.6 Polyurethane Three-Quarter-Dome House

At approximately the same time as the three-level and fibreglass houses were being built, an experiment was carried out by a research group at the School of Architecture of the University of Toronto, resulting in the construction of a three-quarter dome made of polyurethane. From the little information the author was able to obtain from the Department of Indian Affairs and Northern Development, the dome was built at the lower limit of

the sub-arctic in northern Ontario. This house had many problems, the main one being the fragility of the polyurethane which rendered the house susceptible to damage by vandals and accidents. The project was never publicized and is mentioned here because it was one of the few dome houses designed for the north.

1.4.2.3.7 Two-Storey Prefabricated Wood Panel Five-Eighth-Dome House

This house built in 1975 was made of triangular-shaped prefabricated wood panels enclosing a ground floor plan approximately 27' (8.2m) in diameter with an overall height of 18' (5.5m). The bedrooms are situated at ground level while the living areas are on the first floor. From a practical standpoint this was a good arrangement because heat would rise by natural convection to the living space. However, the Inuit prefer the convenience of direct access to the cooking area from the exterior (preliminary plans by Shelter Construction and Development Ltd. for Inuit Tapirisat of Canada, 1975).

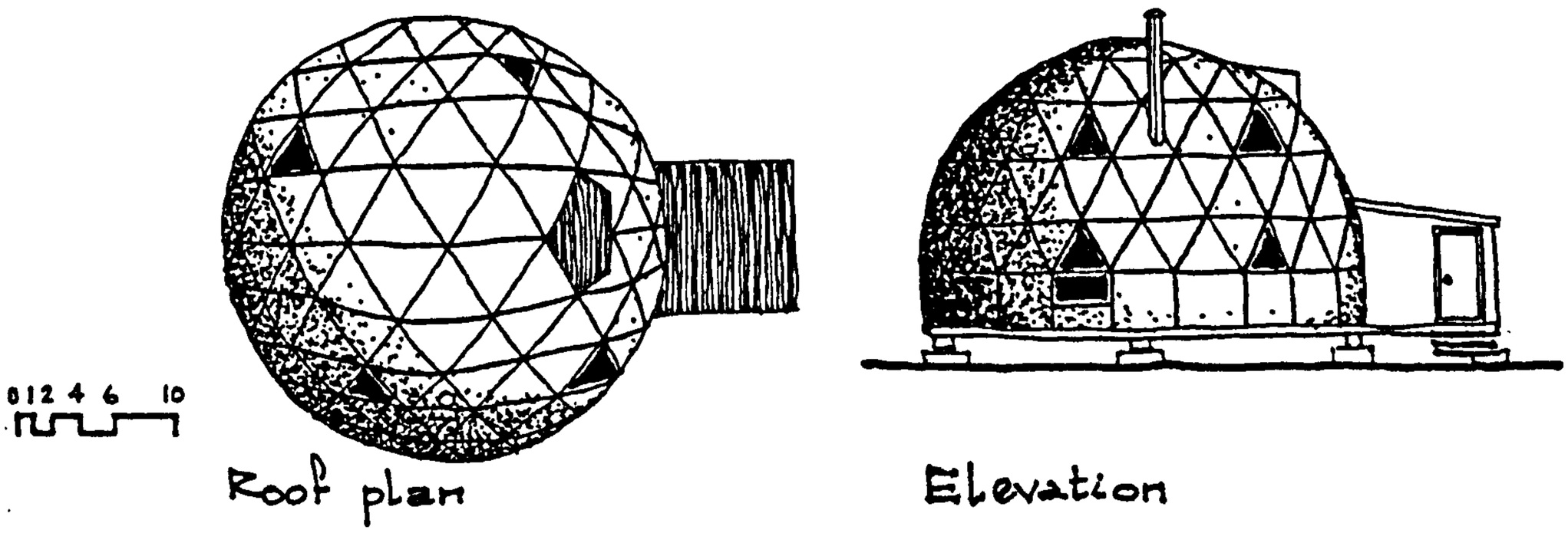
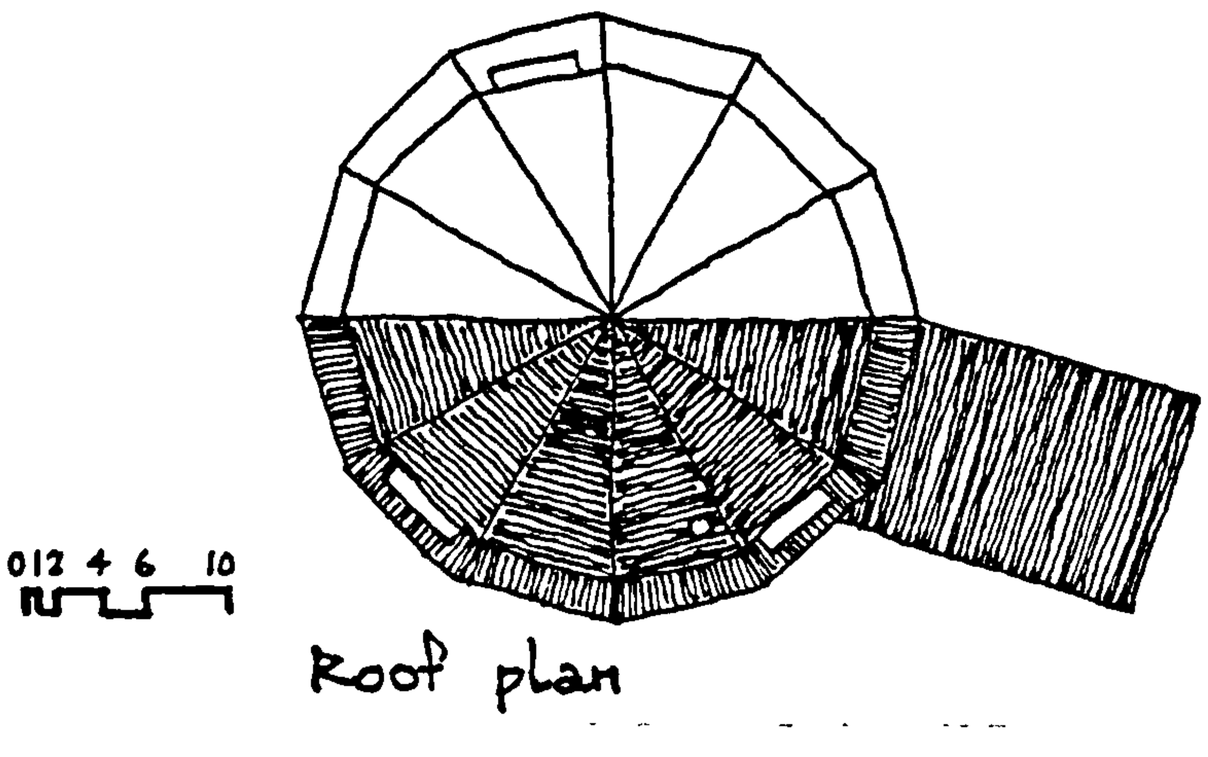


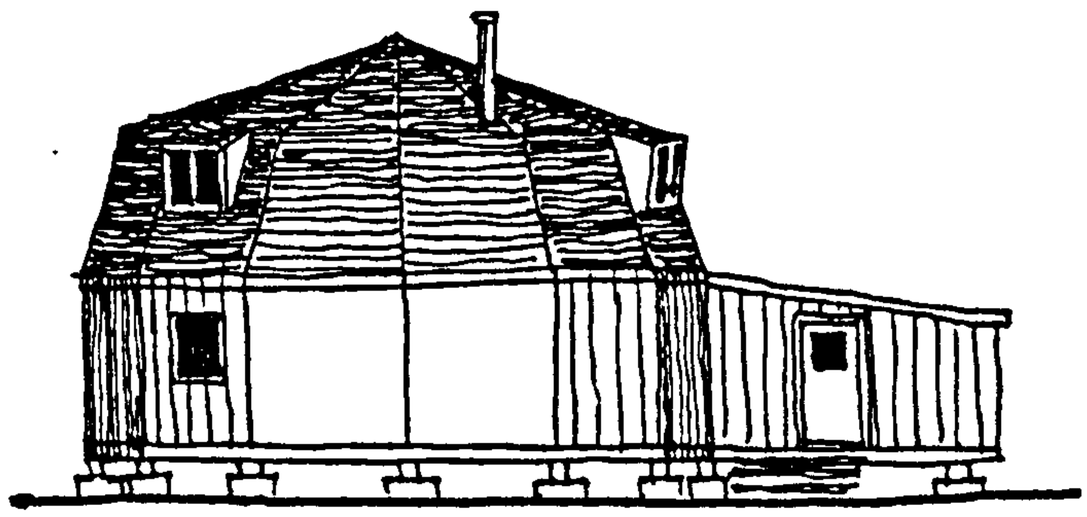
Fig. 109. Prefabricated wood panel, two-storey 5/8 dome (Shelter Construction, 1975).

1.4.2.3.8 Two-Storey Prefabricated Wood Panel Cylindrical House with Conical Mansard Roof

This house, built by the same company as the previous example, was an attempt to resolve the problems encountered when placing furniture near inward curving walls and when standing height was limited by the dome shape. The base is therefore a cylinder and the roof is a conical mansard roof. This plan also has the living area on the first floor with the bedrooms beneath (plans by Shelter Construction and Development Ltd. for Inuit Tapirisat of Canada, 1976). See Fig. 110.



Roof plan

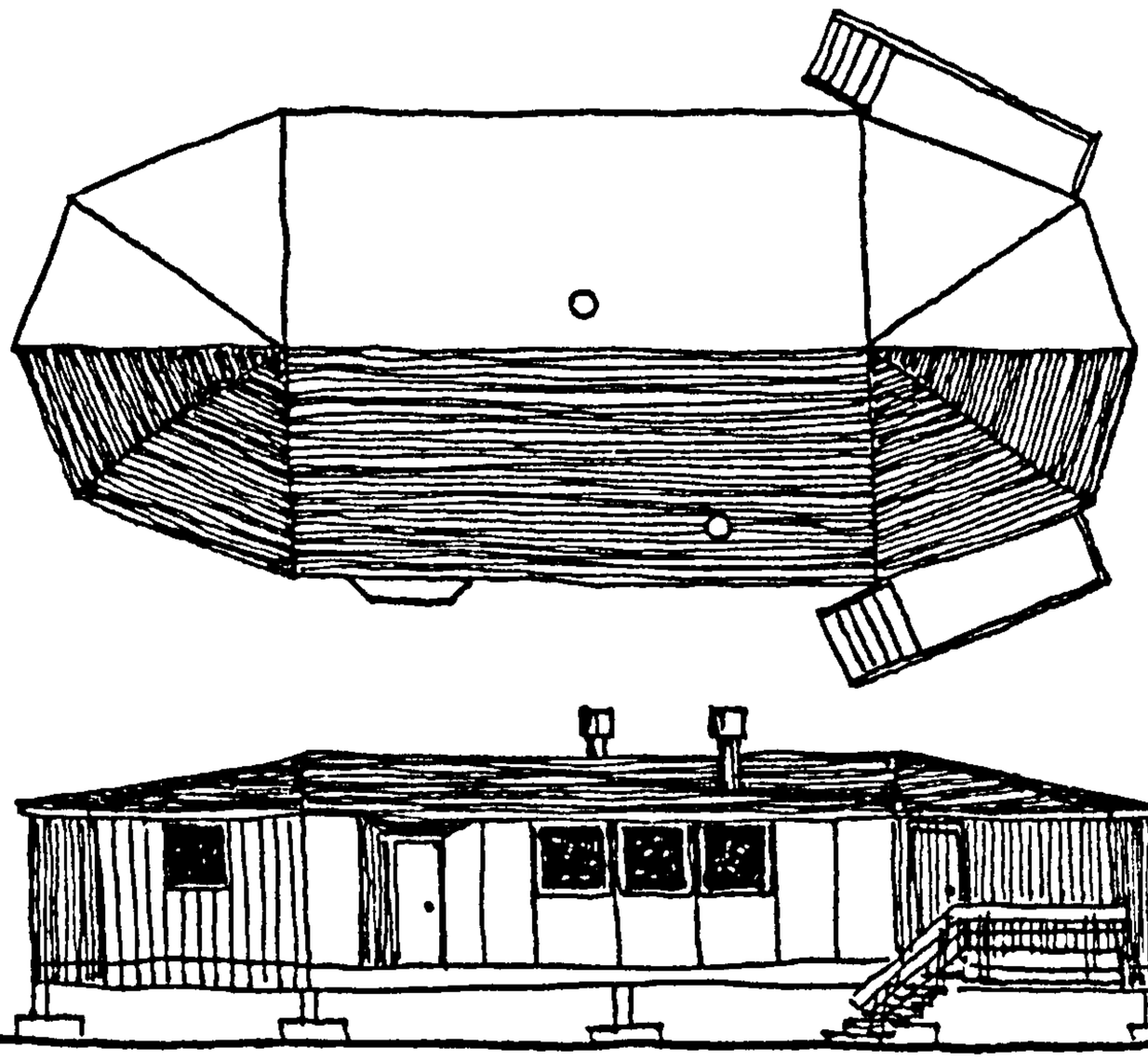


Elevation

Fig. 110. Prefabricated wood panel cylinder with conical mansard roof - two-storey house (Shelter Construction, 1976).

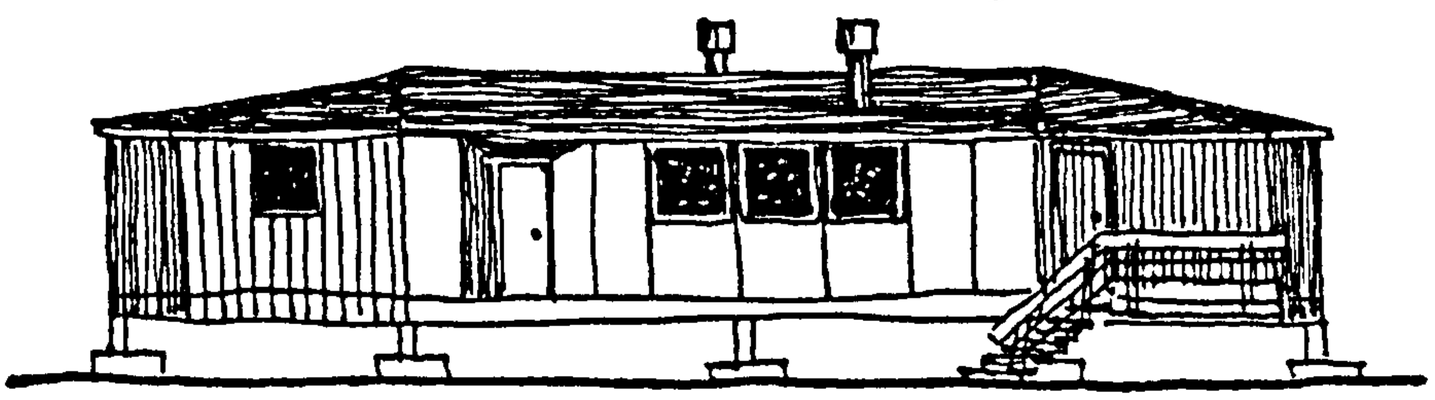
1.4.2.3.9 Decagonal Prefabricated Wood-Panel House

This house proposed by Ralph Erskine is a modification of the standard 455 Model and was an attempt to render this government house aerodynamic (see Fig. 100 for the standard 455 house). The basic house has been extended by 14' (4.3m) by adding a 4-sided element at either end of the rectangular plan. The extensions provided space for 2 extra bedrooms as well as additional storage space and a large living area. The author was unable to uncover any tests that were carried out to determine its aerodynamic performance (plans from Egelius, 1977, p. 848).

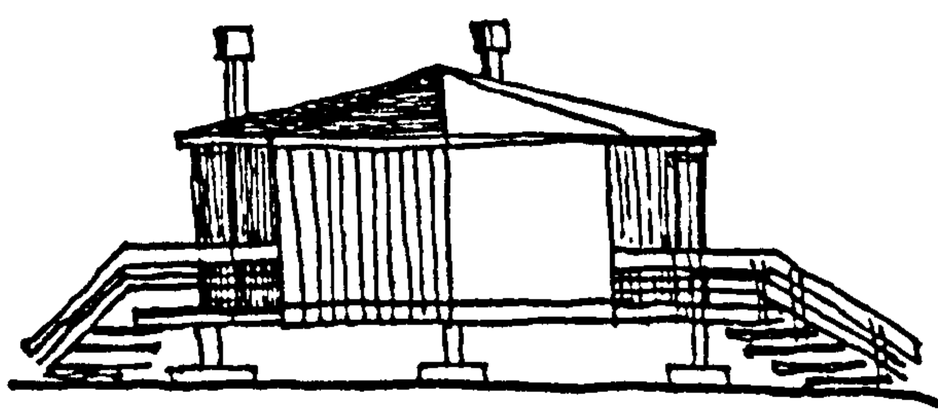


Roof plan

0 1 2 4 6 10



Front Elevation

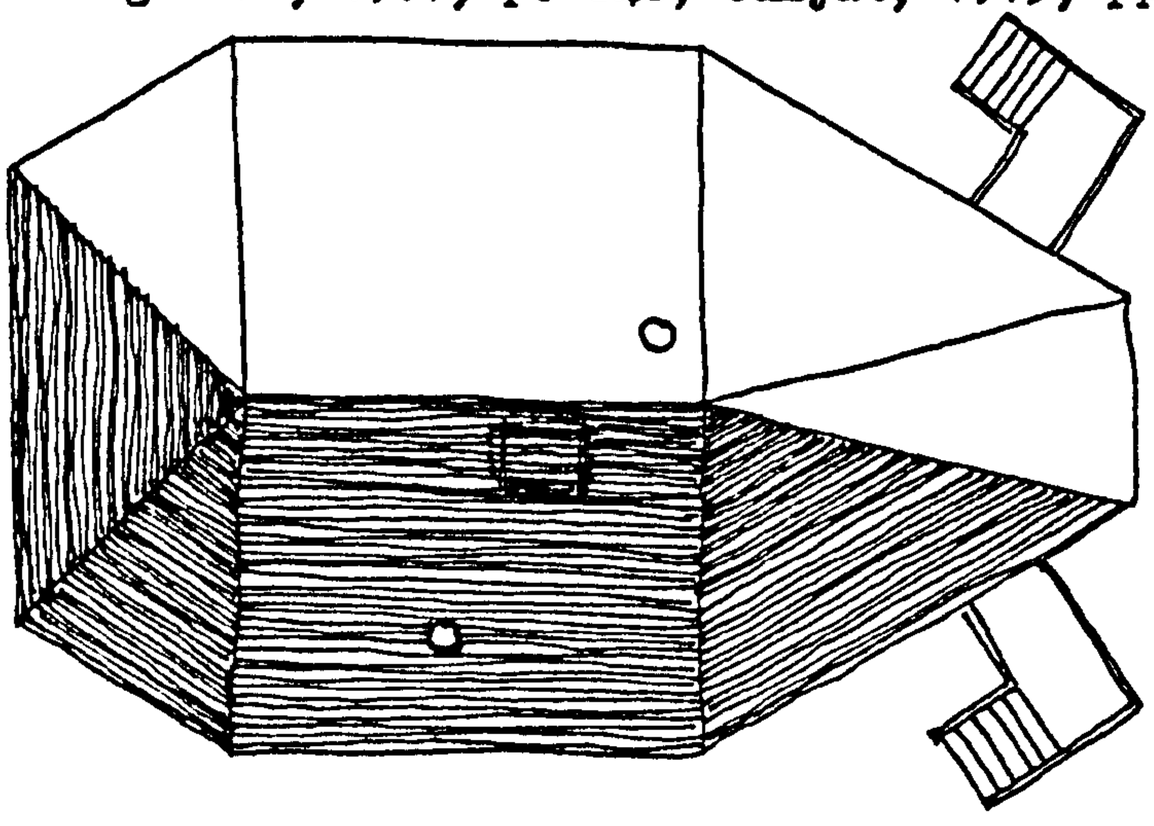


Side Elevation

Fig. 111. Decagonal prefabricated wood-panel house (Egelius, 1977).

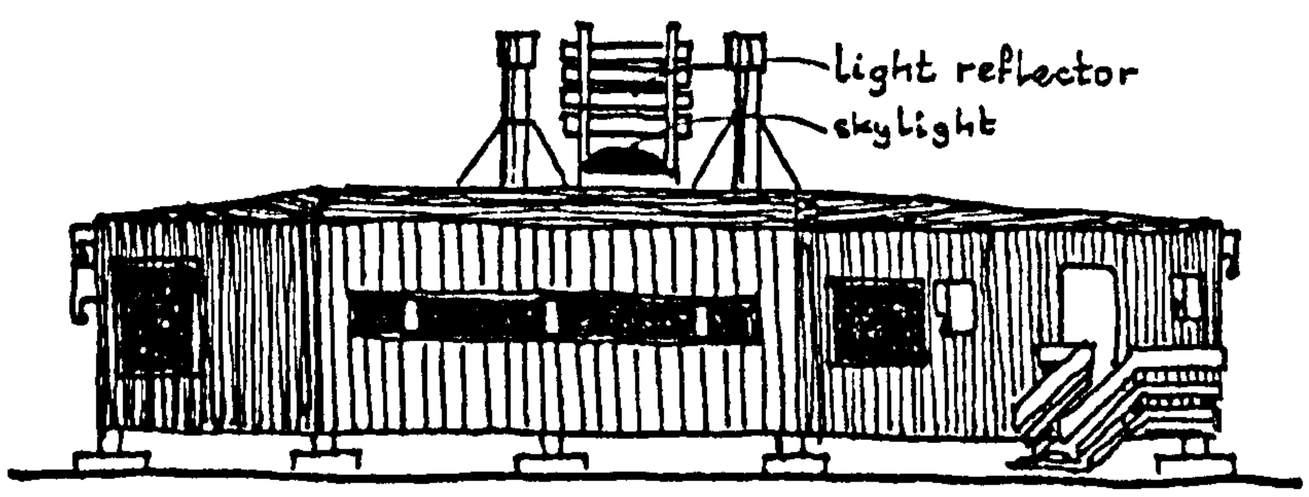
1.4.2.3.10 Octagonal Prefabricated Wood-Panel House

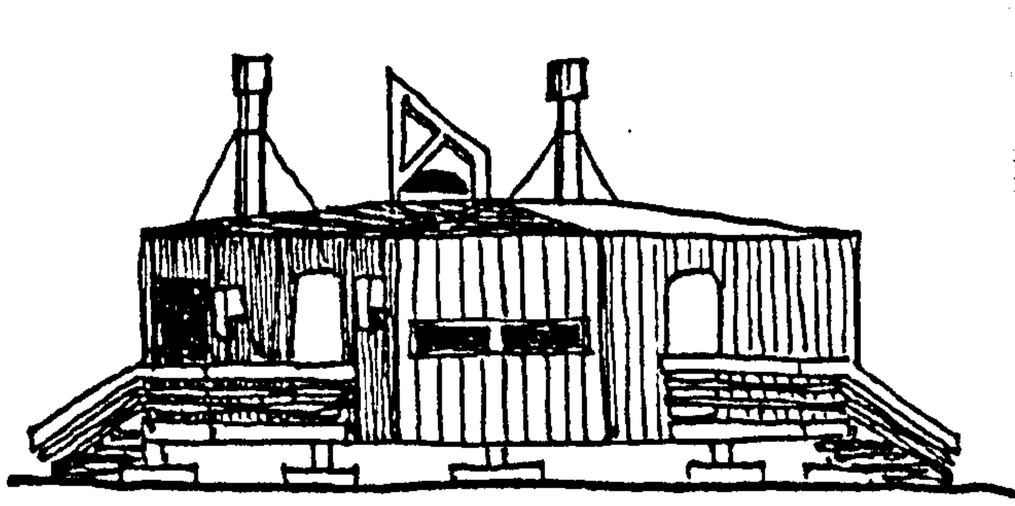
This design developed by Erskine for the Arctic village of Resolute is an irregular octagon in plan with 3 sides elongated giving it a pear-like shape. The elongated portion of the house gives the impression that it was designed for a dominant wind direction because the smallest wall area faces one particular direction. This form provides less flexibility for advantageous orientation when considering dominant wind directions (plans from Egelius, 1977, p. 848; Culjat, 1975, pp. 270, 293,s:61, s:62).



Roof plan

0 1 2 4 6 10





Front Elevation

Side Elevation

Fig. 112. Octagonal prefabricated wood-panel house (Egelius, 1977).

1.4.2.3.11 Two-Storey Octagonal Prefabricated Wood-Panel House

Erskine also developed a two-storey octagonal house for the same village, based on the principle of creating a cold-air trap at the ground level entrance with the living spaces at the upper level where the heat rises by natural convection. The plan is an irregular octagon at both the ground and first floor levels, but approximates a circle and is therefore more aerodynamic than the usual rectangular houses. The ground floor is

approximately one-half the area of the first floor and houses the fuel tank, furnace, mechanical equipment, storage and entrance vestibule. The first floor contains the living, dining, kitchen, bedrooms and bathroom projecting over the ground floor on all sides on Y-shaped pilotis. These pilotis require very special soil conditions for their structural stability (plans from Egelius, 1977, p. 848; Culjat, 1975, pp. 259, 294, s:59, s:60).

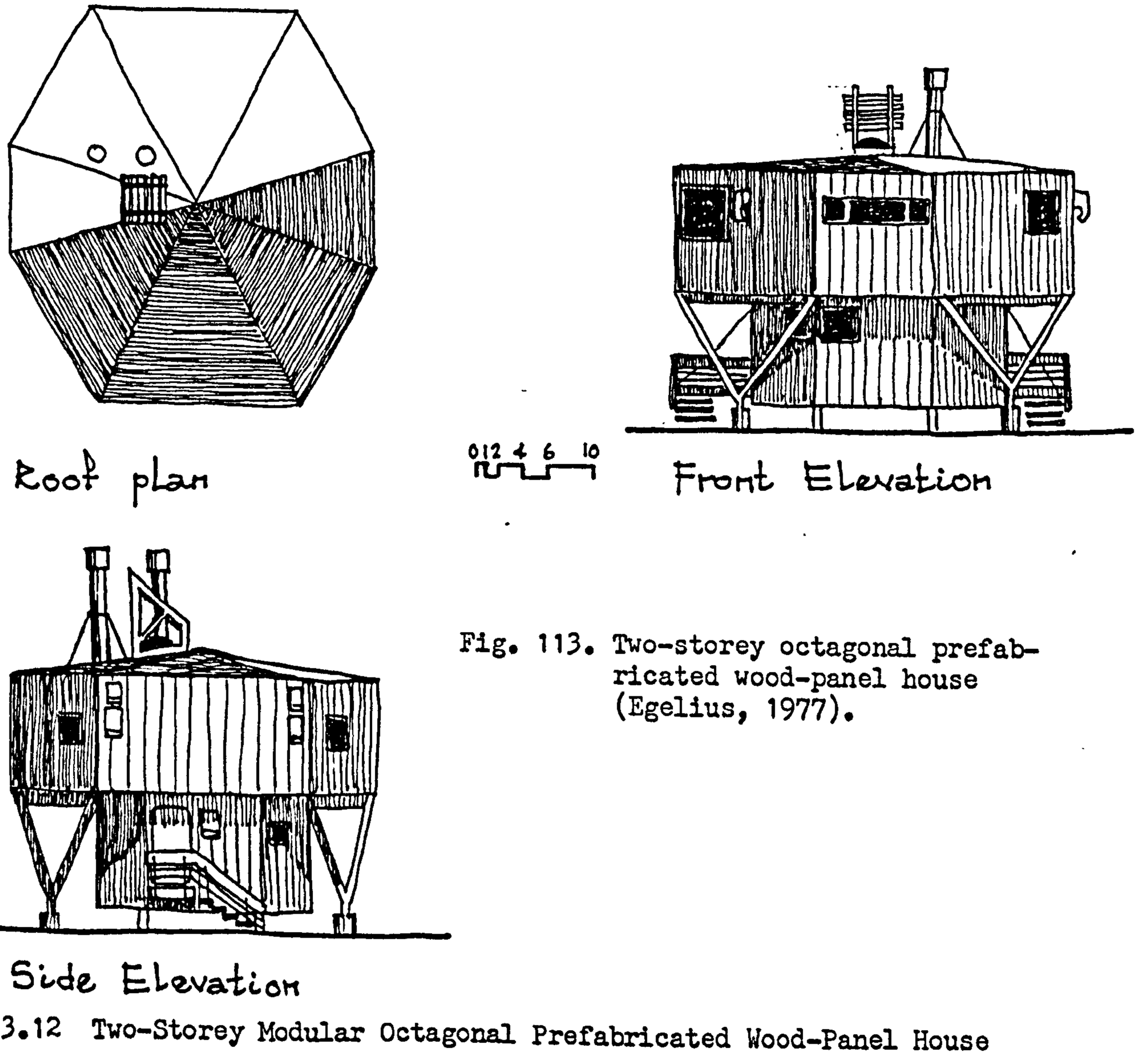


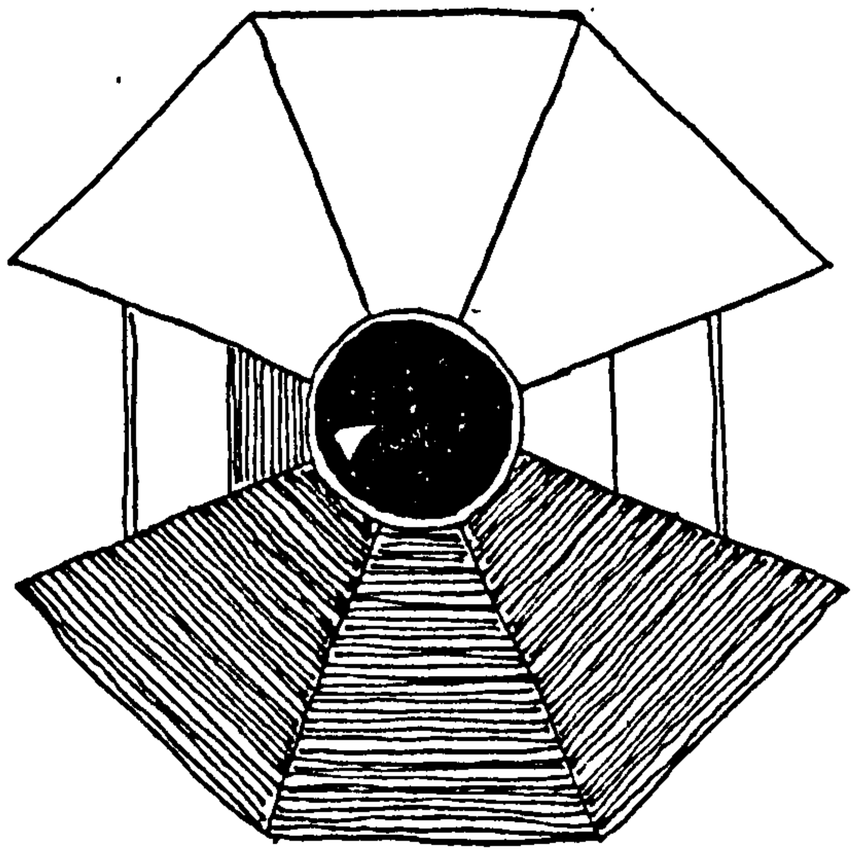
Fig. 113. Two-storey octagonal prefabricated wood-panel house (Egelius, 1977).

1.4.2.3.12 Two-Storey Modular Octagonal Prefabricated Wood-Panel House

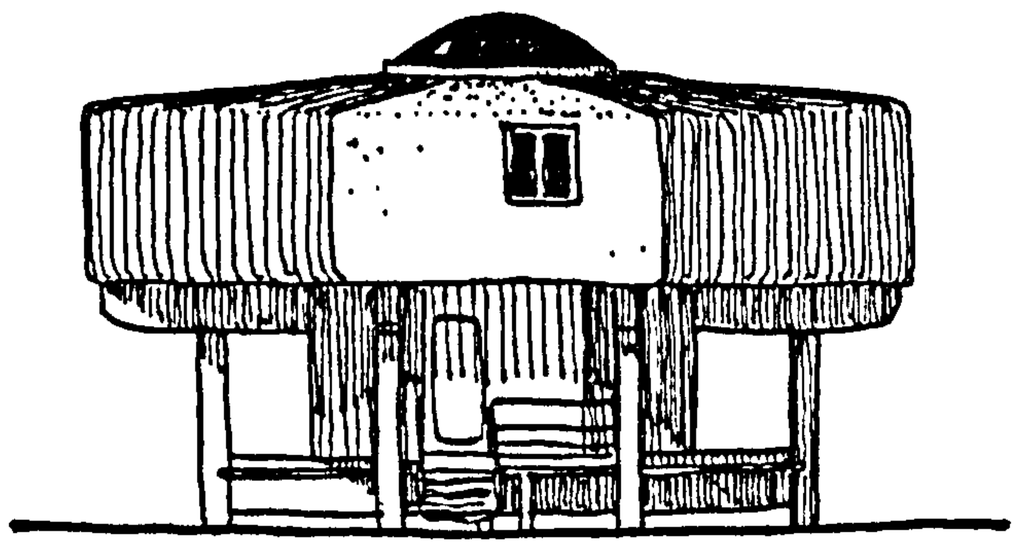
This house was planned by Moshe Safdie for Frobisher Bay in rctic Canada. The basic plan shape is a regular octagon at both the ground and first-floor levels. As in the previous example, the ground floor is smaller than the first floor which is supported on pilotis and a cantilevered beam. The first floor is designed around a central core housing the main

living-eating area from which radiate the kitchen, bedrooms and bathroom. The house size varies according to the owner's needs with radiating segments (to a maximum of six segments) which can be added to the central core. Therefore the house at the first-floor level can vary in size from the simple octagonal core two storeys high with no segments, to a house with 3, 4, 5 or 6 segments.

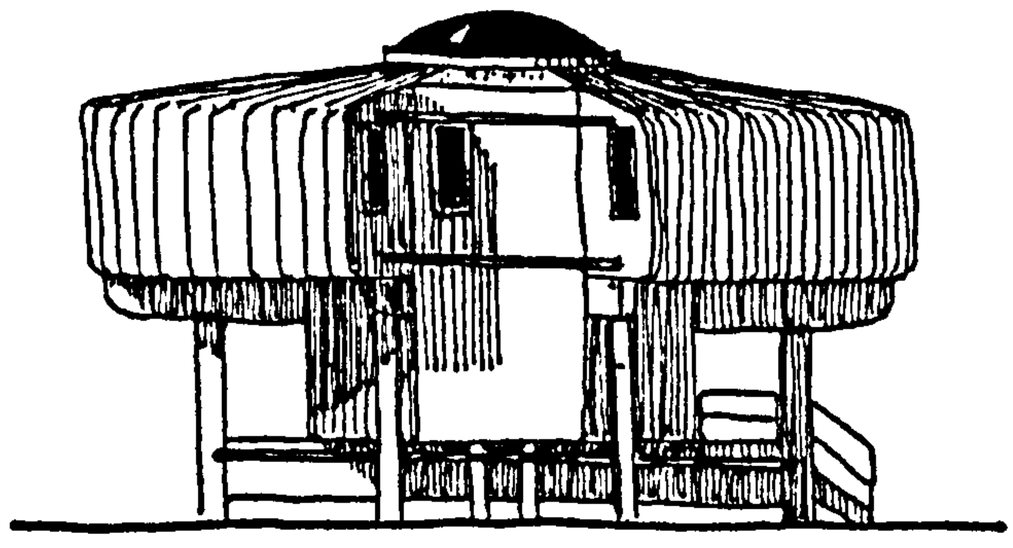
The geometry of the form was chosen for its combinatorial possibilities and the empty segments allow houses to be joined together while still maintaining outside windows. The empty segments would, however, create turbulence in high winds and increase the surface to volume ratio (plans from Van Ginkel Assoc., 1976, vol. 2, pp. 58, 59).



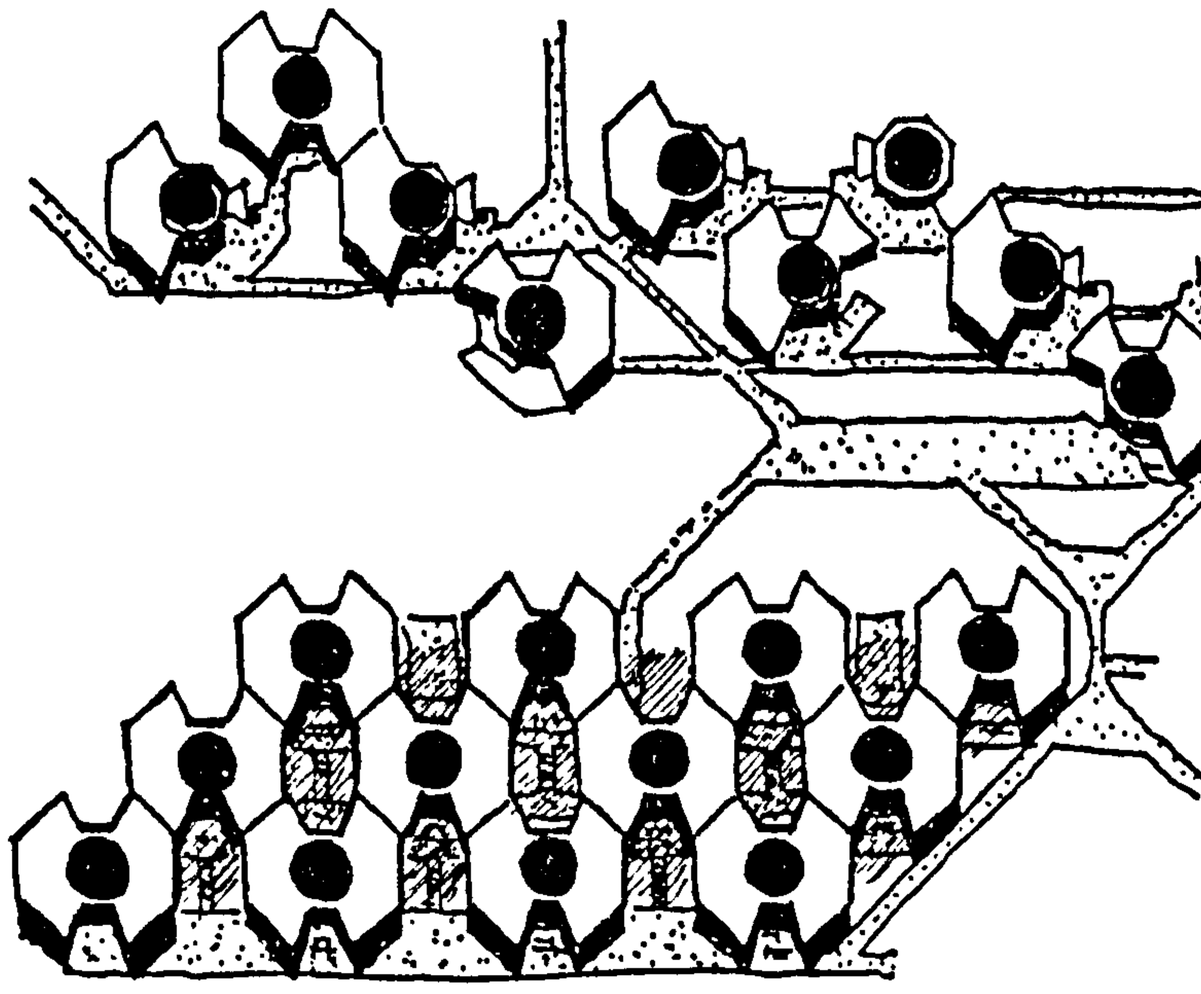
Roof plan (6 segments)



Front Elevation (6 segments)



Side Elevation (6 segments)



Plan of groupings (0, 3, 4 and 6 segments)

Fig. 114. Modified octagonal two-storey prefabricated wood-panel house (Van Ginkel, 1976).

Conclusion

From this historical description of traditional and contemporary housing in the rctic, it is obvious that housing forms changed radically once the Inuit became more sedentary and occupied permanent houses.

In relation to interior spatial organization, all traditional houses followed essentially the same pattern. The Inuit dwelling consisted of one large room or space, arranged in a fairly strict manner, the zones of activity being clearly defined. Every occupant has his place in the interior hierarchy arrangement as did every material possession which was essential to their way of life.

Contemporary Inuit housing reflects the complexity and changing life-style of this once predictable group of people. From the early houses which were basically one room, the Inuit is now occupying houses which have three to five bedrooms, with separate living, kitchen, bathroom and storage rooms.

The impact of southern culture has had enormous repercussions on traditional family activities and relationships. No longer are they a cohesive entity struggling for a common goal. Hunting has become more of a recreation to supplement a southern diet. The youth are preoccupied with popular music, fashion, junk foods, motorcycles, furniture, etc., and as a result their energies are fixed for the moment in other directions away from the family.

This turning away from traditional modes of life has played a large role in encouraging the Inuit to desire housing that allows for greater privacy for each family member. Many youths use their bedrooms not only as a place to sleep, but also as a place where they receive and entertain their friends. The bed thus becomes the sleeping and entertaining area recalling the role of the platform in the traditional house (used for sleeping-working-entertaining), except that it is no longer a common space for the whole family, but rather the domain of one individual in that family. In some cases when conflicting use of space arises, a tent is set up near the house and used to house such activities as playing music late at night, working on stone sculpture, repairing machines and equipment, etc.

As has been discussed previously, in a relatively short period of time the changes in housing have been phenomenal not only in terms of spatial division

but also in size. In the 1950's, one-room houses were similar in spatial use to the traditional houses, but in 1965 the first house-type with two separate bedrooms was introduced followed in 1966 by the first three-bedroom house. In 1974 the first four-bedroom houses were built in Arctic Québec followed by a five-bedroom duplex in 1980. This trend points out most clearly the individualization of the sleeping areas with almost every member of the family having his own bedroom if we assume that the five-bedroom houses are available to the average family which has 6.2 persons (Bigué and Pageau, 1980, p. 58).

Another large common space called the pulaarvik (approximately equivalent to living, dining and kitchen) seems to be also undergoing the process of change, but up to 1974 had been retained as an important pattern in space utilization (Nunaturliq, 1974, pp. 147-153). In a user-participation project carried out by the author and students of rchitecture at Laval University in March, 1980 in two villages in the Ungava Bay area, Arctic Québec, a few of the participants designed houses in which the pulaarvik was broken up into two separate but adjoining spaces. These plans demonstrate the desire to separate the living from the kitchen area, with the possibility of the dining area situated in either space depending on whether traditional or non-traditional food is being consumed.

In November 1980, during another user-participation study directed by the author in two Inuit villages on the east coast of Hudson's Bay, house designs were produced by the Inuit which showed further subdivision of the pulaarvik into three distinct spaces, the living, dining or eating area, and the kitchen. Because the project could not reach a large enough sector of the population this pattern cannot be taken as representative until a more detailed study is undertaken. It is evident, however, that the Inuit are modifying their use of space.

As can be seen from the historical description, traditional housing could often be found in clusters made up of two and three houses joined together. One of the reasons for contemporary housing was to provide single family dwellings to alleviate the overcrowded conditions which were blamed for the tuberculosis epidemics in the late 1940's. However, most families were of the extended rather than the nuclear-type, and as a result the single

family houses were inhabited in some cases by as many as 13 people (Nunaturliq, 1974, p. 210), but on the average, multi-generational families were made up of 9.3 persons (Bigué and Pageau, 1980, p. 66). This demonstrates clearly that many houses were overcrowded. The subsequent subdivision of the houses into many bedrooms and the break-up of the pulaarvik could be related to the desire of a multi-generational family attempting to define their own domestic space within a single volume. In traditional multi-family or multi-generational houses, the total volume was broken up into separate alcoves or separate house volumes while still maintaining some common spaces. In contemporary Inuit housing, the author is aware of only two multi-family houses which exist in Povungnituk. These two houses could be classified as duplexes in that they are two separate houses attached together sharing a common wall and a common entrance porch. Both houses were modifications of existing single family houses and were due to the initiative of four families. The existence of these duplexes, even though they are not a generalized phenomenon, does point out the need to investigate this type of housing.

In 1980 the Societé d'Habitation de Québec proposed to build double or duplex houses for the Inuit of Arctic Québec. This housing concept received a negative reaction from the Inuit which would seem to be a contradiction in terms of the prior existence of double and triple housing in the traditional period. This can be explained in part by the fear of fire which could start in a neighbour's house resulting in the loss of two houses instead of one, plus the undesirability of living in close proximity to someone who was not either a good friend or a relative. The second objection can be attributed to the practice of local housing committees which allocate houses based on greatest need rather than social affinities. A family in greatest need is interpreted as one having many members or a family housed in an older, overcrowded house.

This allocation policy has resulted in the displacement of portions of kin-related groups from their personal social group into a group which is defined in terms of need only (see Graburn, 1969, p. 168). If kin-related group structures could be maintained when relocating families to multiple-family houses, this could be a far more acceptable housing type. To

achieve this kind of coordination requires the participation of the population in the allocation of housing whether of the single or multiple-family type.

From the examples cited in the section dealing with the history of contemporary arctic housing, it is evident that there is a lack of variety in house form. The stucco and wood igloo as well as the experimental houses of Ralph Erskine and Moshe Safdie are the only houses to date which show some imagination, but present many practical problems. The pear-shaped single storey and the modified octagonal two-storey houses by Erskine, as well as the octagonal two-storey house by Safdie all have rooms that are difficult to furnish because of the acute angles. The two-storey models require special foundation considerations as the columns supporting the first floor have to be anchored into the permafrost for structural stability. In addition, the Safdie two-storey house also has the problems of wind turbulence, greater air infiltration, and an increased surface to volume ratio resulting from the missing segments of the octagon.

All of the government-built housing has been rectangular in shape with double or single-slope roofs suggesting little if any form research.

In the North-West Territories, the government has built dome-shaped houses, but many objections have been raised to this shape of house, especially by the Inuit of Arctic Québec. In the two-storey dome shape the inward curving wall-roof greatly restricts the efficient use of small spaces. Therefore the large open spaces (the pulaarvik) were placed on the first floor. The Inuit objected to the pulvaarvik being located on the first floor because they would have to bring food up one level, while they prefer direct access from the outside to the pulaarvik at ground floor level. Another problem with circular plans in general, is the difficulty in placing rectangular furniture in rooms with curving perimeters.

Because the dome-shaped snow house image has become synonymous with the Inuit, it is often proposed that the most suitable house form is a dome. In order to explore this concept the Nunaturliq research group included the design of a circular house in the battery of other user-participation concepts to be verified with the Inuit. In this particular study, all rejected the circular plans because they were too difficult to subdivide into

usable spaces and to place furniture in a manner that did not waste space. However, the author has personally come across a few individuals for whom the circular form had some cultural validity, but the form needs to be verified with a larger segment of the population, as should other house forms which have practical advantages such as good aerodynamic qualities, simple construction, etc.

From the foregoing discussion it would seem that research is required to determine how the future use of domestic space will evolve; how, if at all, multi-family housing will fit into the notion of family housing groups; and finally what is the range of feasible house forms in cultural and practical terms.

The author believes that a search for appropriate house forms based on cultural as well as technological and climatic needs is important, but as houses are grouped in a pattern called a settlement which structures social interaction and cultural needs, the planning of communities is equally important. The historical description of arctic housing helps to situate the Inuit in a process of transition from which the house was the most important expression of cultural needs as it changed from season to season and from place to place. However, as soon as the Inuit adopted a sedentary way of life, the settlement became a more important concern in his daily life. Now his very existence is dependent on the services provided by the settlement, and the cultural considerations brought into the overall planning of his environment are crucial, as a settlement layout cannot be easily changed once in place.

The present-day Inuit needs to be aware of his true history in order to have a real choice when deciding on what kind of future environment he wishes to identify with. In the past few years he has had to meet head-on with a foreign culture that has disrupted his former living patterns, causing him to feel overwhelmed and disoriented.

This is the reason for devoting this work to the important but rather difficult task of partnership which implies giving just consideration to the cultural, climatic and technological needs of future settlement planning in the north.

1.5 HISTORY OF ARCTIC SETTLEMENTS

1.5.1 Traditional Inuit Settlements

There are very few plans of early Inuit settlements that can be considered as representative of a settlement layout at one particular point in time. For example, the winter villages during the middle Dorset period were small "nucleated" entities, whereas in the same period in the Central Coast the villages were more dispersed (Fitzhugh, 1980, p. 600). Sites during this period were often abandoned and not always reutilized by the same people or in the same manner.

At times the village or settlement might have been made up of only a few houses, while at other times when families grew too large for one house or when families from other areas joined the local population, additional houses had to be built. Thus when analysing the ruins of traditional houses, one has to consider that the houses as a group were not necessarily all occupied at the same time. Therefore, house groups can be indicators of the orientation of the dwellings and their relationship with natural features, but they cannot be used as precise indicators of relationships between dwellings nor of the exterior spaces associated with each house. An important factor influencing the grouping of semi-subterranean, sod and stone houses was the availability of local materials for construction, as well as sites which were well drained and easy to excavate. Therefore, the distance between houses was influenced by the proximity of materials and the location of earth that could be easily excavated.

As has been seen in the history of traditional Inuit housing, during certain cultural periods, communal or longhouses replaced individual houses. Often the entire village was composed of only one or two houses, making the village plan extremely simple. Unfortunately, the author could not find any drawings which situate these houses in relation to natural features and general orientation.

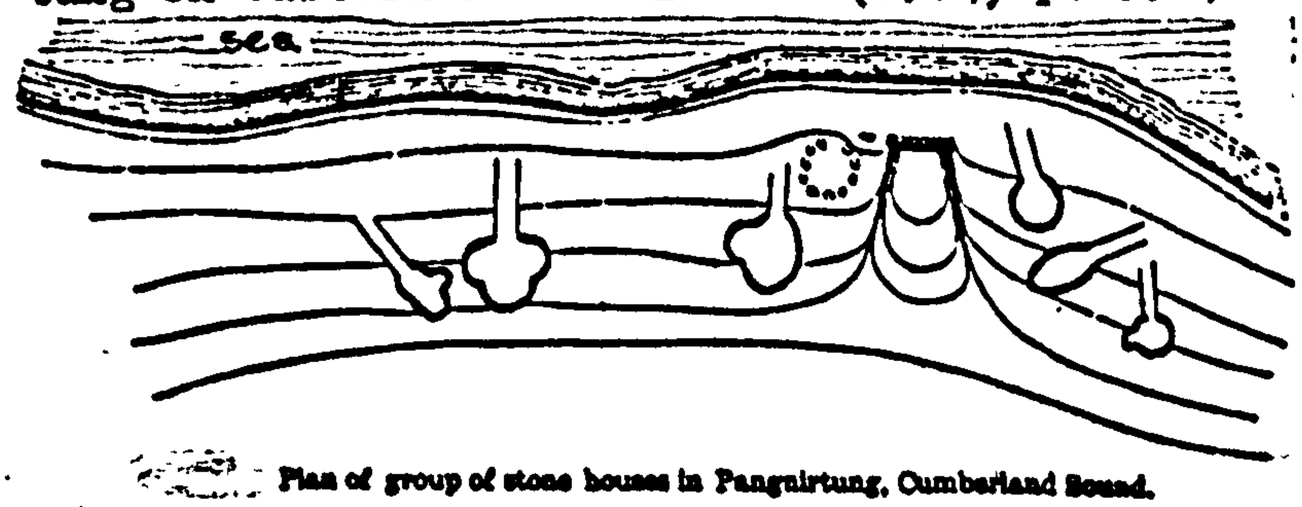
Plans of snow villages are also rare, and the author has only uncovered one. It should be noted that the layout of a snow house settlement is probably more dependent on the availability of suitable snow than on any cultural

needs or traditions. Therefore this plan (described in section 1.5.1.2) may be more of an indicator as to where deep, firm snow was found, rather than of the desired spacing of houses or the orientation of the entrance tunnels.

No plans were found for traditional tent villages. However, the plans of contemporary tent villages give an indication of what the orientation, grouping, and relation to natural features during the traditional period might have been. The materials used (caribou skins) were not dependent on the immediate environment which allowed greater choice of site and proximity of dwellings.

1.5.1.1 Stone House Settlements

A sketch presented by Boas shows a group of autumn stone houses at Panqnirtung on eastern Baffin Island (1974, p. 550). See Fig. 115. These houses were situated in the lee of a ridge close to a beach and are oriented such that all the entrance tunnels face the sea. It seems likely that the placing of the houses in a loosely formed single row parallel to the seashore may be due in part to the lack of space between the sea and the crest of the ridge which also prevented the formation of other rows of houses. This village consisted of six houses.



Plan of group of stone houses in Pangnirtung, Cumberland Sound.

Fig. 115. Plan of group of stone houses in in Pangnirtung (From Boas, 1974).

Rasmussen made a drawing of a stone village site at Malerualik, King William's Land, which shows houses in four distinct rows situated on four different levels (in Mathiassen, 1927, p. 306). See Fig. 116. It is unlikely that these four rows of houses were one settlement, but rather four different settlements built at four different periods. Mathiassen hypothesized that the land had risen above the sea and that as the sea receded, a new settlement was built closer to the sea's edge (1927, pp. 8-10). He based this opinion on the fact that the sea is "...the 'larder' of the Eskimos", and therefore they always built in proximity to it[1] (1927, p. 8). Fig. 116

1. The phenomenon of land rise is attributed to isostatic rebound (Schledermann, 1980, p. 298).

illustrates the height of each row of houses above sea level and its distance from the sea. For example, the first row of houses is 15m above sea level and 90m from the water, while the fourth row is 22m above sea level and 370m from the edge of the sea. Looking at each row as a separate village, we see that the first village closest to the sea has a string of houses built slightly behind the first row. Of the total of 28 houses, 10 are clearly occupying this position. It is interesting to note that every house in this village had an unobstructed access and view to the water in at least one direction (Mathiassen, 1927, pp. 110-112). The first village contained no multiple house forms, whereas the second village of 15 houses had 5 groups of 2 houses so close that they touched each other. The third village of 17 houses was made up of 2 triple houses, 2 double houses, 3 groups of 2 houses abutting each other, and 7 single houses, while the fourth village had 4 houses all quite separate. The third village, one of the oldest, may have coincided with the cooling period mentioned by Schledermann (1976, pp. 34-36), resulting in the use of multiple housing to conserve heat and to better share less plentiful food supplies.

Mathiassen describes another village at the Naujan site on the north coast of Repulse Bay near the Arctic Circle. It was at this site that Mathiassen developed his hypothesis concerning the rising of the land above the sea (1927, pp. 6-10). He points out that the many raised beaches and layers of sea shells are a good indication that the sea was once closer to the houses. See Fig. 117.

Mathiassen identifies 5 house groups at the Naujan site: group 1 composed of houses I - III (3 houses); group 2 with houses IV - X (7 houses); group 3 containing houses XI - XIV (4 houses); group 4 made up of houses XV - XVIII (4 houses); and group 5 with houses XIX - XX (2 houses). Except for the last two groups of houses facing the lake and houses X and XII which face west, all the other houses generally face south in the direction of the sea. However, groups 4 and 5 had access to the sea via the lake. The houses are generally situated in rows falling within the same contour line with three notable exceptions: houses VII, X, and IX which were built behind a house or group of houses. In this settlement, there were 2 double houses and 1 triple house, with all the rest being single houses.

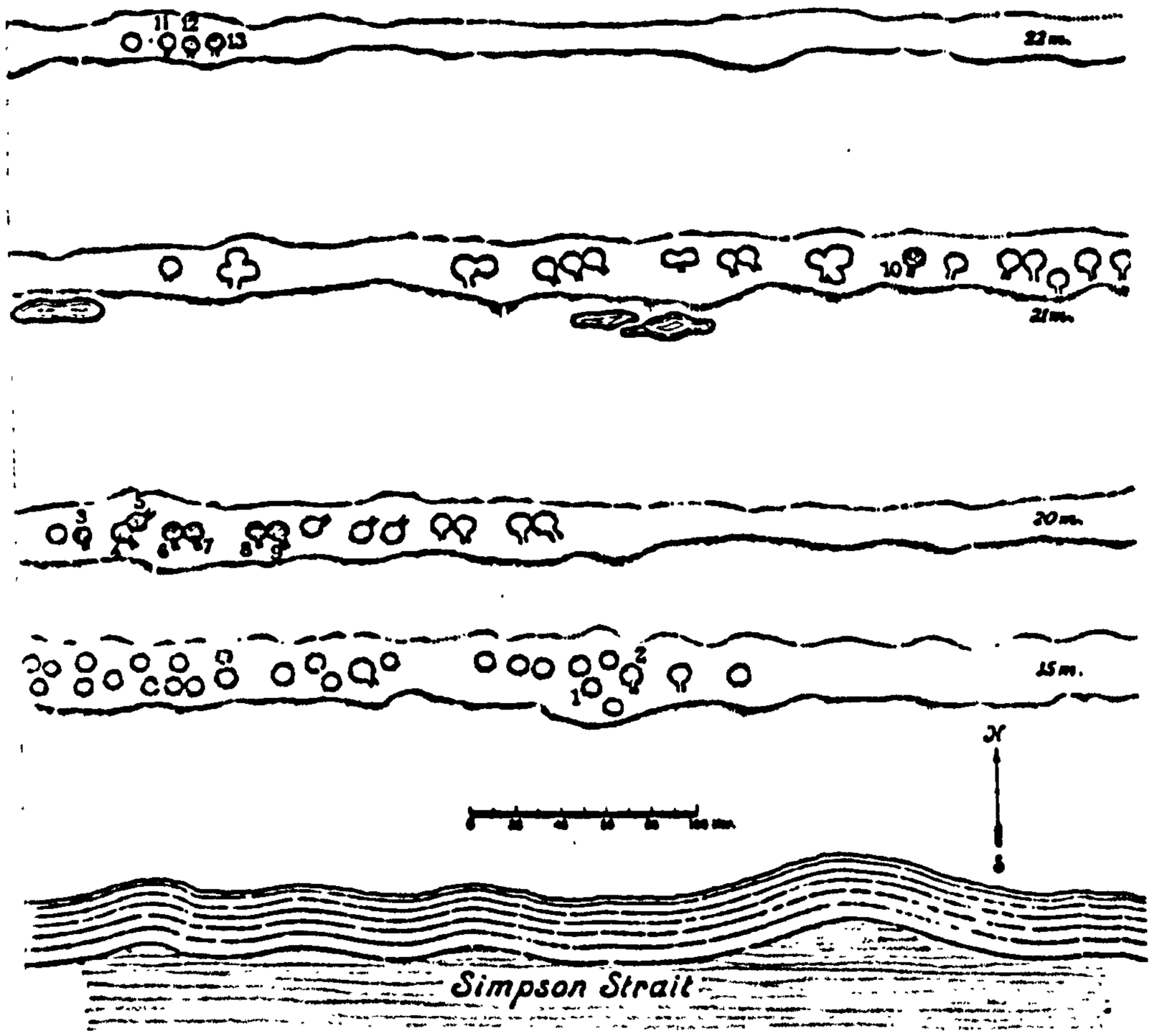


Fig. 116. Sketch of the village site Malerualik (Mathiassen, 1927).

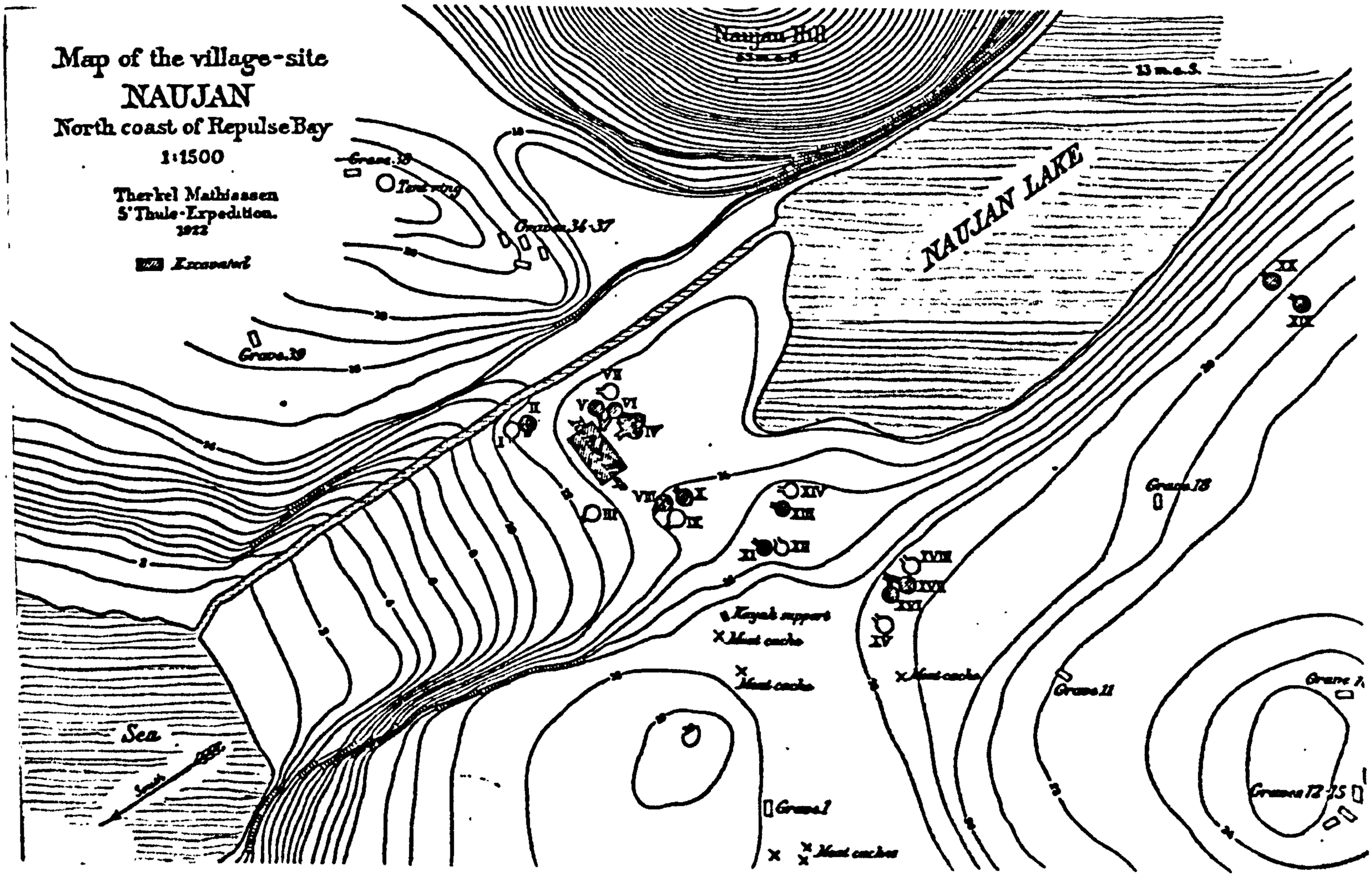


Fig. 117. Village site of Naujan (Mathiassen, 1927).

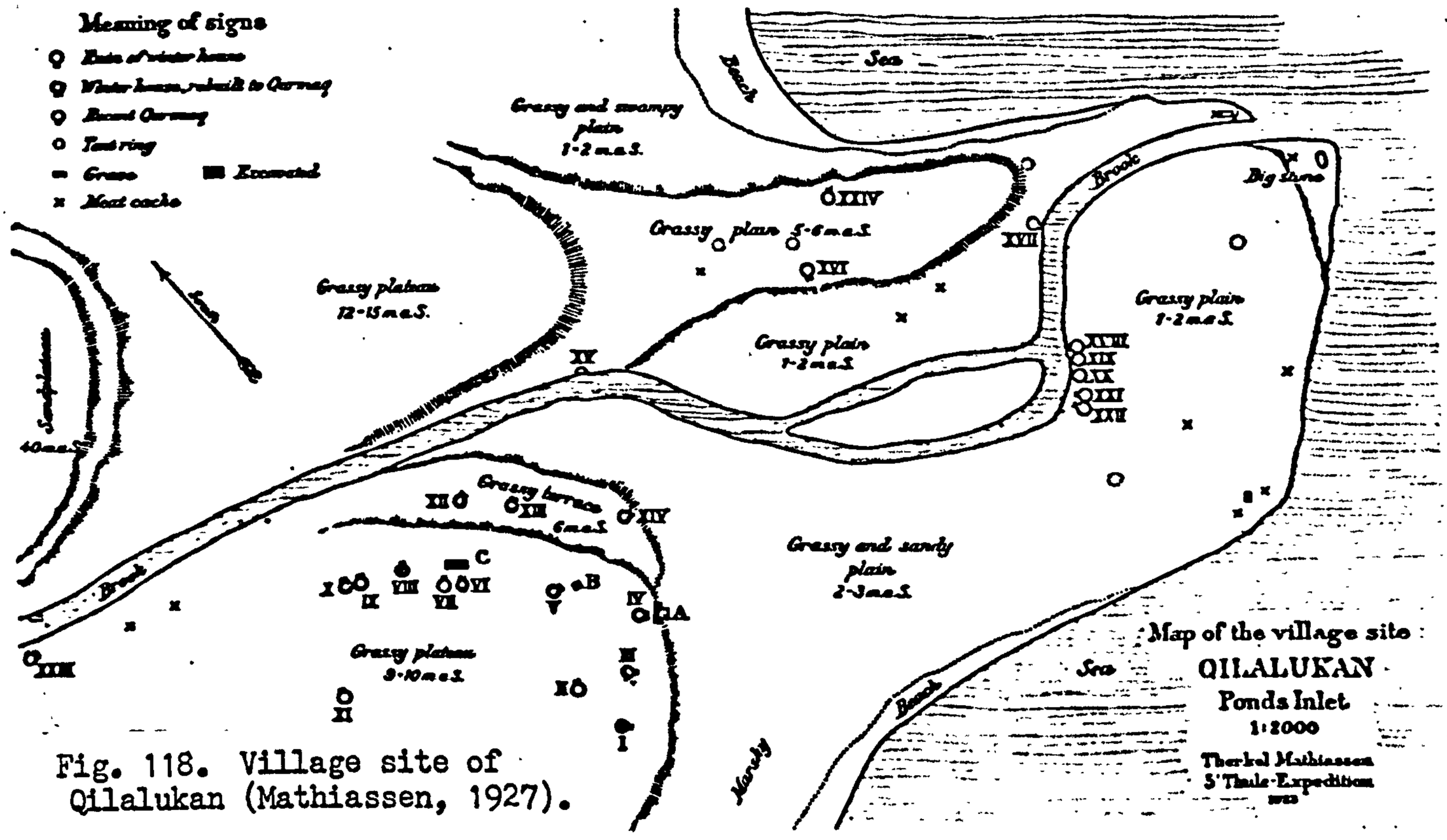


Fig. 118. Village site of Qilalukan (Mathiassen, 1927).

Fig. 118 shows a map of another stone house village site, Quilalukan, in Pond Inlet on northern Baffin Island (Mathiassen, 1927, p. 137). Houses I - XIV generally face in the direction of where the sea would have been before it receded, while houses XVI and XXIV although facing in opposite directions to each other were oriented towards the sea. One can see that before the land rose, the zone where these two houses are situated was a peninsula with water on both sides. Houses XVII - XXIII all face the river, and according to the map symbols are recent autumn houses having direct access to the brook which drains out to the sea. House XV has been partially eroded by the brook which would seem to indicate that the brook is a more recent formation, and that house XV was an early dwelling. It is unusual to find one of the more recent houses so distant from the others as in the case of house XXIII, which is quite far inland. It would seem to belong to the same period as houses XVII - XXII because of its orientation to the brook. The map symbols indicate that some of the ruined winter houses have been rebuilt as autumn houses. An analysis of house orientation shows that of the 24 houses; 9 face southwest, 5 southeast and the remaining 10 face west or northwest. They all, however, are oriented towards a waterway.

All the houses seem to be single dwellings, although 3 groups of 2 houses have a portion of their walls contiguous. The number of houses in each

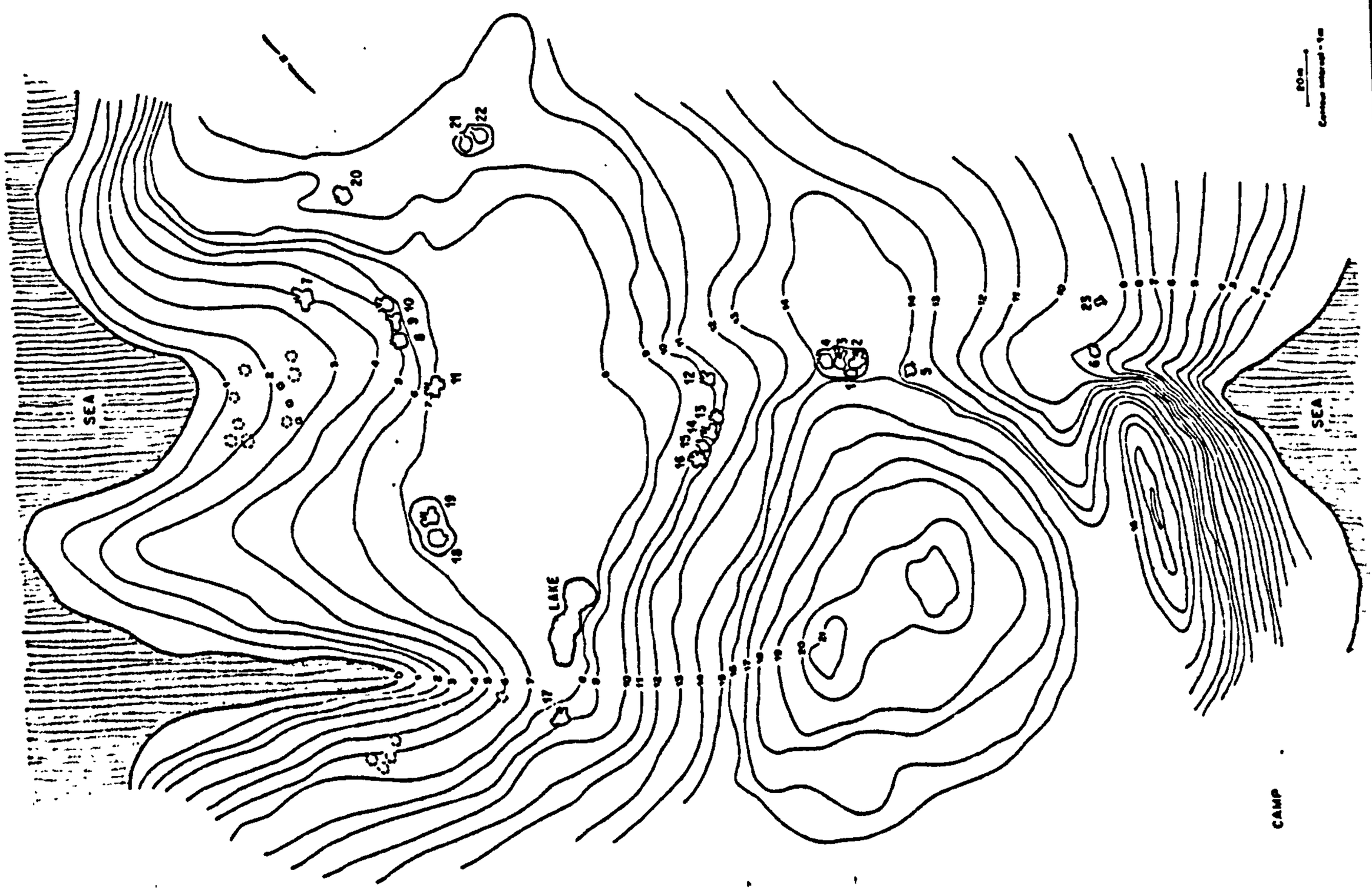


Fig. 119. The Skraeling Island Site (From Schledermann & McCullogh, 1980).

group varies greatly. Group I - XI has 11 houses; group XII - XIV has 3 houses; group XV, XVI and XXIV has 3 houses; and the last group 6 houses, made up of houses XVII - XXII.

The next example is from the Skraeling Island site off the east coast of Ellesmere Island. Once more the rising land phenomenon is evident here in the situation of the house groups (Schledermann and McCullough, 1980, p. 835). See Fig. 119. It would seem that the majority of the entrances are oriented toward he sea with only a few exceptions. Of the 23 houses, only houses 6, 18, 21, 22 seem to be oriented in a direction other than the sea. Some of the houses shown on the map seem to be multiple houses, but no details of the houses were available, therefore no interpretation of housing types is possible. The number of houses in each group is as follows: 5 houses in group 1 - 5; 2 houses in group 6 and 23; 5 houses in group 7 - 11; 5 houses in group 12 - 16; 2 houses in group 18 - 19; 3 houses in group 20 - 22; and 1 house alone in number 17.

Maxwell describes the Lonesome Site situated on the northeast coast of Ellesmere Island (1960, p. 9). See Fig. 120. In this plan there are pit houses, houses with entrance tunnels, and tent rings. Because there are

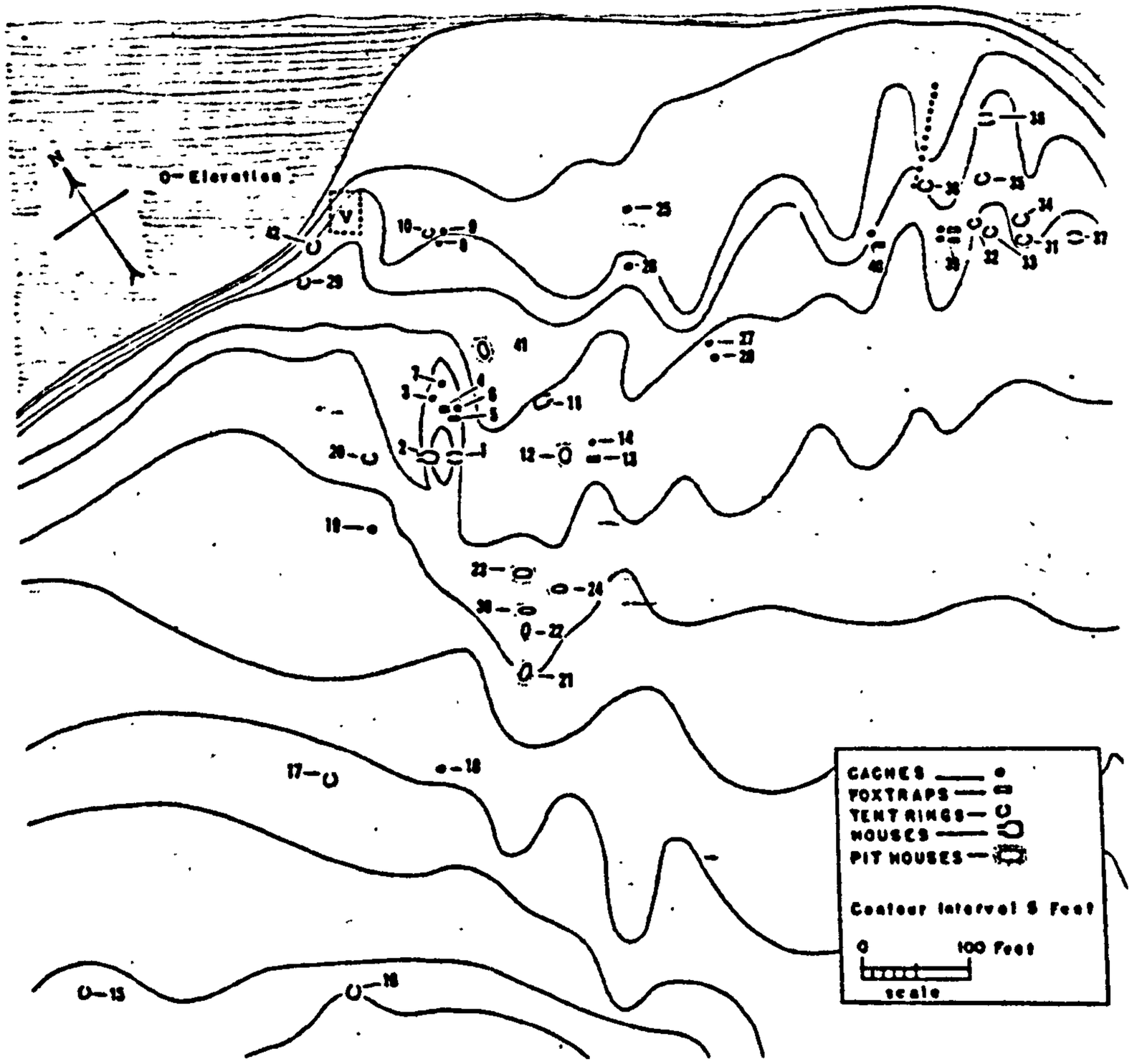


Fig. 120. Lonesome Site (From Maxwell, 1960).

only two houses with tunnels it is difficult to ascertain the orientation of the other houses. There are 4 houses (2, 11, 12 and 41) which are quite distant from all the others, while 5 houses (21 - 24 and 30) are grouped together. In general, the houses seem to follow the land contours. Some tent rings are far apart (15 - 17) while others are closely grouped (31 - 38).

From this site no particular layout pattern emerges, giving some indication of the difficulty of using archeological sites as indicators of settlement layout. However, the 5 previous sites displayed a certain structure in layout, but the above described site exhibits only some form of structure in the western portion of the site where tent rings 31 - 38 were found.

Mathiassen has made a sketch of a more general nature of the Kuk settlement on the northern part of Southampton Island (1927, pp. 223-225). See Fig. 121. The settlement was originally situated at positions 8 and 2 and eventually moved to 1, 11 and 3. Position 4 was the site inhabited when the sketch was made. Zones 1 and 3 had winter houses, while zone 11 contained tent rings and was therefore a summer location. The importance of direct access to the sea or a river is illustrated in this site plan. Information was not given as to the number of houses at each site.

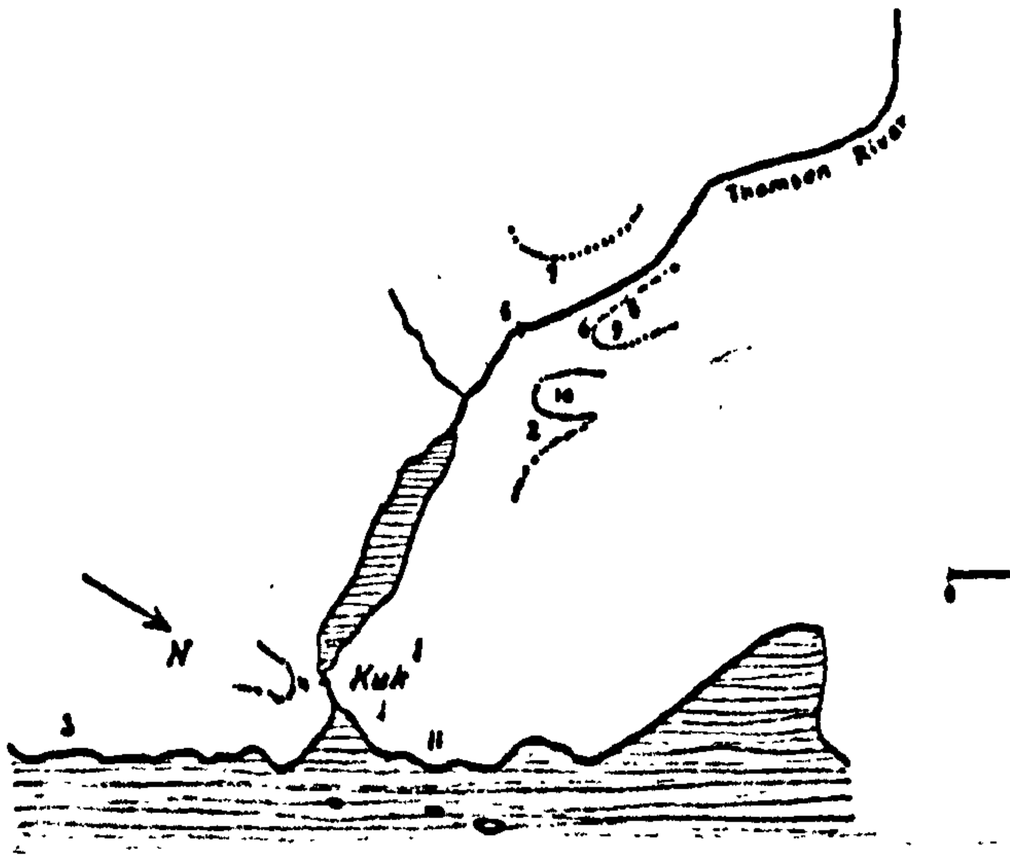


Fig. 121. Sketch of Kuk and environs (Mathiassen, 1927).

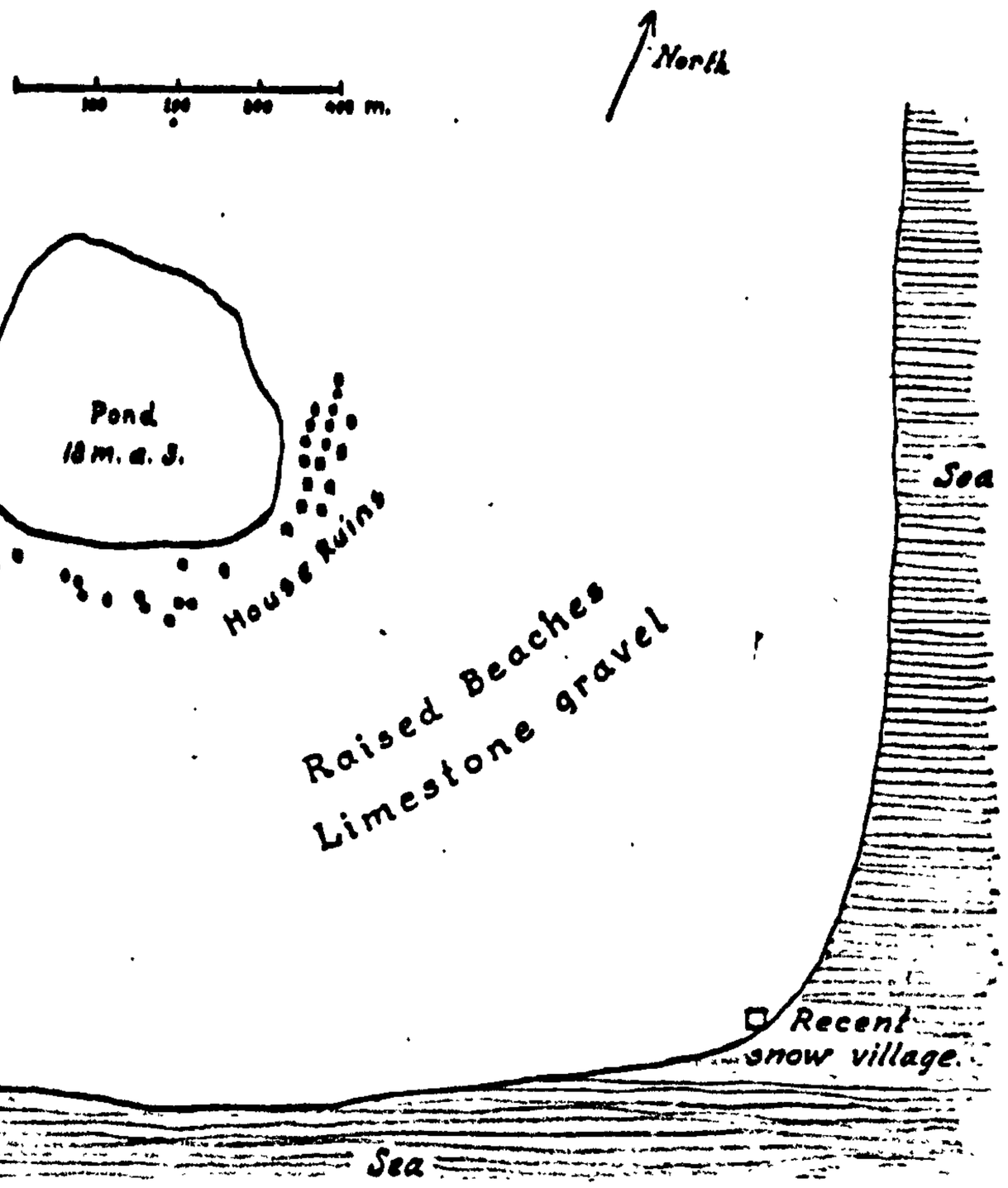
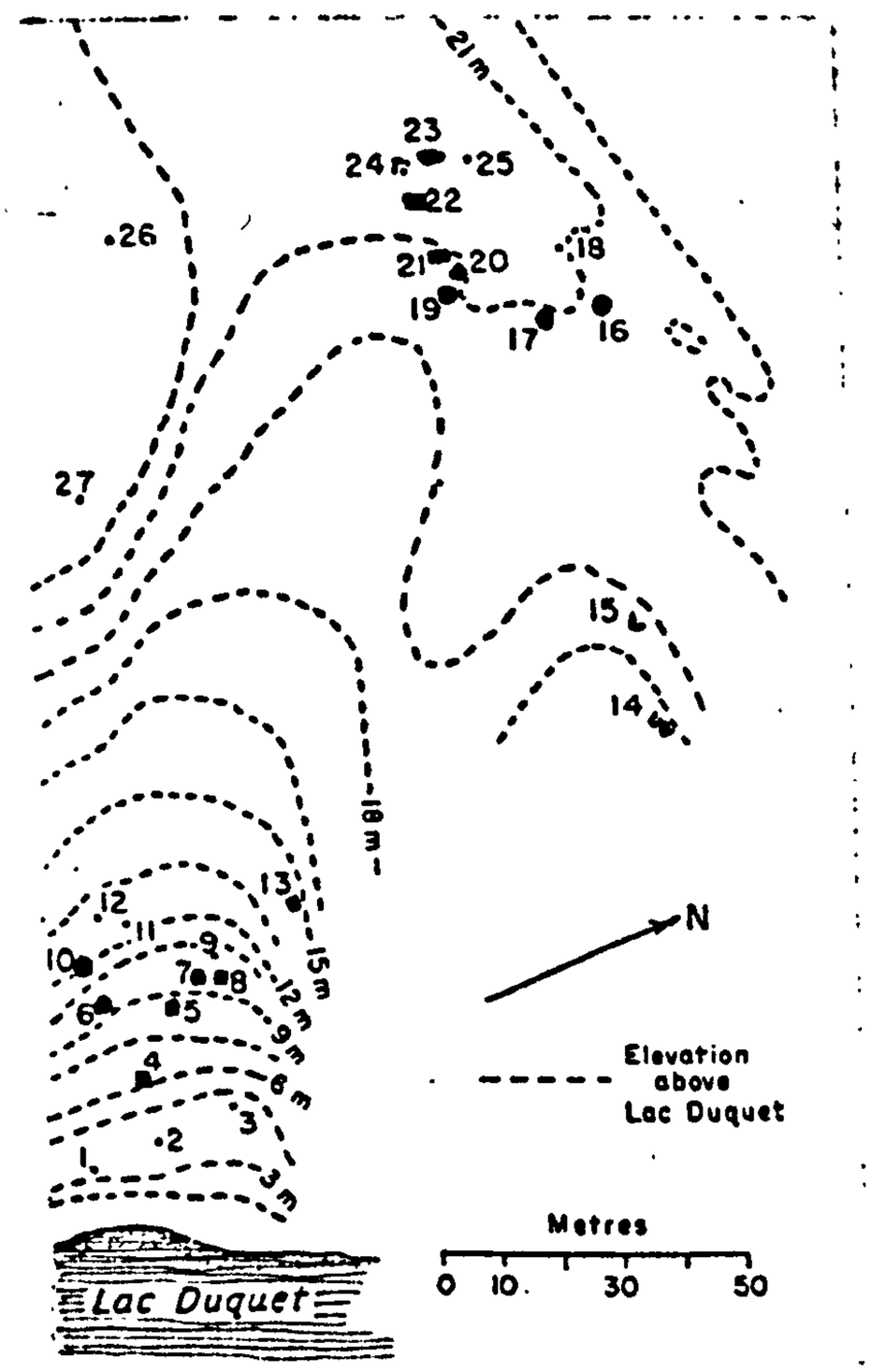


Fig. 122. Sketch map of the Pingerqualik village (From Mathiassen, 1927).

The Pingerqualik site is shown in Fig. 122. Mathiassen shows house ruins distributed around the eastern and southern edges of a pond. There were 2 house groups with 17 houses in each. The eastern group contains 3 rows of houses parallel to the edge of the pond, while there is a semblance of 2 rows on the southern shore of the pond (1927, p. 119). The location of a recent snow village is also shown on the shore immediately adjacent to the sea.

Matthews provides a drawing of the Deception Bay site in the Labrador - Ungava area which displays two general groupings (1975, p. 248). The group closest to the sea is made up of square and pentagonal houses while the group further inland is made up of circular and oval houses. Recent tent rings are situated near the lake shore, indicating three different periods of occupation including the stone house sites. See Fig. 123.



Group 2

1, 2, 3	Recent Eskimo tent rings
4	Square foundation
5	Square foundation with dividing walls
6	Pentagonal foundations
7	Square foundations with dividing walls and alcove
8	Square foundations
9	Cache
10	Pentagonal foundations with dividing walls
11, 12	Cache
13	Structure against rock face

Group 1

14	Two walls against rock face and cache
15	Circular foundations against rock face
16, 17	Circular foundations
18	Two stone pillars
19	Circular foundation
20	Circular foundation connected to no. 19 by small cache
21, 22	Elongated foundation
23	Oval foundation with collapsed elongation and human bones
24	Indistinct circular group of stones
25, 26	"Coffin-like" stone fall-trap
27	Vertical stone on hill top

Fig. 123. Distribution of Group 1 and Group 2 structures at Deception Bay (From Matthews, 1975).

Generally, it can be stated that the stone houses in settlements followed the land contours, although there are a few exceptions, and that houses were approximately oriented towards waterways which gave direct or indirect access to the sea. As has been noted, there were always exceptions to the close grouping of houses. In some instances a single house could be quite distant from all the other houses, indicating a degree of individuality among the Inuit.

1.5.1.2 Snow House Settlements

Only one plan of a snow house settlement has been found in all the literature surveyed by the author. It would seem that the main efforts of anthropologists, ethnographers, archeologists, etc., were directed to the recording of the construction and use patterns of individual houses, and ignored the relationship of one house to another or of houses to their site.

Fig. 124 is a sketch of a snow house village which was drawn by Mathiassen (1928, p. 32). He points out that this village was situated year after year in the same area because of the occurrence of a large deep snow drift in the lee of the ridge providing sufficient snow depth for the houses. The 10 houses were laid out parallel to the shore with some houses closer together than others, perhaps due to kinship links. It is important to

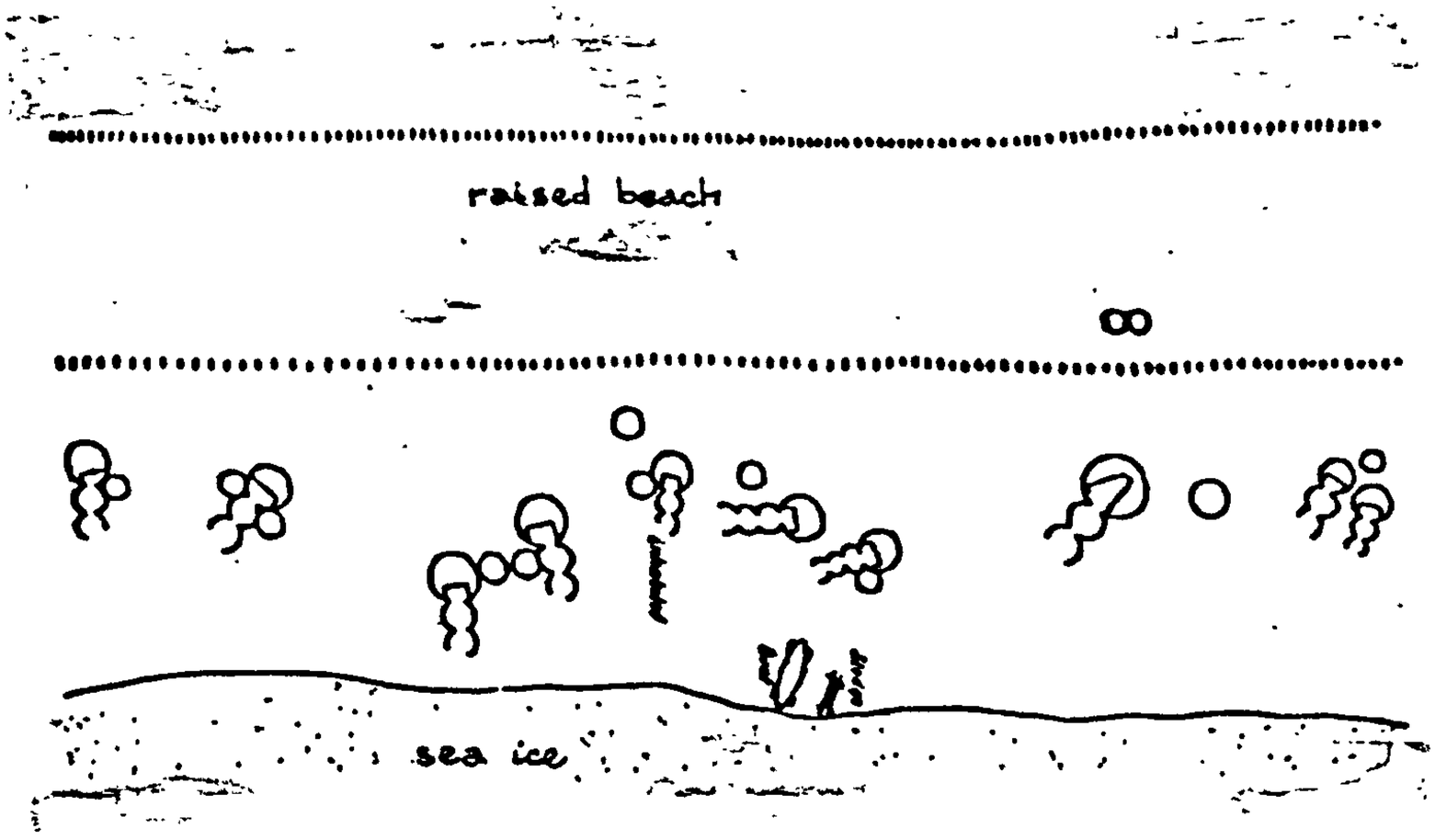


Fig. 124. Sketch of a snow village - Iglulik. Scale 1:1000 (From Mathiassen, 1928).

note that no houses are situated on the inland side of another house, emphasizing the importance of access to the sea or ice. Since every family is relatively autonomous, there was no need to be tightly grouped around a central house. The village measured 400' from one end to the other, thus no family was far from any other family. The entrance tunnels are generally oriented towards the sea with the exception of two houses which have their entrance tunnels parallel to the shoreline. At the time the sketch was made only 5 families were living in the village while 3 other families had temporarily left the village on a trading trip. When Mathiassen returned in May, 17 families were living in the settlement as some families living out on the ice had moved in. The village seemed to be in a constant state of flux making its overall population difficult to determine.

From photographs in Stefansson (1913, pp. 274, 278) and Jenness (1922, p. 255), and from conversations with people who lived in the Arctic during the period when snow houses were still being used, it seems that when snow villages were built on the ice, they were much more spread out than when they were built on the land. Jenness observes that at times the houses were spread out over a large area, while at other times they were "...crowded together" depending on the availability of snow. One settlement he mentions consisted on 21 dwellings covering an area of 300 to 125 yards (127m x 108m). Of the 21 dwellings, 5 were double house dwellings, the rest being single dwellings quite spread out because the snow cover was shallow (Jenness, 1922, p. 76). The same group of people at another location built their houses so close to one another that they almost touched.

Jenness, describing the layout of houses in five successive settlements of of the same group of Inuit, noted that in the first settlement built in November, the houses (most were double houses) were laid out in a single row, while in the next settlement the houses (double houses once again) were built in an irregular line. The houses in the third settlement (there were few single houses) were built roughly parallel to the shore line, while in the fourth settlement occupied at the end of February, the houses (half were double and the other half were single houses) were built on

the ice "...scattered in all directions". In the fifth settlement set up in March, the houses (single, double and triple houses) were built very close to one another because there was only one long snowdrift from which to build the houses (Jenness, 1922, p. 76). From this description it can be seen that the layout of the snow house villages was intimately dependent on the location of sufficient quantities of snow and was influenced by natural features such as protective ridges and shorelines. The snow villages as described by Jenness fluctuated from 10, to 16, to 21 dwellings (1922, pp. 76,78) while Stefansson noted villages of 3, 4, 27, 30 dwellings, and in one case a village (formed by 6 different tribes) contained 50 houses. Stefansson points out, however, that a settlement was normally made up of 12 to 15 houses.

These descriptions give an indication of the number of houses in an average settlement as well as their layout, depending on whether the settlement was on land or on ice, as well as the influence of natural features such as ridges or shorelines. Even if plans of actual snow house settlements were available, it is questionable that they could provide a clear pattern on which to base the design of contemporary settlements, being dependent as they are on factors other than those of a cultural nature. Stefansson mentions the case of an Inuk building his snow house far from the others and another putting up a tent in late winter while the other members of the settlement were still living in snow houses. This lends support to the author's opinion that these small demonstrations of individualism should not be overlooked when analysing traditional models for the benefit of contemporary settlements.

1.5.1.3 Location of Traditional Settlement Sites

It is important not only to note the layout of traditional settlements, but also their location in relation to the general geography of a region in order to determine what type of location was preferred.

A map made by Mathiassen gives the location of several house sites as well as the situation of two snow villages (1927, p. 122). The sites marked with a V indicate a village site with more than 10 remains. The three

sites marked with a V are either on a peninsula of land or very near the point of a peninsula. See Fig. 125. One snow village was on the edge of of the sea while the other was inland along a river. The snow village on the sea's edge could have been the winter site, while the deserted snow village on the river could have been the autumn site of the same group. This would be plausible given the normal settlement cycle which in autumn moves from the rivers as they freeze up to the sea's edge. The snow house village on the river underlines the importance of rivers as a location for villages because of access to the sea.

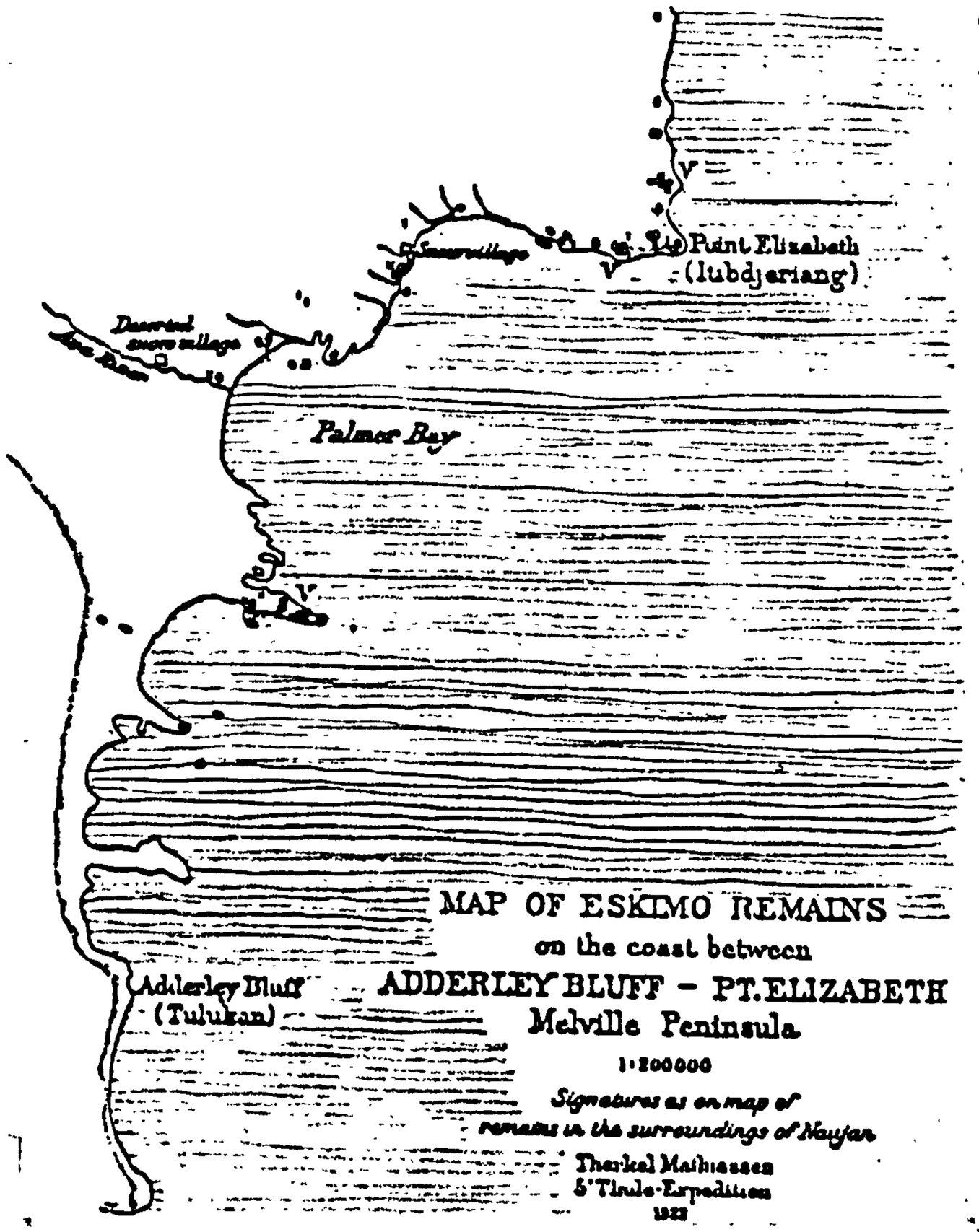


Fig. 125. Village sites between Adderley Bluff and Pt. Elizabeth (Mathiassen, 1927).

Mathiassen provides us with another map which shows the distribution of settlements in the region of Repulse Bay. See Fig. 126. From this map major concentrations of houses marked with a V can be seen at Aivilik, Tent Island, both sides of Cape Welcome, the mouth of Wet Valley, Naujan Lake, Naujan, right side of Naujan Fjord and Sitorarfik. Secondary concentrations can be observed at Whalers Point, Simiutaq, the peninsula in Naujan Fjord, Trap Island, and Inuksulik. Of the 14 house concentrations or settlements, 8 are on peninsulas jutting into the sea and 3 are on islands. It would seem that peninsulas were favoured sites for settlements. It should be pointed out that a Hudson's Bay Company post existed in the area at the time that the map was made, but that no Inuit settlement was

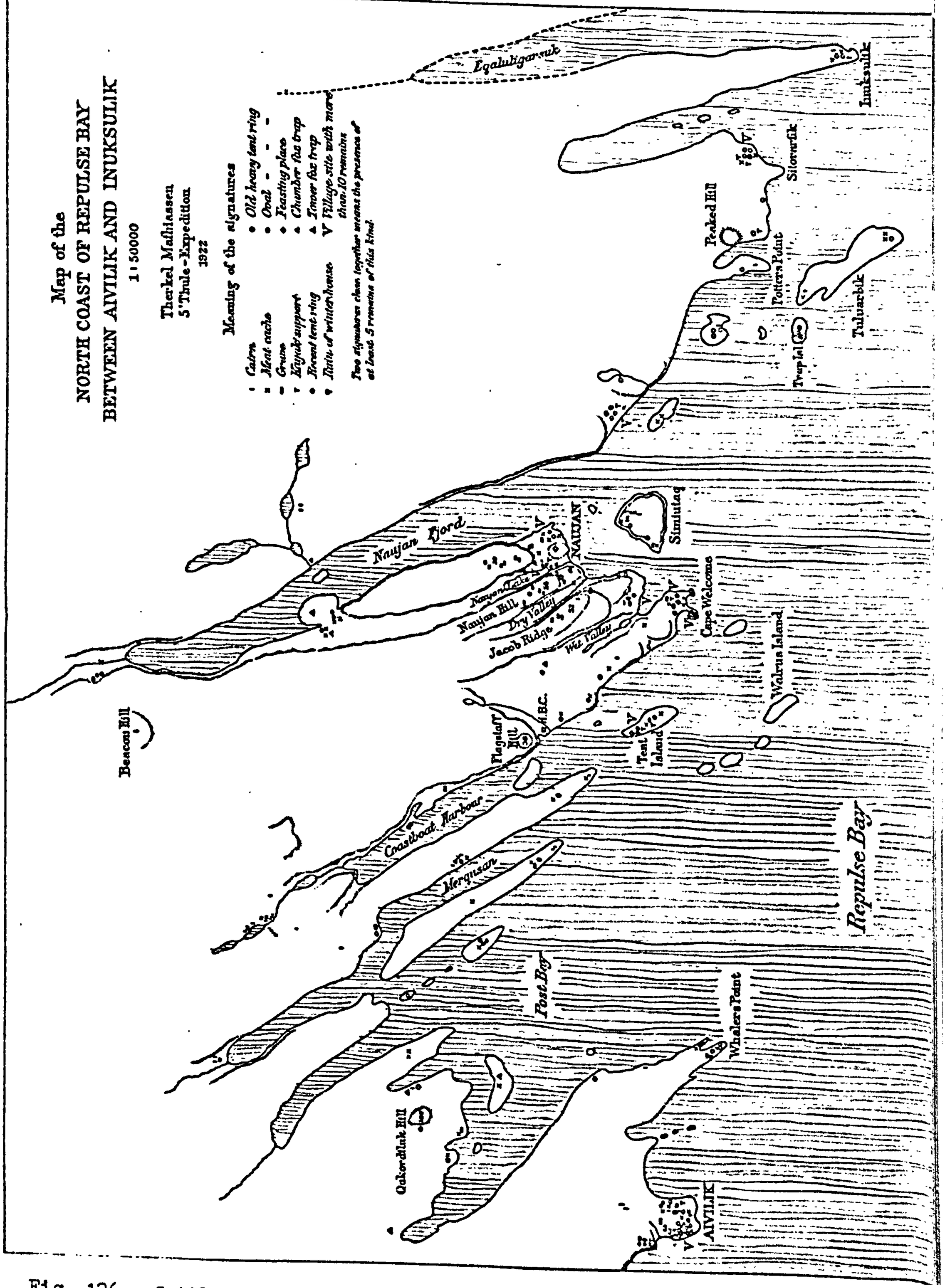


Fig. 126. Settlements in the region of Repulse Bay (Mathiassen, 1922).

located in the immediate vicinity.

It would seem plausible to state that the early Inuit settlements were often found on a peninsula of land jutting into the sea or on a river giving access to the sea. Badgley describes the characteristics of settlement sites in Arctic Québec which gives an intimation of the qualities the Inuit sought in a settlement site. He observes that the sites studied were "...well-drained gravel beaches, (with) linear and parallel bedrock outcrops, (protected) from prevailing north-westerly and northerly winds and with sheltered access to the bay. Availability of sod (though unproven) and easily recuperable construction materials (such as flagstones) from earlier habitations may be additional features affecting the selection of the precise location of later dwellings at the site." (Badgley, 1980, p. 584).

Matthews noted sites were gently sloping and in one case noted a slope as less than 3° (1975, p. 256). This information is interesting, but needs to be verified to determine whether it was a common site feature.

1.5.2 Contemporary Arctic Settlements

Permanent Inuit settlements began when contact with Europeans became more frequent. The arrival of the Hudson's Bay Company posts in the Arctic in the late 1800's and early 1900's, had the effect of gathering the Inuit around the post in varying numbers. The periods of time spent near the post reached a maximum at the end of the summer with the arrival of the supply boat, and at holiday periods such as Christmas. The Anglican and Catholic missions were usually built shortly after the establishment of the Hudson's Bay Company trading post, and along with the post's store, the manager's residence and warehouses were the first permanent buildings in a settlement.

By the 1930's, the Inuit were beginning to spend the majority of their time at the trading posts, and by the 1940's permanent residents were formed by the families who waited for the return of family members from tuberculosis sanatoria in the south. The Inuit who returned from extended convalescence periods in the south tended to be unwilling to return to the hardships of their nomadic way of life, and thus in the early and mid 1950's the sedentarization process was well underway.

1.5.2.1 Evolution of an Arctic Settlement - Povungnituk, Arctic Québec, Lat. 60°N.

To illustrate the growth of settlements and their transformation from the early relatively unstructured layouts to the "southern" suburban layout typical of most of the present settlements, see Fig. 127 which shows the growth of Povungnituk, Arctic Québec.

Present-day Povungnituk was established in 1950 when the Hudson's Bay Company closed its posts which had been previously established in 1919 north and south of Povungnituk and moved to its present site. Two or three buildings were erected at this time on a small peninsula near a good beach for landing boats. Five years later the Catholic mission constructed buildings approximately 1700 feet (518m) west of the H.B.C. post, presumably because it was closer to where the Inuit built their dwellings. The Inuit were discouraged from setting up their houses close to the post

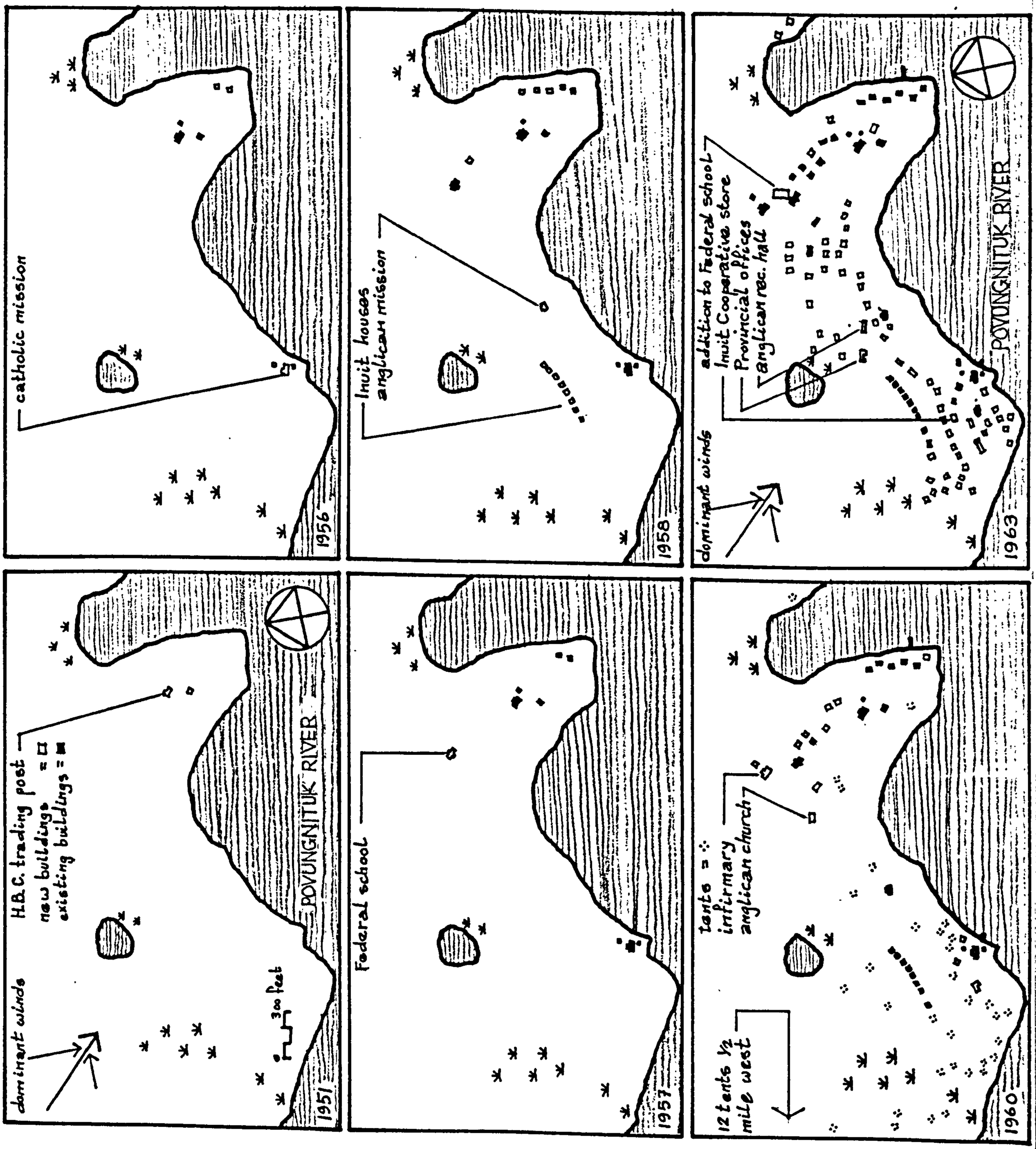


Fig. 127 A. Povungnituk, Hudson's Bay, 1951 - 1963 (Adapted from Gilles Larochelle - 1976 unpublished research paper, Canadian Mines and Technical Surveys air photo, 1960, and Project Nunaturliq, Phase 1, 1974).

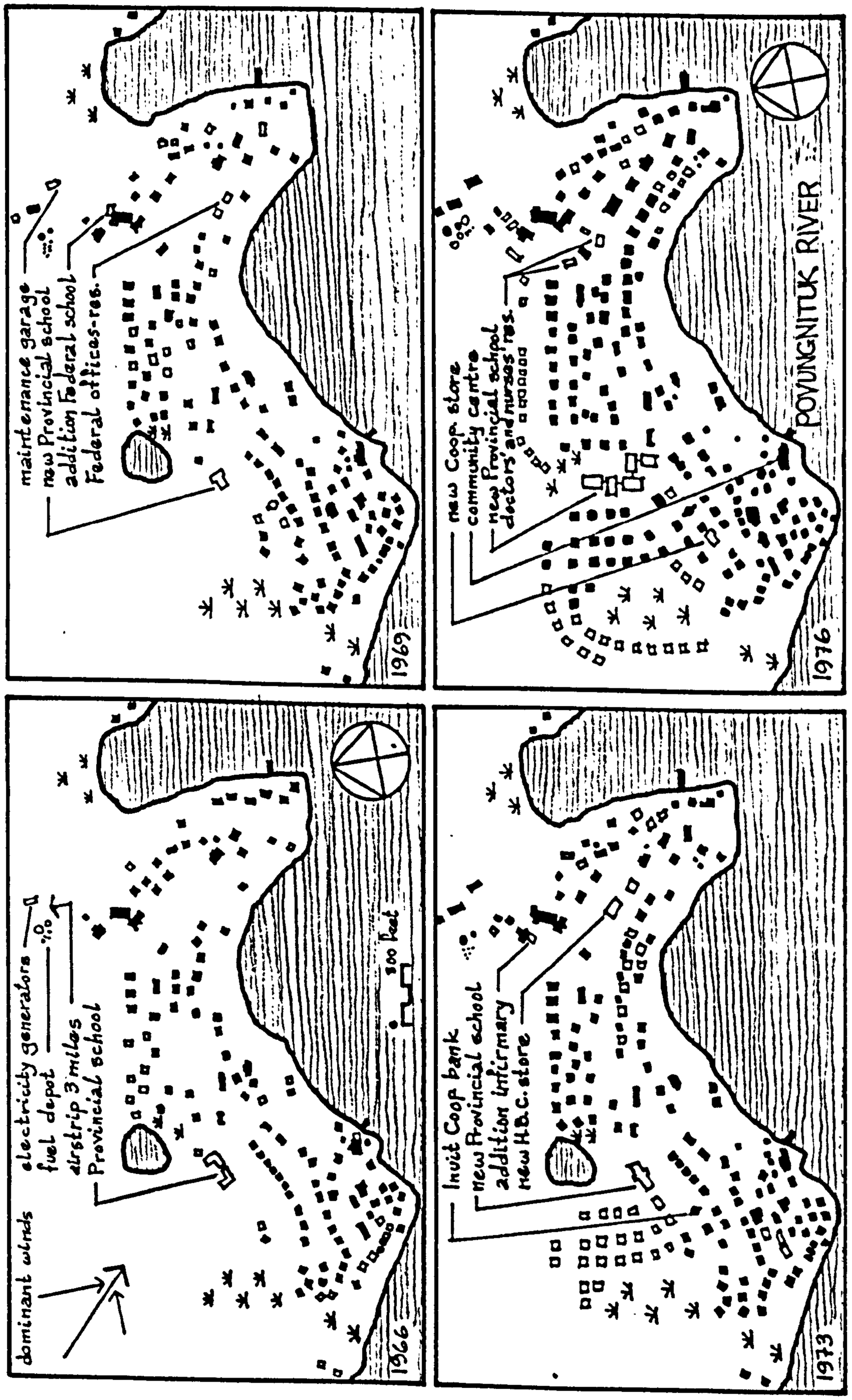


Fig. 127 B. Povungnituk, Hudson's Bay, 1966 - 1976 (Adapted from Gilles Larochelle, 1976 unpublished research paper and Project Nunaturliq, Phase 1, 1974).

and therefore built their houses at a distance from it. Thus two poles of attraction were created in the community, one which was commercial and the other where spiritual and daily activities were carried out.

In 1957 the Federal school was set up close to the post, reinforcing the importance of this sector of the village. The first wood houses for the Inuit in their sector of the settlement were constructed in 1958, along with the Anglican mission which was placed halfway between the Inuit and post sectors, as well as a house for the government administrator and two warehouses which were built in the post sector.

An aerial photo taken by the Mines and Technical Surveys of the Canadian Government in 1960 shows that additional buildings were constructed near the Catholic mission, as well as the Anglican church, an infirmary, teacher's residence and other buildings in the post area. This map also indicates the approximate location of tents that were mainly concentrated in the Inuit sector with another cluster of tents one-half mile further to the west. There are, however, 4 tents in the post-administration area which might indicate Inuit in the employ of the government or the H.B.C. One isolated tent can be seen to the east of the post-administration area which is worthy of note. (Later on a house was constructed on this site.)

By 1963 the Federal Inuit housing program was well underway and many houses were built in the village, and it can be seen that the area between the two sectors was gradually being filled in with permanent dwellings. It was in this same year that the last snow houses were abandoned. The Co-operative store and Provincial government offices were built in the Inuit sector, while the addition to the Federal school was placed in the post-administration sector along with some houses and warehouses. An interesting detail is the location of one house to the east of the post-administration sector built on the same site as the lone tent in the 1960 map.

In 1966 the Inuit sector became relatively dense with new houses extending into the zone between the two sectors. At this time the Provincial government built a school in the Inuit sector while the electricity generators and fuel depot were set up in the northeast zone of the post-administration sector. This was the beginning of the establishment of the service infra-

structure which would have an important impact on the layout of the settlement.

Three years later in 1969, the general alignment of houses along clearly defined access roads (begun in a small way in 1963 in the Inuit sector) was extended to the zone immediately to the west of the Federal school and infirmary. The Federal school was extended while a new Provincial school was built to replace the previous school destroyed by fire. New garages were placed near the electricity generators. Housing construction was increased in the zone between the two sectors and to the south of the H.B.C. store.

Four years later in 1973, houses were built in the zone to the south of the Federal school near the water, some of which were inserted between the earlier small one-room houses. The H.B.C. built a large modern store in this same zone. The Provincial school expanded and a new residential sector developed to the west of the school. This was the first housing to be laid out perpendicular to the water, causing the Inuit to refer to it disparagingly as the "Champs Elysée". A Co-operative Bank was established at this time as well as many warehouses and workshops belonging to the Co-operative. There was also an addition to the infirmary.

By 1976 the layout of Povungnituk had become more ordered, with the exception of the zones south of the Co-operative buildings and west of the former Catholic mission. The road network was having a greater influence in the layout of the houses. The small one-room houses which were near the water in the zone south of the Federal school in 1973 were moved to form a third row of houses immediately to the west of the infirmary. A post office, nurses' and doctors' residence were built in the zone immediately to the west of the new H.B.C. store. The Provincial school was rebuilt after another fire, and because of its new importance as a large secondary and technical training school, it became an element dominating the surrounding houses.

At this stage the village now had three major poles of activity. One was situated in the centre of the old Inuit sector and contained the community centre, community council offices, the Co-operative store,

restaurant, pool hall, bank, workshops, etc. The second zone borders the first on the northeast and includes the Provincial school, radio station and Provincial offices. The third zone is centred on the H.B.C. store which included the store, infirmary, Federal school, Federal offices, post office, nurses' and doctors' residence, and the Anglican church.

The plan of Povungnituk evolved rather haphazardly until 1973 when a determined effort was made to re-align the houses and to create a clear and simplified road, telephone and electricity network. The Federal zone developed in the vicinity of the H.B.C. store (post-administration sector), forming a white enclave which was gradually eroded by time and the need to situate Inuit houses as close as possible to this pole of activity. The Inuit had developed their pole of activity in the old Inuit sector while the Provincial government had developed its zone more in the centre of the new Inuit sector. This resulted in much coming and going from one end to the other in the village. This meant that the Inuit living east of the H.B.C. store had 1600' (488m) to walk to the Provincial school and 2000' (610m) to the Co-operative store, while the Inuit in the old Inuit sector and the newest sector had approximately the same distances to walk to the infirmary or the H.B.C. store.

In periods of cold weather with high winds, the distance from the houses to the poles of activity could be very uncomfortable, especially as the dominant winds are northwest, west and north. The Provincial school could have provided some protection from the winds, but it was unfortunately placed too far from the pedestrian way to provide protection. However, if the school had been placed in this position large snowdrifts would have formed on the lee-side, blocking roadways, thus rendering vehicular circulation difficult. (This is an effective argument for the separation of pedestrian and vehicular traffic.)

It would seem that the major planning considerations in Povungnituk were related to the need for vehicular access (delivery of heating oil, water, and the collection of rubbish and human waste), and to the minimum distances for electricity and telephone lines. The activity poles grew out of the original location of the H.B.C. store and were not concerned with minimizing pedestrian distances. The growth of Povungnituk is fairly

typical of many Canadian Arctic settlements and therefore is a good illustration of the growth process by accretion. The village presently has a population of 787, making it the third largest village in Arctic Québec.

1.5.2.2 Evolution of Kangiqsuk, Arctic Québec - Lat. 60°N

Unfortunately, very little information on the growth of other Arctic villages exists, and Kangiqsuk (also known as Payne Bay) is no exception. However, two plans, one taken from a 1960 aerial survey photo, and the other from a site survey plan made in 1975 give some idea of its evolution. See Figs. 128 and 129. The significant feature of both these plans is the location of the H.B.C. on the side of the small bay which has good access to deep water, with the rest of the village located on the other side of the bay.

The map of the village in 1960 reveals the existence of six buildings belonging to the H.B.C. and five Federal buildings, (the school, two warehouses and two residences) situated on the opposite side of the bay. In between the two groups of buildings were a few tents and two permanent houses. The only other permanent building was to the southeast of the Federal buildings near the major rock outcropping.

The map of the village in 1975 shows that the main portion of the village developed behind the rock outcropping separating it from the H.B.C. buildings and store. The Federal buildings are situated to the northwest of the village with the Provincial school and the Co-operative store situated between them and the Inuit houses. The infirmary and community centre are the only institutions situated within the confines of the Inuit housing area.

This village is unusual in that the two major poles of activity are not immediately within the limits of the Inuit village. The H.B.C. store is 3400' (1036m) from the nearest Inuit house, but because it is better stocked than the Co-operative store people make the long trip to the H.B.C. store, many on foot. The wind diagrams for Kangiqsuk indicate that the northwest wind is dominant all year round with secondary winds

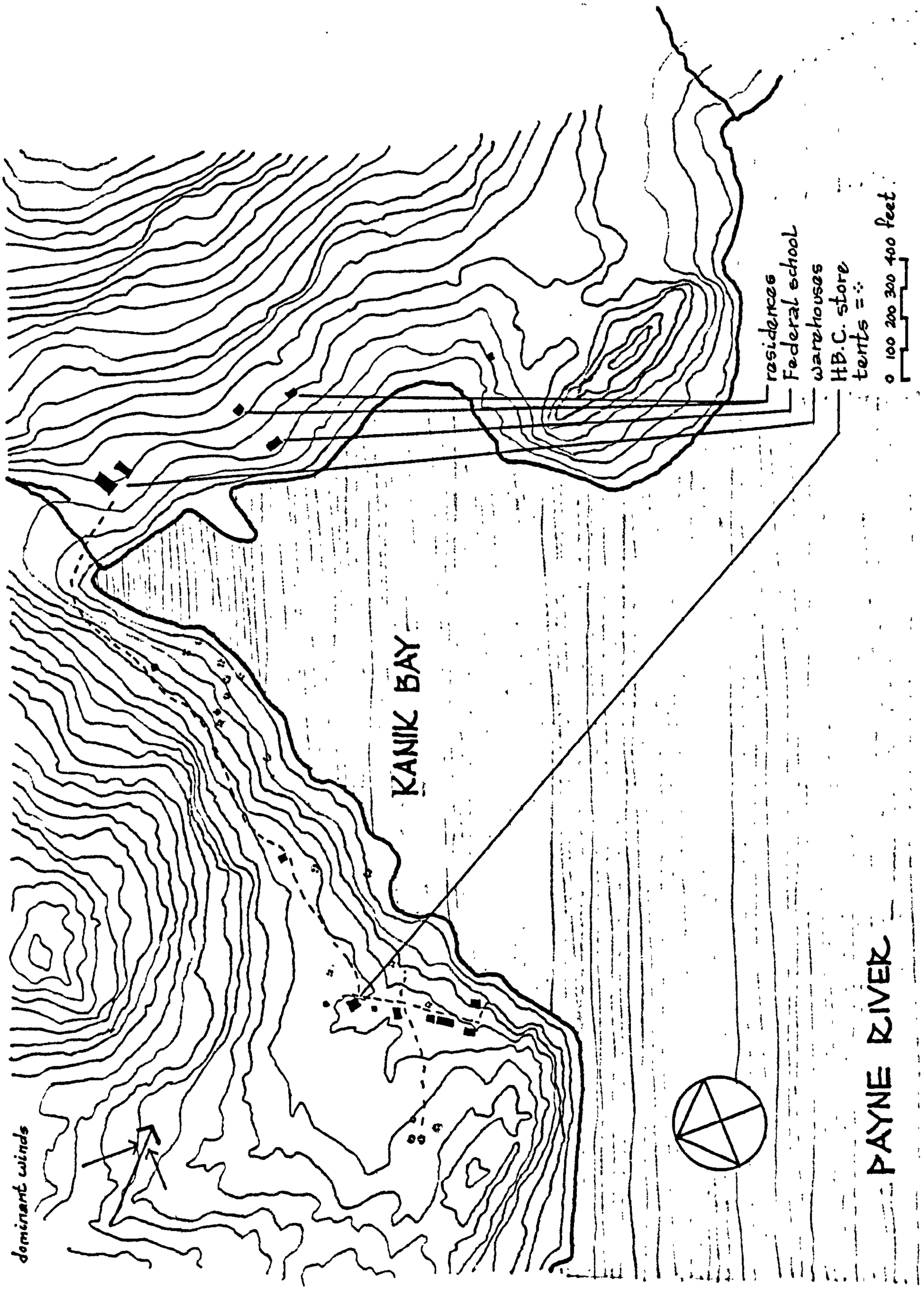


Fig. 128. Kangiqsuk, Ungava Bay, 1960 (Canadian Mines and Technical Survey, 1960).

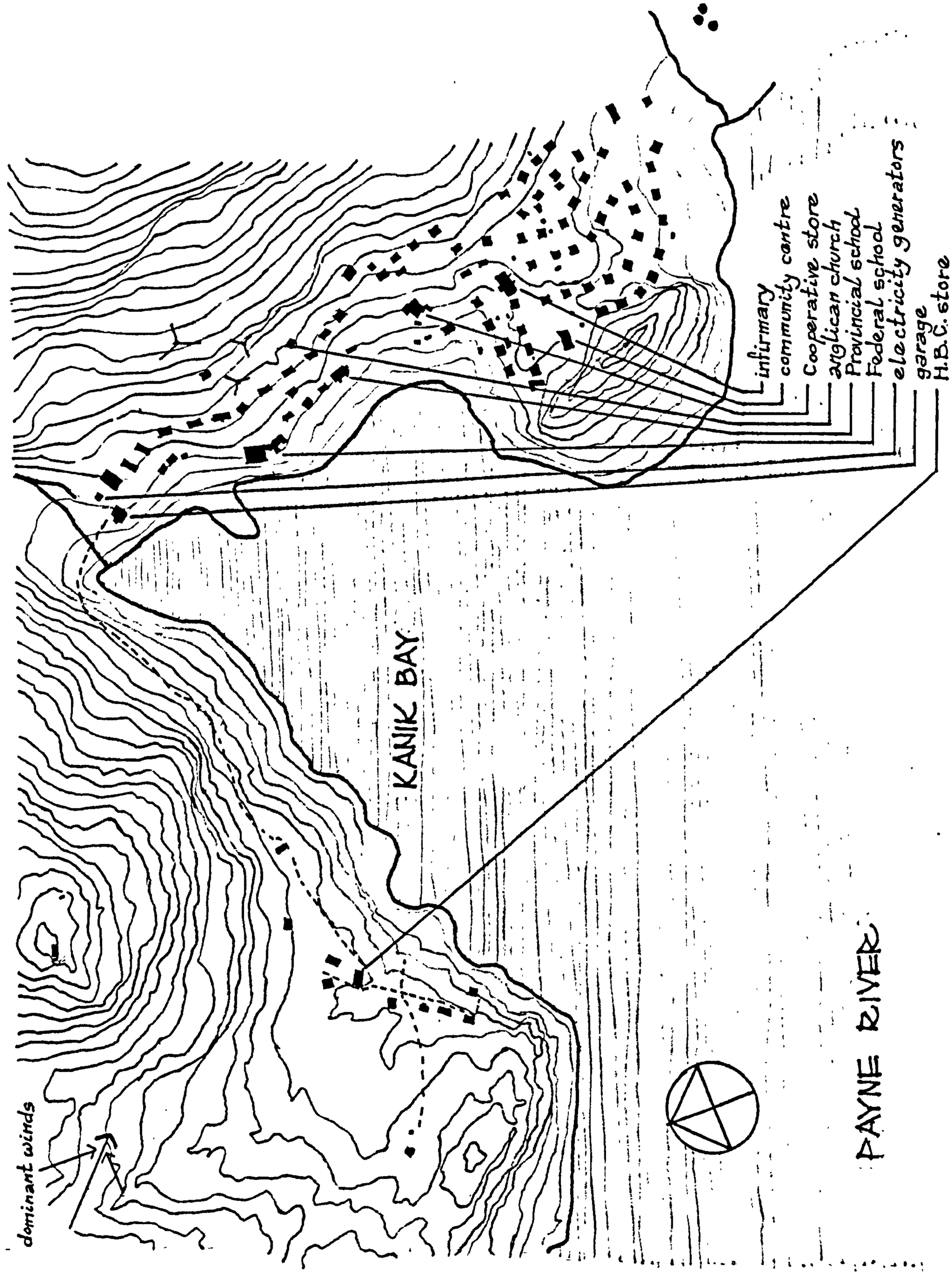


Fig. 129. Kangiqsuk, Ungava Bay, 1975 (From Lemieux et al., 1974 and Ministère des Terres et Forêts, Québec, 1975).

from the west, southwest and southeast in winter. The long portion of the road between the Federal buildings and the H.B.C. store would seem to be protected by the hill to the north until approximately 400' (122m) from the store when the full force of the northwest winds would be felt. However, for the west, southwest and southeast winds, no protection exists. The Inuit village itself is quite well protected from the northwest winds by the high hill to the northwest and from the west and southwest winds by the rock outcropping. From the point of view of wind protection, the Inuit village is better situated than the H.B.C. buildings, though the latter have the advantage of close access to deep water. The village is not close to a suitable site for a landing strip, as the nearest long relatively flat surface is approximately three miles to the northeast of the village. In winter, however, once the Payne River is frozen over, aircraft are able to land in front of the village.

The rock outcropping, although it provides wind protection for the village, presents the problem of snowdrift accumulation on the leeward side. Therefore, west winds could inundate the whole village with snow.

The village seems to be more influenced by climatic and cultural considerations than most villages, even though the schools and Co-operative store are located at the edge of the housing area (the Federal school is 1900' (579m) and the Co-operative store is 1100' (335m) from the farthest house). The location of the Federal and Provincial schools was probably influenced by the initial placement of the Federal buildings, while the Cooperative store was most likely situated outside the confines of the houses in order to have access to the water. Due to the steeply rising terrain to the northeast of the existing houses, large buildings would have to be situated outside the confines of the housing area in order to leave sufficient land for future houses.

Kangiqsuk with a total population in 1979 of 271 is one of the smaller of the 13 settlements in Arctic Québec which vary in size from 66 to 1068 persons (Bigué et Pageau, 1980, p. 57).

1.5.2.3 Evolution of Salluit, Arctic Québec - Lat. 62°N

Salluit is a village of 552 persons and is used as an example here because of the existence of two plans which show its transformation over the years.

The first plan, (taken from Graburn, 1969, p. 169) illustrates the lay-out of the village (known then as Sugluk) in 1964, while the second is a plan of the village in 1975 including its proposed zones of expansion. See Figs. 130 and 131.

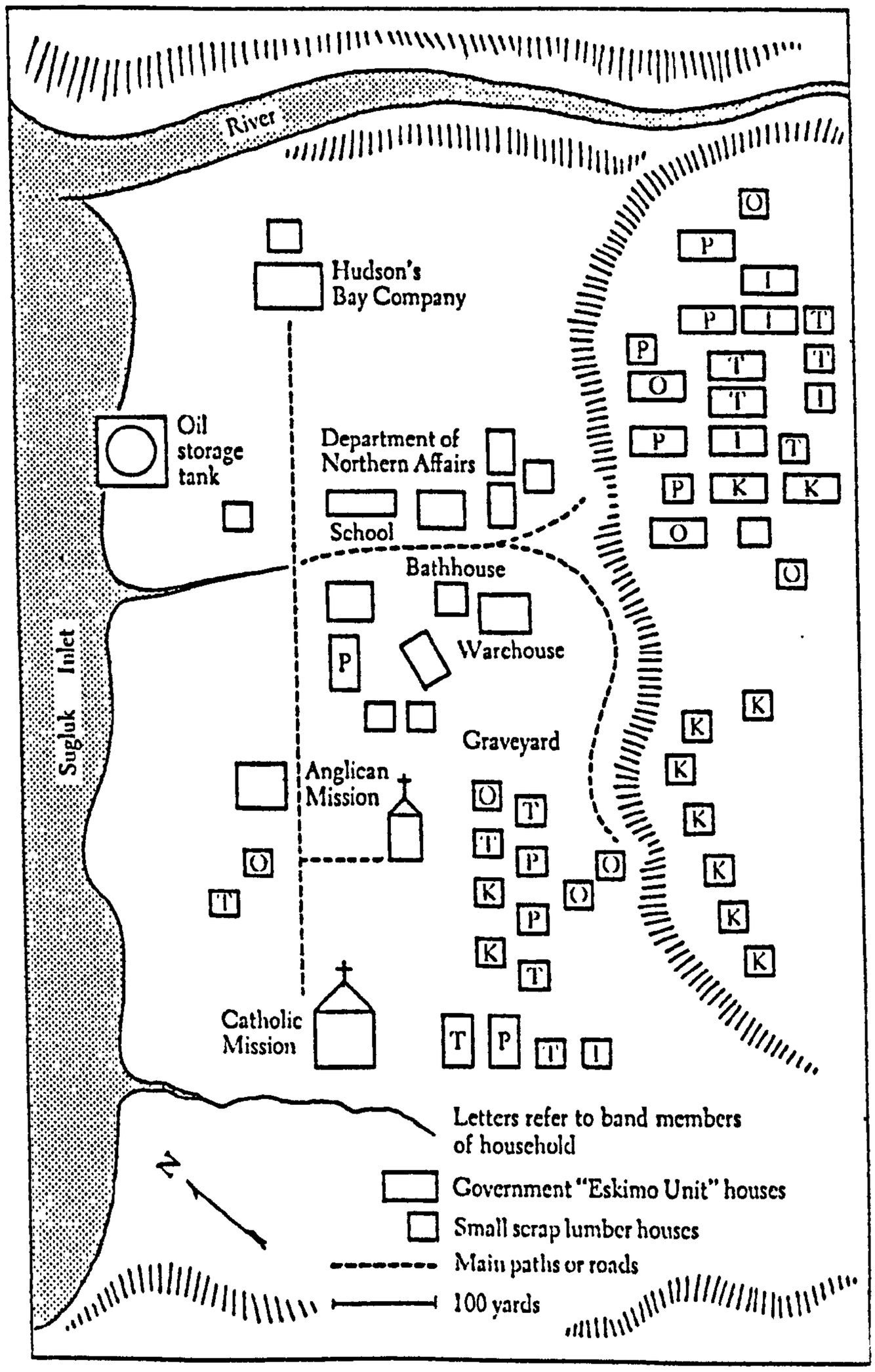


Fig. 130. Salluit (Sugluk): Community Plan and Eskimo Household Groupings, 1964 (Graburn, 1969).

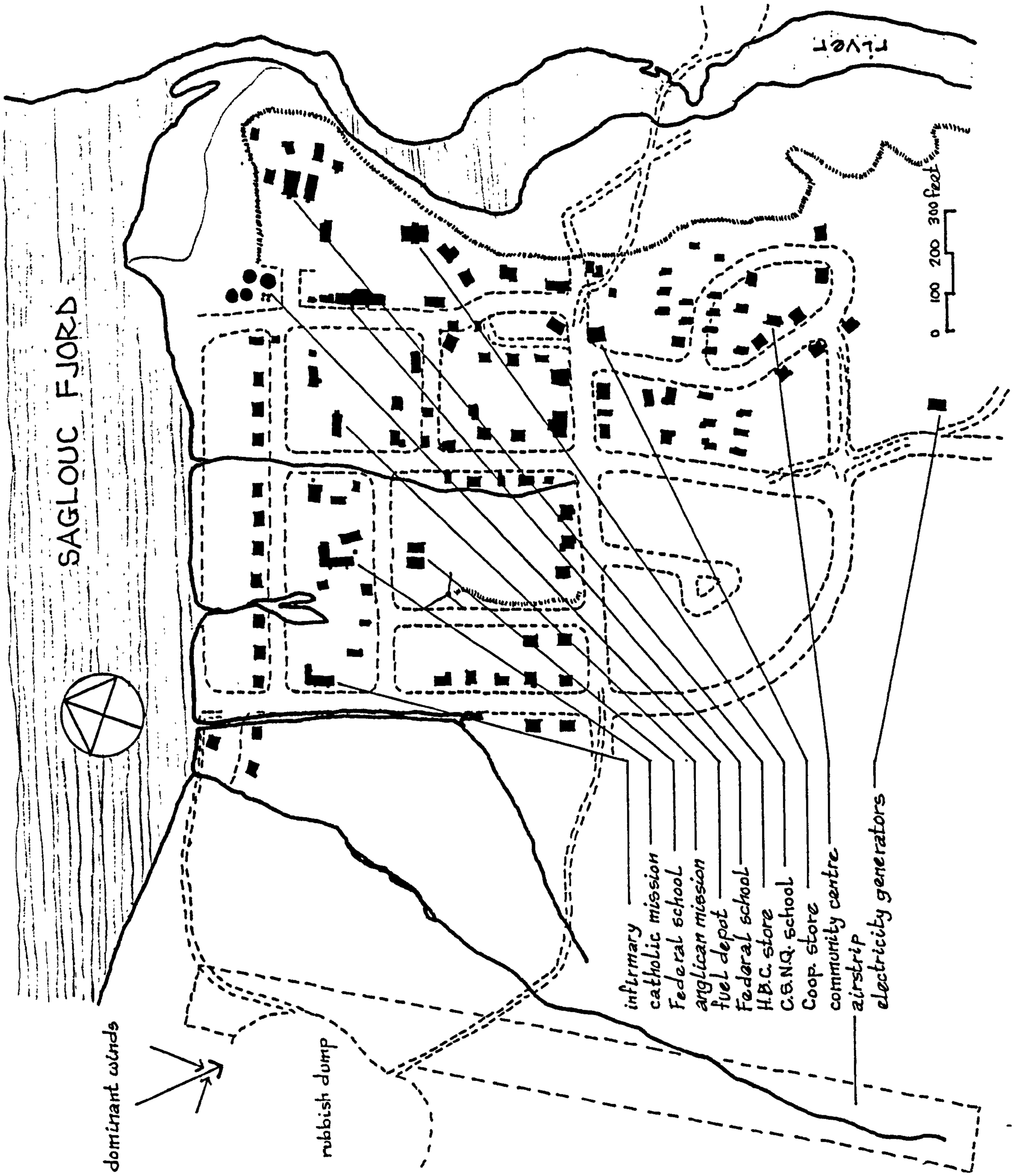


Fig. 131. Salluit (Sugluk), Hudson's Strait, 1975 (From Ministère des Terres et Forêts, 1975).

In 1964, the village consisted of 15 government "Eskimo Unit" houses, 30 "small scrap lumber houses", as well as the Catholic and Anglican missions, the Federal School, the H.B.C., and the nursing station (see Graburn for a history of the village of Sugluk up to 1964). From this plan it is interesting to note that all the white men's buildings occupied the prime position closest to the shore.

The plan (Fig. 130) illustrates by means of a lettering system the way in which families from the same band (clan) grouped themselves together. The houses in the third row to the southeast of the Anglican mission, designated by the letter K, display a tightly knit group of houses belonging to families from the same band. The houses are laid out in a single line roughly parallel to the water's edge and with no fellow band-member's house immediately in front of another. Because these houses are all "small scrap lumber" houses and follow no regular orthogonal pattern, we can assume that they were placed according to the wishes of the band or individual families.

The houses in the first two rows immediately behind the Anglican mission display an orthogonal pattern which is typical of southern planning. The impression that this section was planned by southerners is reinforced when one notes the diversity of the band members inhabiting these houses. There are never more than two band members adjacent to one another, as for example in the case of bands designated T and O. An interesting feature of the layout leading the author to believe that there was a certain degree of Inuit influence on the position of the houses, is the fact that the houses in the second row are offset, allowing a view to the sea between the houses in the front row. The 7 houses of band group K immediately behind the mixed band group have a view of the sea because they were constructed on a plateau slightly higher than the two rows next to the Anglican mission.

The other two house groups (behind the Catholic mission and the Department of Northern Affairs buildings) display a more rigid layout in which the houses are placed one behind the other in four rows. In these two house groups are found all the new government "Eskimo Unit" houses which were allocated according to need rather than kinship ties. One observes that

never more than two "Eskimo Unit" houses belonging to members of the same band are located next to each other. It may not be desirable to locate all band members in the same sector of a settlement because it could create a series of band ghettos. However, there could be more grouping together of families of the same band as is the case of the house groups behind the H.B.C. In this area one can observe that the band members in the "scrap-lumber" houses situated themselves as closely as possible to members of the same band living in the "Eskimo Unit" houses. This would seem to indicate a desire for band members to remain in close proximity to one another. In support of this opinion, Graburn mentions that "...the need for social groupings smaller than the total community itself which has been brought about by the large size of the settlement and which renders "...face-to face interaction difficult, has created ...intense social interaction within the band." (1969, p. 173).

It is interesting to note that in this plan the main road and paths service the white establishments in a very direct manner, while the Inuit houses are serviced in a very minimal fashion. This could be explained by the fact that at this time (1964), there was very little in the way of services provided to Inuit houses.

Comparing the 1975 village plan to that of 1964, it is evident that servicing the houses has become an important planning consideration as witnessed by the new road system. The older houses in the southeast sector of the village would be obliged to move to conform to the new roadway. A major change in the plan is the situation of two rows of Inuit houses between the "white establishment" buildings and the sea, each house having physical and visual access to the water. This modification of the 1964 plan gives the impression that the Inuit finally had an influence on the location of their houses. However, due to the physical limitations of the site and the location of the Co-operative store in the southeast zone, new housing has been planned in the southwest sector far from the river and the sea. It is worth mentioning that the airstrip is very close to the village, making contact with the south and other villages feasible in any season.

The social and commercial services are still located in a thin band running roughly east to west parallel to the water's edge, although the

Co-operative store has been situated approximately 600' (183m) inland close to the older Inuit houses. The two small new Federal schools with a large playground are situated near the centre of the village. From the point of view of distance, the H.B.C. store is situated about 1500' (457m) from the three furthest corners of the village, while the Co-operative store is 1300' (396m) from the farthest point in the village. The infirmary is 1600' (488m) from the farthest house. With regard to the dominant winds, the people living in the two rows of houses facing the sea and on the western edge of the village would sustain the ill effects of the northwest, north, and west winds. Snowdrifting would probably be quite severe in the area leeward of the houses in these two locations.

This village was strongly influenced by the location of the original white establishment buildings which were situated close to the water for their functional convenience. The location of the H.B.C. buildings in a privileged position at the junction of the river to the sea, permitted the village to grow only in directions radiating from it. Other buildings such as the Federal school, the Catholic and Anglican missions, the Provincial administrative offices, and the infirmary in a zone parallel to the sea, took up the choicest land, forcing the Inuit houses to be built away from the sea and closer to the river. The oil storage depot is located on the sea edge, but almost in the middle of the socio-commercial zone, unlike the preceding plans where they were situated away from the central pole of activity.

In general it can be said that this village layout is dominated by the linear socio-commercial zone and is very little adapted to Inuit cultural needs, with the exception of two rows of houses bordering the sea.

1.5.2.4 Evolution of Quartaq, Arctic Québec - Lat. 61°N

This village of 157 people is an example of one of the smallest villages, but also of a site with special topographic conditions. See Figs. 132 and 133 for plans of Quartaq in 1966 and 1975.

The 1966 map of Quartaq is taken from a sketch by Louis-Jacques Dorais,

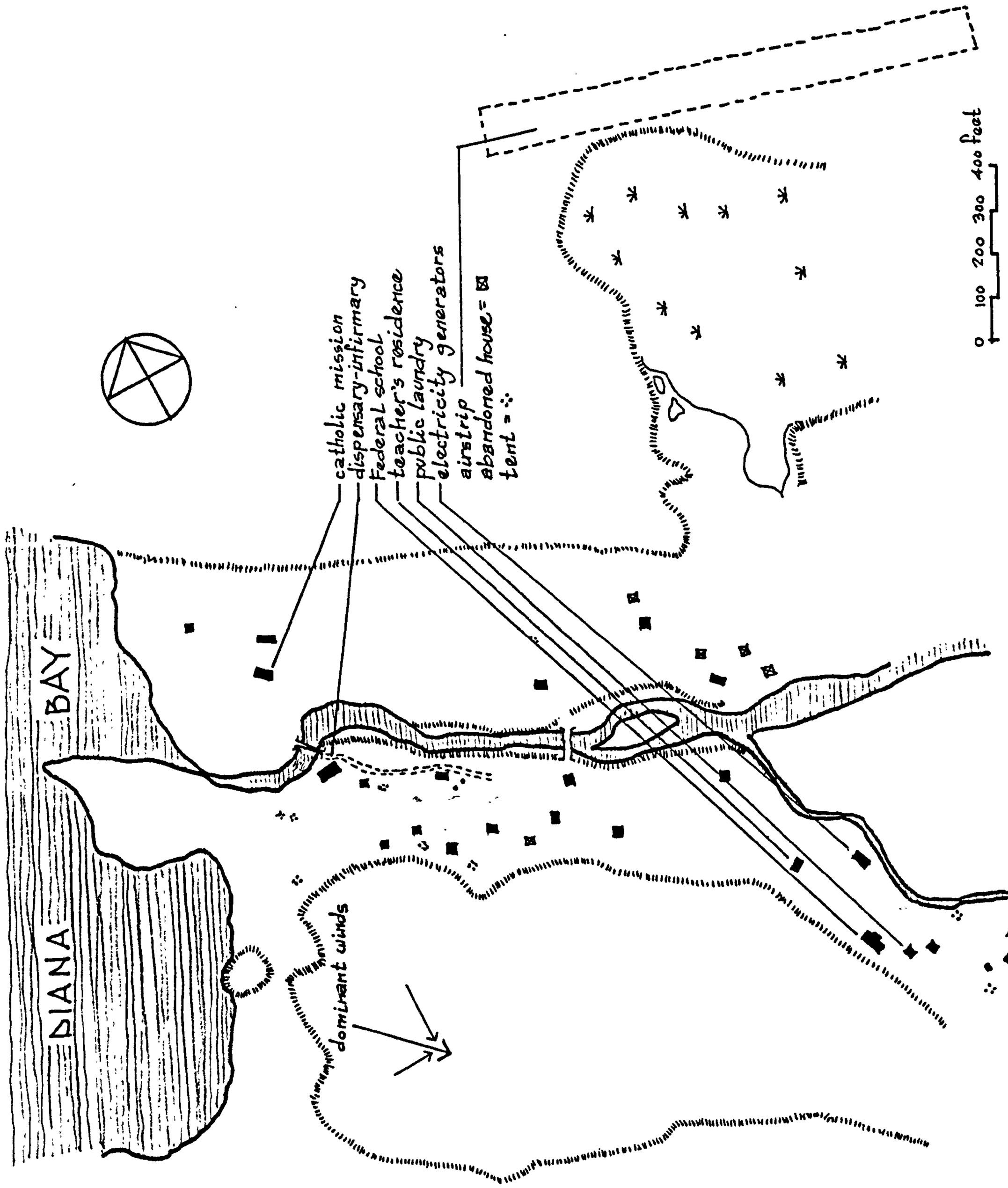


Fig. 132. Quartaq, Hudson's Strait, 1966 (Taken from a sketch by Louis-Jacques Dorais, 1966).

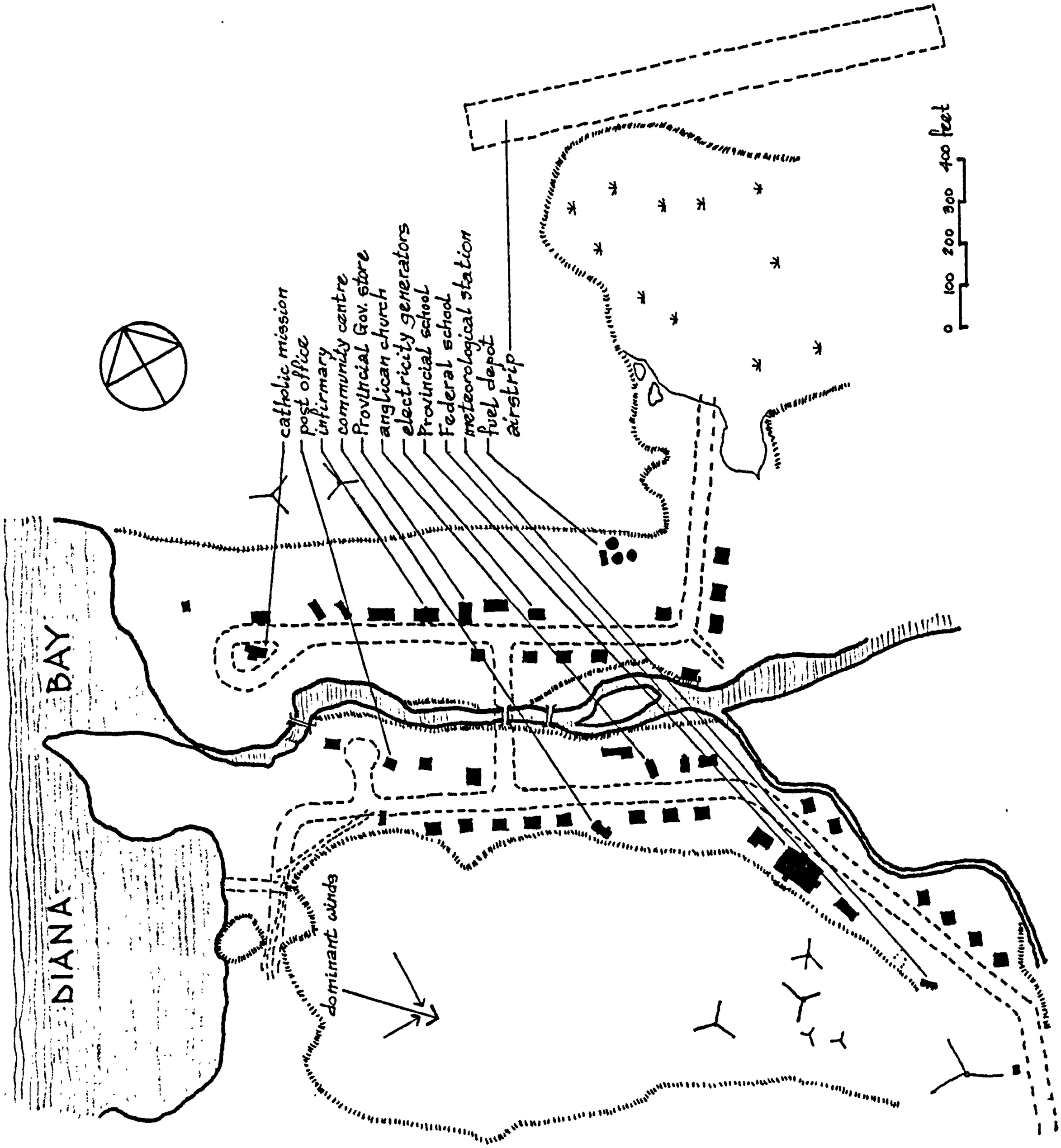


Fig. 133. Quartaq, Hudson's Strait, 1974 (From Ministères des Terres et Forêts).

an anthropologist-linguist at l'Université Laval done in 1966. At this period the village consisted of 29 buildings and 9 tents. Of the 29 buildings, 21 were Inuit houses (7 had been abandoned) and the others were the Catholic mission, the dispensary, the Federal school, the teacher's residence, a public laundry and the electric generator. At this time, the village had two activity poles, one near the mouth of the river which included the Catholic mission and the dispensary, and the other further along the river inland where the Federal school, laundry and electric generator were situated.

The development of the village perpendicular to the bay was necessitated by the lack of space parallel to the sea, and by the two high hills on either side of the river, which left only a small narrow flat area between them suitable for building. The buildings at this stage were laid out without any particular plan, but in close proximity to the river.

The plan in 1975 displays the difficulties due to the site constraints. The village developed along two roads which parallel each side of the river with future expansion planned at the mouth of the river. The village had two activity poles, one on the north side of the river stretching from the Catholic mission up to the bridge, and the other near the Federal and Provincial schools on the south side of the river and southeast of the bridge. The schools are 1800' (549m) from the farthest houses on the north side of the river, while the Provincial government store and the infirmary are approximately 1600' (488m) from the farthest house, putting them in a central position. Because these two institutions were built after the village expanded, it would seem that they were intentionally placed close to the geographical centre of the village. The new Provincial school was probably placed in the same area as the Federal school in order to have the educational services in one area.

Because the dominant winds are from the northwest and west, the wind would be channelled through the valley creating an uncomfortable environment. Snowdrifting should be minimal due to the north wind, and would occur in the lee of the buildings. The west wind could cause some drifting on the lee side of the hill south of the river and in the lee of the houses, creating snowdrifts which could block the roads, but as

this is the third dominant wind, this should not be a frequent occurence. The northwest wind should blow the streets clear of snow, except in the southeast and northeast sectors of the village.

This settlement plan was dictated more by the site constraints rather than by cultural, climatic, or service infrastructure factors. The physical limitations of the site make direct access to the sea difficult and restricts settlement growth. Quartaq is unlike many other villages in Arctic Québec in that it does not have two competitive commercial poles to contend with (there is no H.B.C. store in this village, only a store set up by the Provincial government). There are, however, two activity poles consisting of commercial and educational services.

The following examples of Arctic villages represent the present-day context only, as no earlier plans of those settlements were available to illustrate their evolution. Therefore these villages will be described mainly in relation to population, layout, distances to activity poles, and attention paid to cultural needs (accessibility to waterways, etc.).

1.5.2.5 Ivujivik, Arctic Québec - Lat. 62° N

Ivujivik is a small Inuit village with a population of 184. This settlement is somewhat similar to Quartaq because its layout is perpendicular to the sea rather than parallel to it. The two activity poles, which are commercial and educational are shown in Fig. 134. It seems that with the construction of the school commission and the community centre in the commercial area, there was an attempt to concentrate activities in one zone. The future extension of the village is very limited as can be seen by the proposed future development to the east of the village.

The pedestrian distances are relatively short being 1000' (305m) from the farthest houses to the store and 1100' (335m) from the furthest house in the proposed western sector of the settlement to the schools. The oil tanks, store, Anglican mission, the new school and the community centre occupy the zone immediately adjacent to the shore line, while the Inuit houses are behind this zone stretching inland. Thus no Inuit houses have direct access to the water, a situation which is similar to that of Salluit.

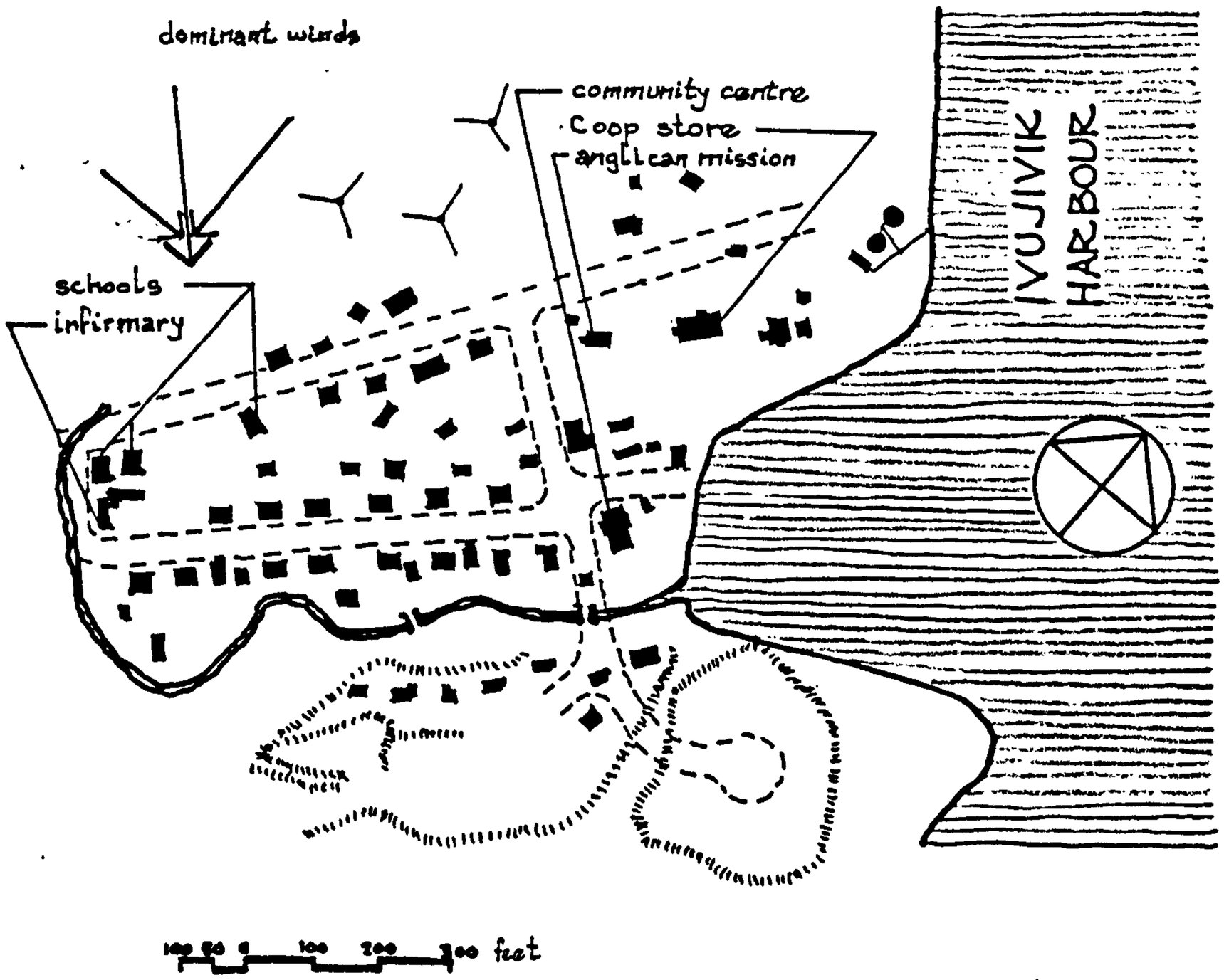


Fig. 134. Ivujivik, Hudson's Strait, 1975 (From Ministère des Terres et Forêts).

This village illustrates the effects of physical or topographical constraints on a settlement plan. The houses were laid out perpendicular to the shore line, but behind a row of institutional and commercial buildings. The village plan therefore favoured the supplying of the store and oil tanks and gave priviliged positions to the Anglican mission, the school and the community centre, even though they did not require direct access to the sea. A few new houses in the proposed western sector will have access to the water, but they represent a small portion of the total number of houses. This plan gives favoured positions to the commercial, educational and social institutions, rather than respecting the needs of the individual families.

1.5.2.6 Tasiujaq, Arctic Québec - Lat. 59°N

This community of 103 persons is typical of Inuit villages that were laid out parallel to the shoreline. In this case the institutional - commercial activity pole forms the southern extremity of the village and is a continuation of the two rows of houses. See Fig. 135. The houses are laid out so that the second row has a view and access to the water between the houses in the first row. Future expansion is planned by the addition of a third and fourth row of houses parallel to the first two rows.

In this settlement the pedestrian distances do not seem great because the village is small, yet the maximum distance from the furthest house to the store is 1400' (427m), which is 300' (91m) further than the distances in Ivujivik with a slightly larger population.

This village satisfies the Inuit need for direct, easy access to the water, but for a small village has an exaggerated pedestrian distance from the institutions to the houses. Locating the institutional and commercial services in the centre of a linear development, with houses on either side, would have been a more desirable layout.

1.5.2.6 Aupaluk, Arctic Québec - Lat. 59°N

This settlement is of interest not only because it is an example of a very recent village, but because it was established by the Inuit. In 1979, 66 Inuit moved from their original site to Aupaluk (in the same vicinity) bringing their houses with them. Their houses, as shown in Fig. 136, are situated in two vaguely defined rows paralleling the water's edge. The infirmary and warehouses (the only permanent service buildings) were built close to the houses occupying a third row. There is sufficient space in this third row to locate the school which is temporarily located in a house, as well as the future store (presently people travel to stores in Kangiqsuk and Tasiujaq).

No formal plan for expansion was found by the author, but the spaces between the houses could be used, as well as extending the rows along the shore north and south. This village is an example of a plan laid out by

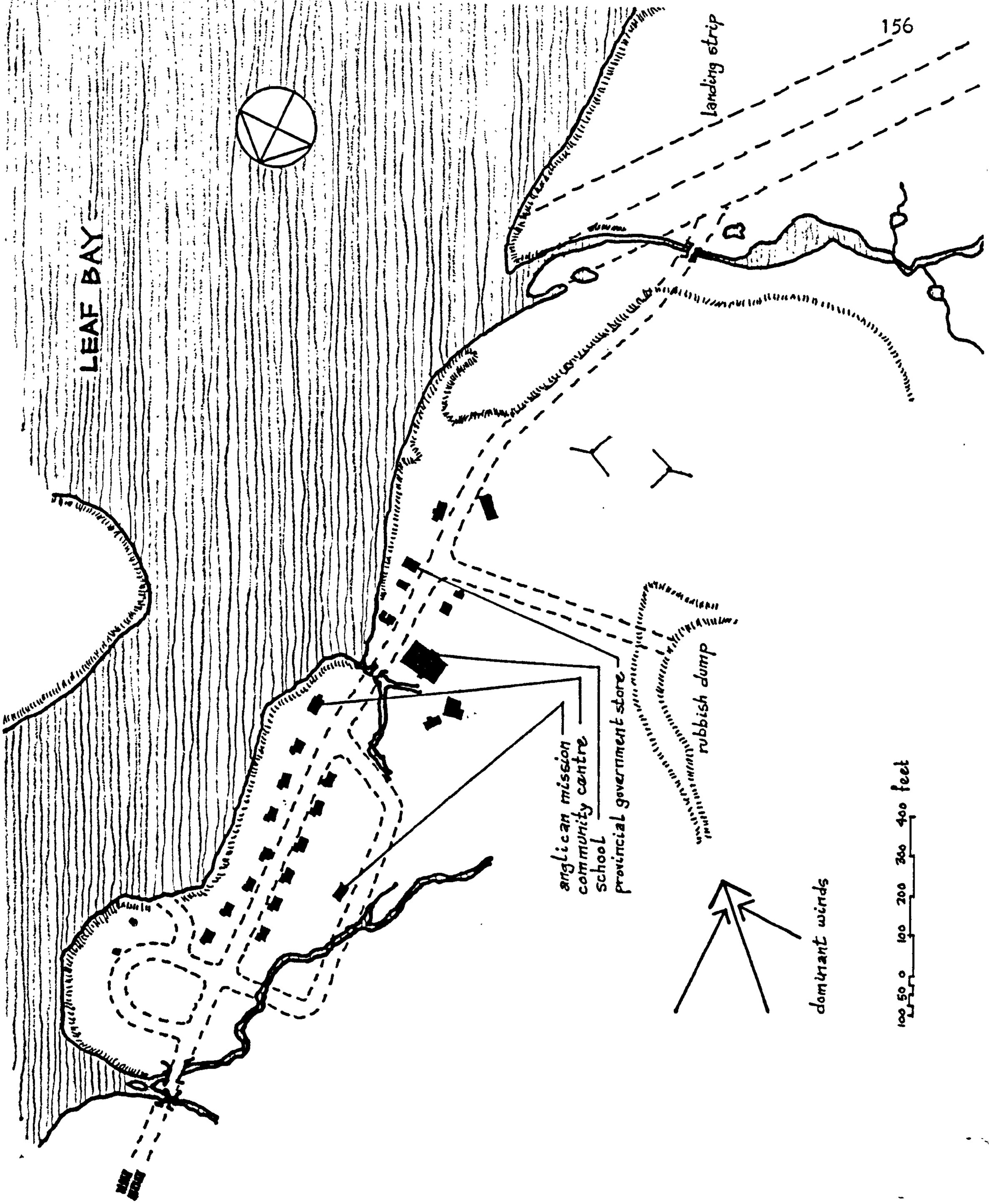


Fig. 135. Tasiujaq, Ungava Bay, 1975 (Ministère des Terres et Forêts, Québec).

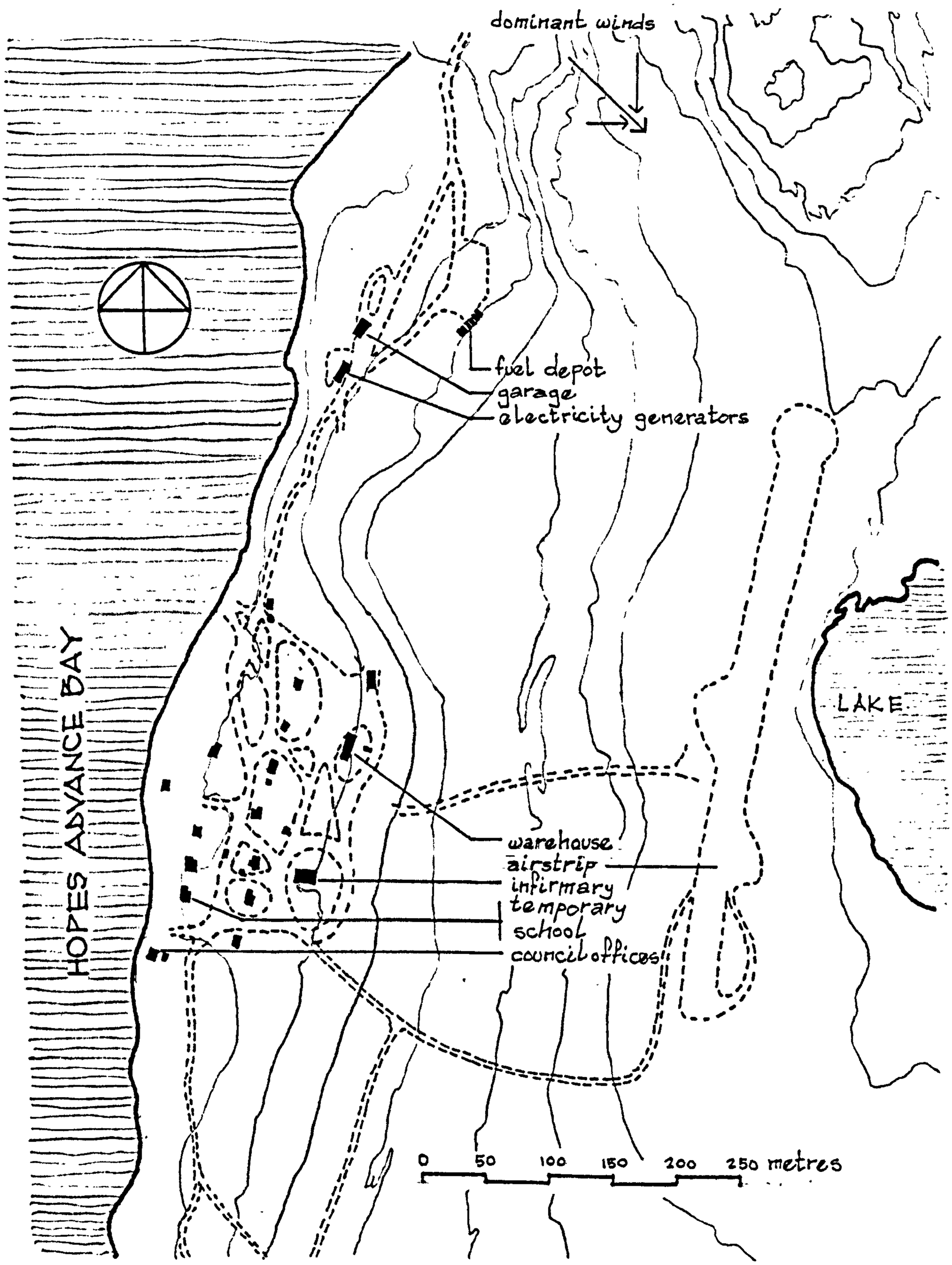


Fig. 136. Aupaluk, Ungava Bay, 1980 (From Ministère de l'Energie et des Resources, Québec, June, 1980).

the Inuit with the later addition of the infirmary and services whose location are presently subordinated to the houses, the latter having direct access to the water.

1.5.2.7 Akulivik, Arctic Québec - Lat. 61°N

Akulivik is another recent village, but one which was planned as a separate entity from the original temporary village that was set up by the Inuit about 7 years ago (1974). The temporary village was established to force the government to set up a permanent village complete with all services (Larochelle and Bernard, 1975, pp. 28-30). The present village of Akulivik is a permanent village laid out parallel to the water's edge in an orderly fashion connected to the temporary village by a short road. See Figs. 137 and 138 for plans of the permanent and temporary villages. The two villages have a total population of 203 persons.

Permanent Village

This village is situated on a peninsula with water on both sides which places a limit on the width of the development. The village is developing along two roads roughly parallel to the water's edge on the bay side of the peninsula. The Co-operative store is placed at the edge of the permanent village where it connects to the original temporary village and at this stage is central to both. However, as the temporary village is phased out, the store will be at one extremity of the village rather than being central as is the community centre and projected school. The store at the northwest extremity of the village is 1400' (427m) from the farthest house.

The village in general seems to be well planned, the houses having been laid out in such a manner that the second row has a view and access to the water. The school, community centre and church are centrally located. However, the location of the infirmary and store would be a little too distant from the centre unless the village expands westward towards the temporary village. At the time of writing the population of the permanent village is approximately 120 persons (20 houses at approximately 6 persons per house).

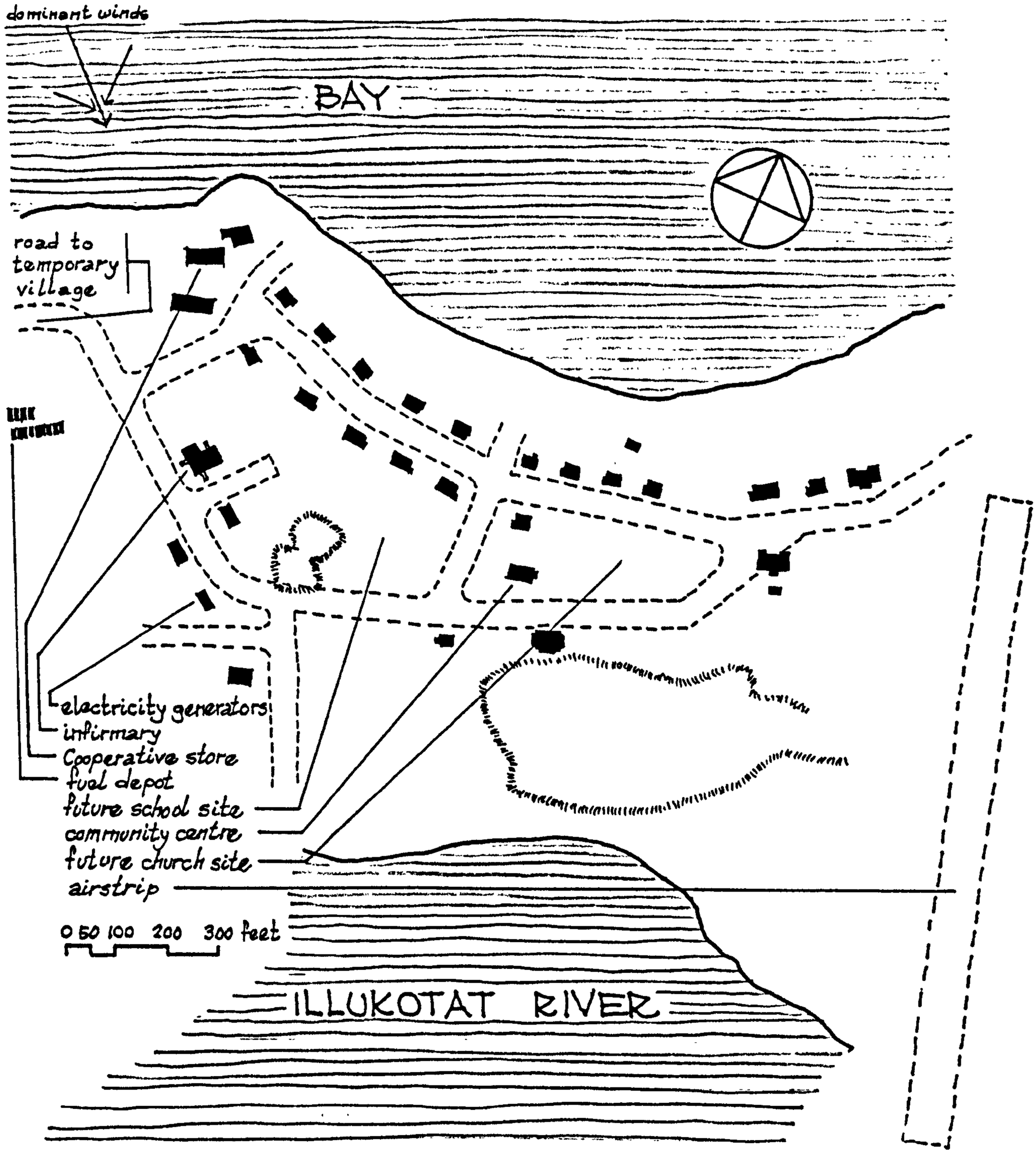


Fig. 137. Akulivik, Hudson's Bay. Plan of Permanent Village, 1980 (From Ministère des Terres et Forêts, Québec, 1980).

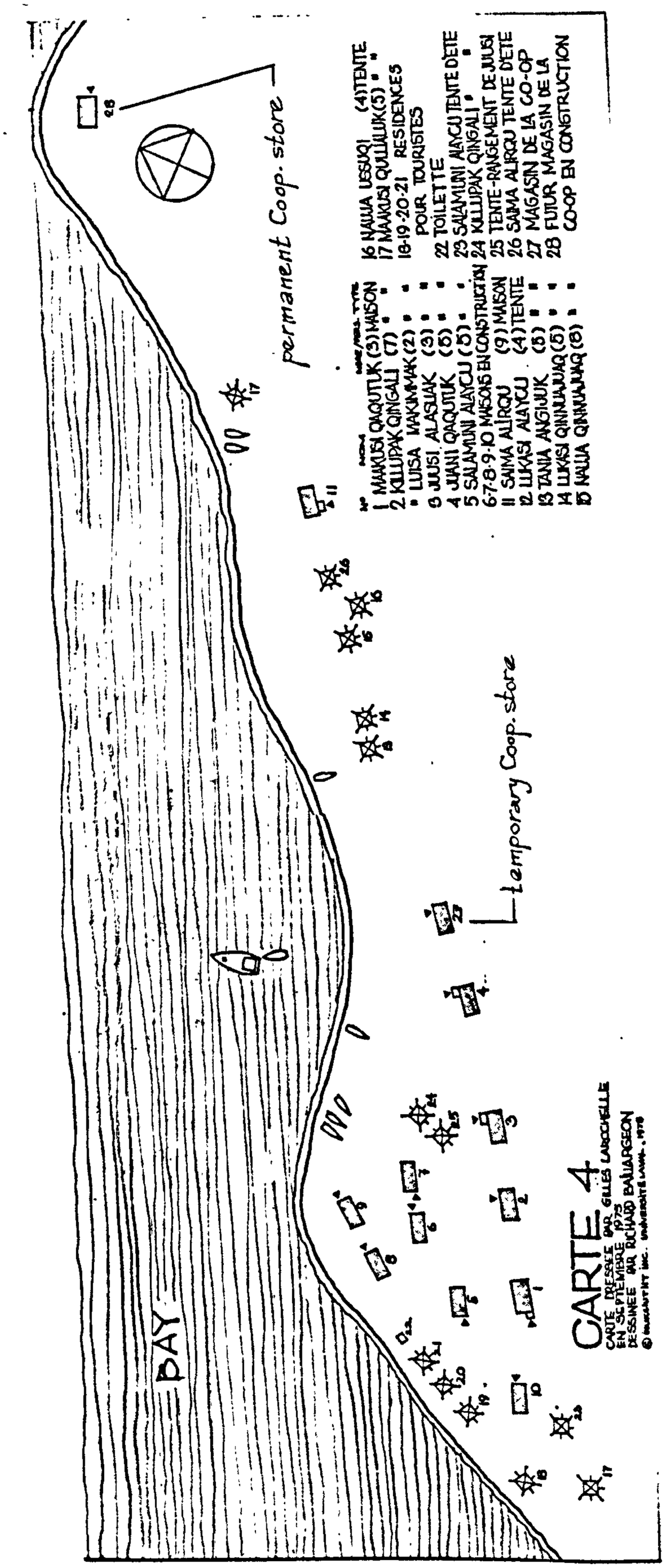


Fig. 138. Akulivik, Hudson's Bay. Plan of Temporary Village, 1975 (From Larochelle et Bernard, 1975).

Temporary Village

The temporary village is situated to the west of the permanent village and although it will be phased out eventually, it provides an example of a village designed by the Inuit. In 1975 the village had a population of 88 persons housed in tents and wood houses (Larochelle and Bernard, 1975, p. 45), and has remained approximately the same up until 1980. The permanent or wood houses are laid out roughly parallel to the shore in three rows and spaced so that each house has visual and physical access to the water. The tents are laid out with less regularity, and some, such as numbers 23 to 26 (see Fig. 138) are summer or storage tents for families occupying wood houses. Structures 18 to 21 are hybrid-wood wall and fabric-roof dwellings for tourists (Larochelle and Bernard, 1975, p. 44). Building number 27 designates the temporary Co-operative store while number 28 indicates the permanent Co-operative store which was under construction. The temporary store was centrally located in relation to the temporary village as approximately one-half of the population was situated to the west of the store, whereas the new Co-operative store was placed to be central to both the temporary and permanent villages.

If the dominant winds are from the south as the photos in Bigué and Pagesu suggest (1980, p. 36), this would indicate that the site was chosen partly for protection from the wind, because the houses would be in the lee of the hill to the south. As mentioned in the section on stone house and snow house settlements (Figs. 115 and 124), sites were often selected in the protected lee of a hill.

The houses and tents suggest a tendency towards clustering as shown by houses numbered 17, 23 and 10; 6, 7, 8 and 9; 13 and 14; and 15, 16 and 26. The group composed of houses 13 to 17, 26 and 11 are quite separate from the central group and may have taken this position in order to be closer to the permanent Co-operative store and the new permanent village. Houses 6, 7, 8, 9 and 10 were under construction at the time the plan was made and suggest a densification of the area to the west of the store rather than to the east which would be nearer the future permanent village and the new Co-operative store. The expansion of the temporary village, although limited, seems to express a satisfaction with the old site.

This plan underlines the importance given to water accessibility, the tendency to clustering in groups, and to the centralization of the major activity pole (the store).

1.5.2.8 Inuvik, N.W.T. - Lat. 68°N

The construction of the new town of Inuvik for a mixed population of white and Inuit was begun in the early 1950's, and was finally completed in 1961. It was designed for the relocation of the Inuit of Aklavik which was subject to frequent flooding and presented many constructions problems (Prichard, 1962, pp. 145-154). The new town, shown in Fig. 139, was planned by the Ministry of Indian Affairs and Northern Development, with the Central Mortgage and Housing Corporation supplying the plans for the housing units.

The layout of the town seems to be loosely based on southern suburban planning principles with its streets curving gently to relieve the monotony of long straight lines. As can be seen from the buildings located in the town centre, there does not seem to be any overriding principle for the grouping of these main service buildings. The white multi-family residences are situated mainly in the sector near the hospital, laid out in a linear pattern. There is also an irregular crescent for single detached houses in the same area. These white residences are serviced by utilidors which carry heat, water and sewage, a factor which probably had a strong influence on the placement of the houses. The Inuit houses are serviced by sewage trucks and therefore the north-west sector, not having the constraints of a utilidor had fewer restrictions on the layout and could have larger distances between the houses.

By 1975, the town of Inuvik (Fig. 139) had already exceeded its planned population of 2000 and by 1978 had reached 3065 persons with a projected population of 5600 in 1986. At this stage it had taken on the character of a congested industrial town with its industrial by-pass road circling the town centre. The northwest residential sector had almost tripled in size since 1966, while the southeast sector had remained approximately the same size (Gerein, 1980, p. 116). The northwest residential sector has developed perpendicular to the river, thereby remaining closer to the commercial zone than if it continued to develop parallel to the river.

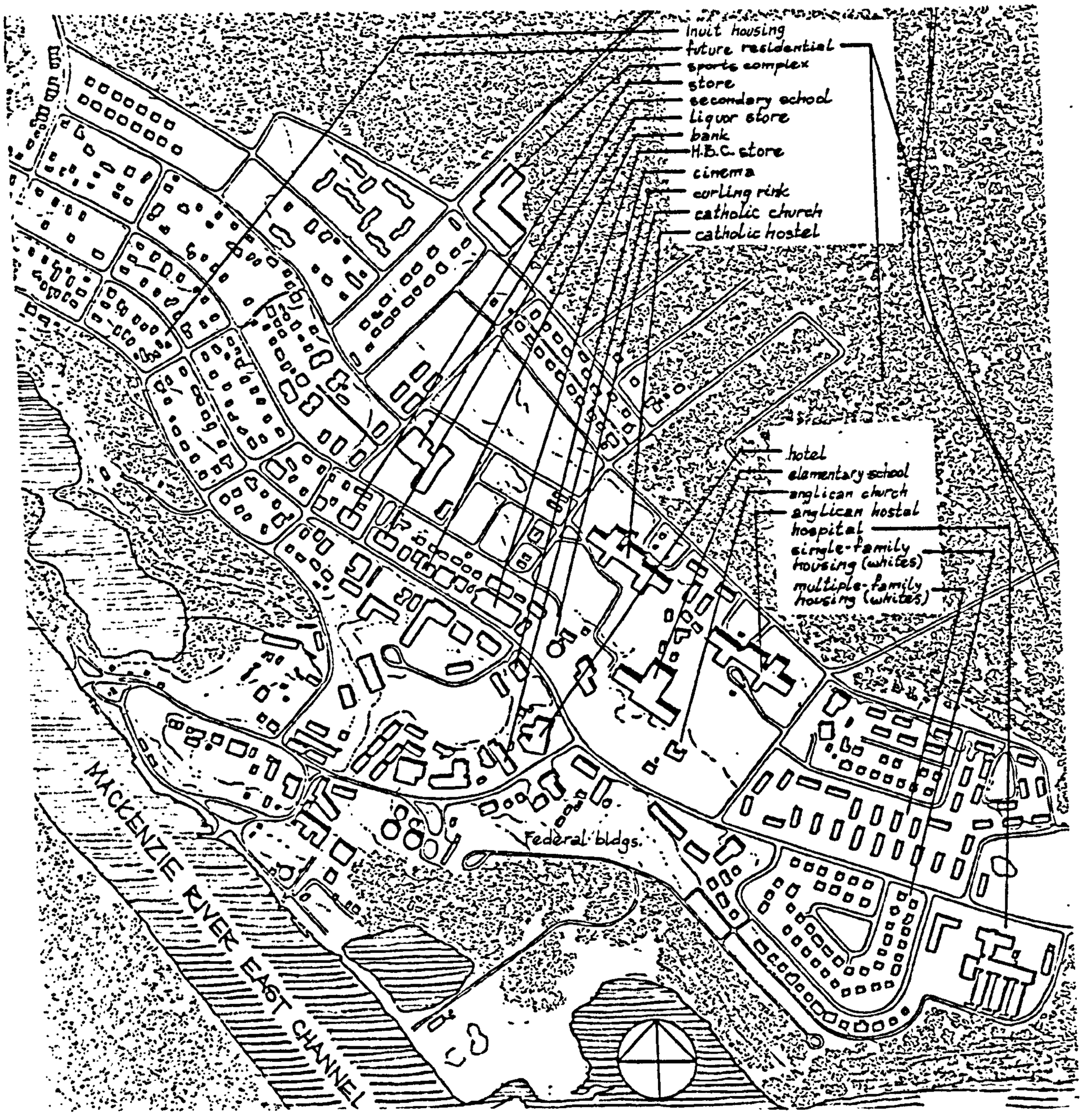


Fig. 139. Inuvik, N.W.T. (From Van Ginkel Assoc., 1976).

It would seem that proximity to the commercial sector was more important than proximity to the water. This suggests a greater proportion of white people settling in this sector.

Eventually, residential areas will completely surround the town centre giving the town a radial-type layout. Thus the centre will be relatively equidistant from the houses on the periphery. However, the small industrial sector, which connects the town centre with the river as well as the two lakes on either side, prevents the residential sectors from extending to the river's edge, much unlike most Inuit villages. This is an administrative centre for the western Arctic, and as such seems to have been planned more with the white population's needs in mind. This opinion is supported by the fact that Apalavik, the town Inuvik was to replace, still exists "...as a centre for (the Inuit) who live more off the land" (Cooper, 1968, p. 144).

1.5.2.9 Tuktoyaktuk, N.W.T. - Lat. 69°N

This village of 746 persons is also composed of whites and Inuit due to the oil exploration in the area. The village, as can be seen in Fig. 140 is apread out on a peninsula of land cut up by lakes and bays. The original village seems to have been situated on the narrowest portion of the peninsula as this is where the commercial area and original school are found, and where the houses are less rigidly laid out.

The village is broken up into four separate activity zones: the first is the commercial area; the second is the original school; the third is the newer school; and the fourth is composed of the curling rink, arena, civic centre and church. Because the settlement is situated on a relatively narrow peninsula, all houses would have direct access to the water. The limited amount of land available has led to this dispersion of activity centres. Alternate sites were investigated, but were rejected for economic and social reasons (Gerein, 1980, p. 108).

1.5.2.10 Holman Island, N.W.T. - Lat. 71°N

This settlement of 306 persons originally developed along the edge of

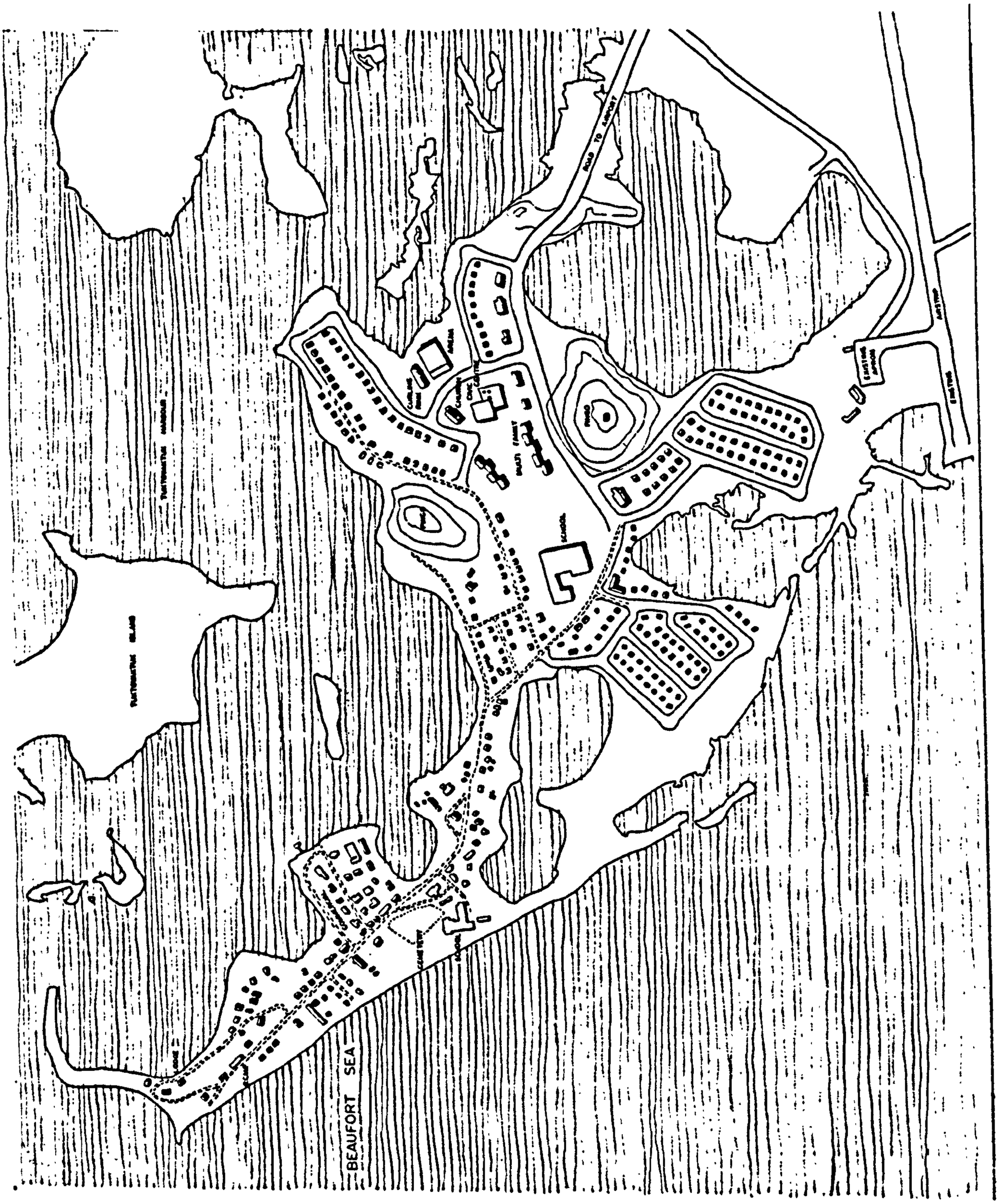


Fig. 140. Tuktoyaktuk, N.W.T., 1977 (From Gerein, 1980).

Queen's Bay with some houses and industrial buildings situated closer to the docking area on King's Bay. See Fig. 141. At the present time, the commercial zone is located closer to the docking area (presumably for ease of provisionment) than the majority of the houses. The farthest house is 2200' (671m) from the commercial sector. The original village has three dispersed activity centres composed of the nursing station; the community hall and school; the churches and commercial buildings.

One of the stated important design considerations for future expansion is the "Proximity to community services and to the land and water where traditional renewable resource harvesting takes place..." (Gerein, 1980, p. 114). The new development proposes houses on several looped streets inland from Queen's Bay on the only flat land in the village. It would seem that the farthest houses would be greatly disadvantaged by the fact that they would be located approximately 1400' (427m) from the sea. However, the new plan proposes future commercial and institutional buildings grouped in the centre of the village adjacent to the nursing station which would be a great improvement over the existing plan, even though the school and community centre would still form another activity pole.

1.5.2.11 Rankin Inlet, N.W.T. - Lat. 63°N

Rankin Inlet had a population of 987 in 1977 with a projected population of 1500 by 1986. It is a regional government centre with a mixed white and Inuit population. The town is planned around two loop roads which extend out from either side of the commercial centre of the town towards the airport. See Fig. 142. Each loop contains a school and smaller commercial areas, while a larger commercial centre is located near the water and in the zone linking the two loops.

The site is subject to serious snowdrifting, and therefore "The streets are of sufficient width to provide for snowplowing and are oriented so as to minimize problems..." The future development was designed to keep the town compact so that water and sewer lines could be economically installed "...and to provide for easy pedestrian access to any facility in the community." (Gerein, 1980, p. 111). However, distances from the furthest houses in the loops to the town centre vary from 750 to 850m.

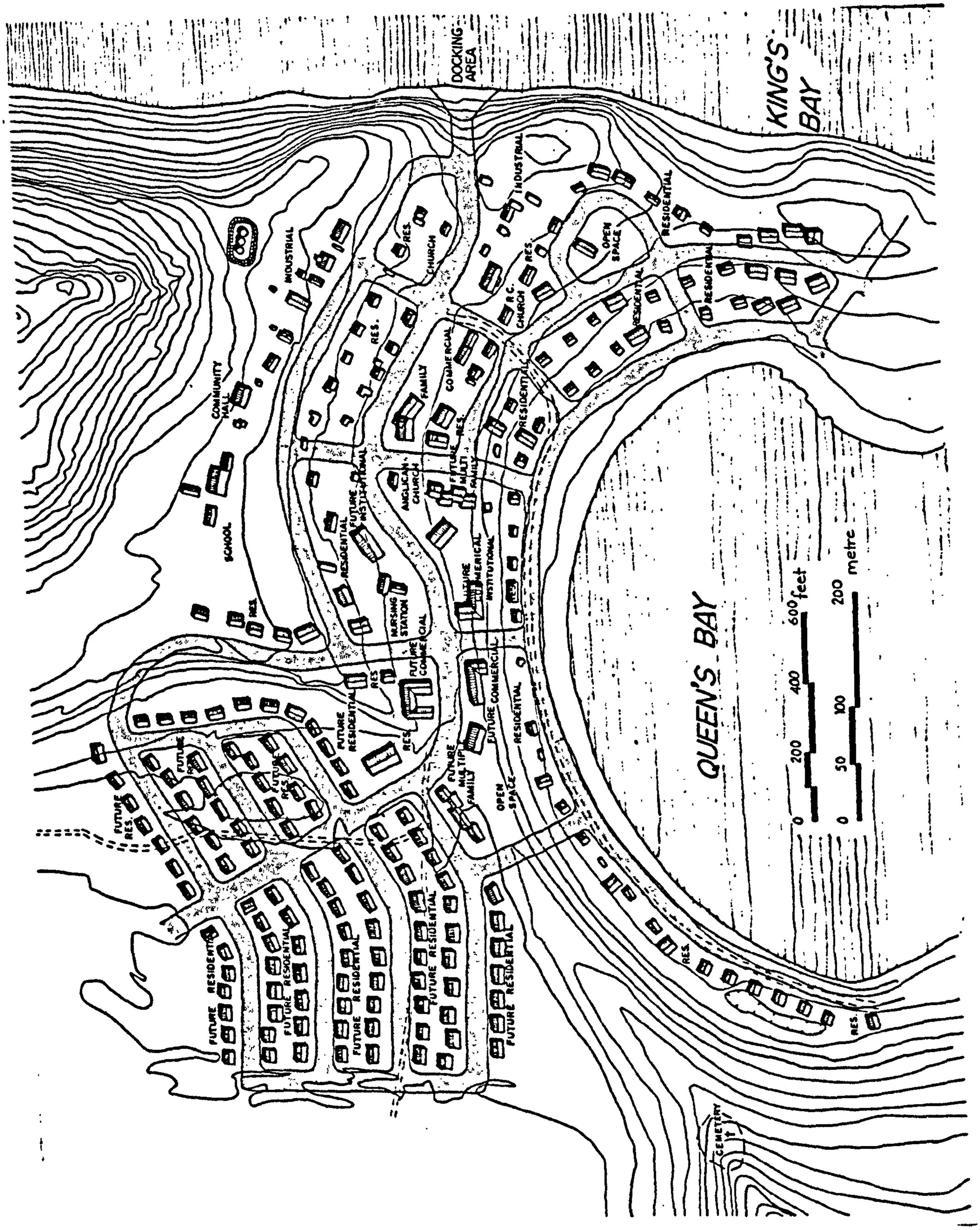


Fig. 141. Holmon Island, N.W.T., 1978 (From Gerein, 1980).

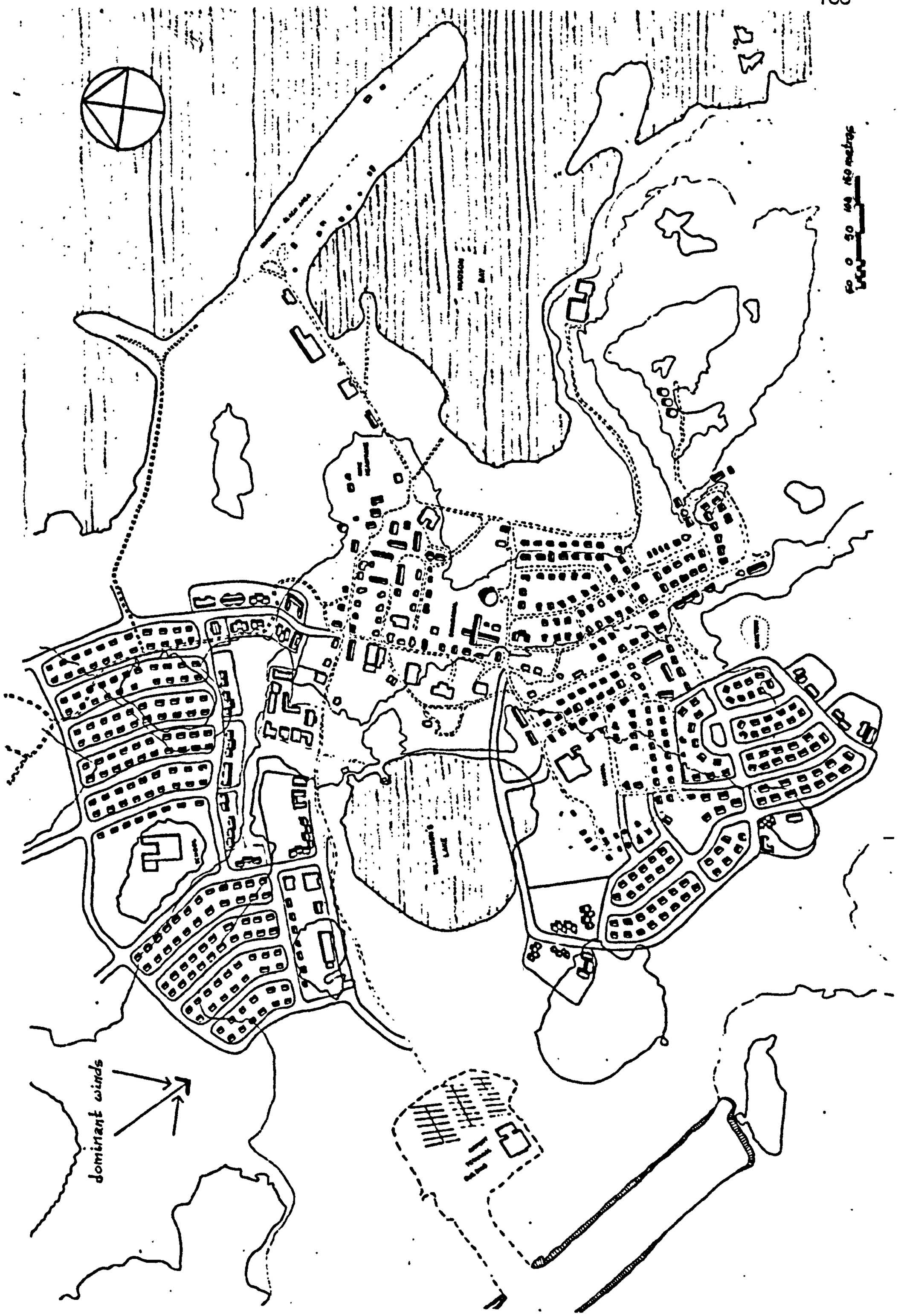


Fig. 142. Rankin Inlet, N.W.T., 1977 (Gerein, 1980).

It would seem that these distances would make the latter design consideration difficult to achieve in the proposed plan. With regard to snow-drifting, the majority of the streets are laid out on a north-northwest and west-southwest axis which is approximately the direction of the dominant winds. Therefore this problem should be minimized as planned.

1.5.2.12 Igloolik, N.W.T. - Lat. 69°N

This settlement had a population of 737 in 1978, and a projected population of 1500 by 1990. The school and the council office are located near the water and central to the houses. See Fig. 143. This site also has snow-drifting problems, and the planners have proposed a street orientation to minimize this condition. Other design considerations were "freedom of movement between buildings, ...quick access to "the land" for the carrying out of the traditional hunting and trapping economy" and a central community activity core "...surrounded by the residents it seeks to serve." (Gerein, p. 103).

The plan, with the proposed future development, is roughly linear in layout with the new houses being situated inland from the original houses located near the water. If we take the area north of the small school as the centre of the village, then the distances from the furthest houses in the west and east-residential sectors to the centre are 2000' (610m) and 2300' (701m) respectively. These distances would seem to be exaggerated if the activity core is to be close to all residents. It is also questionable that the roads would in reality minimize snowdrifting, as the winds are dominant from the northwest, west and north, and the streets are mainly oriented west-southwest with only a few streets oriented north and northwest.

1.5.2.13 Resolute, N.W.T. - Lat. 75°N

This village, designed in 1973 by British-Swedish architect Ralph Erskine, is one of the few plans of a recent village in the Arctic that has made a conscious effort to integrate the environmental factors of solar orientation, high wind speeds and drifting snow in the design of a village. The plan is inspired directly from Erskine's earlier plans for

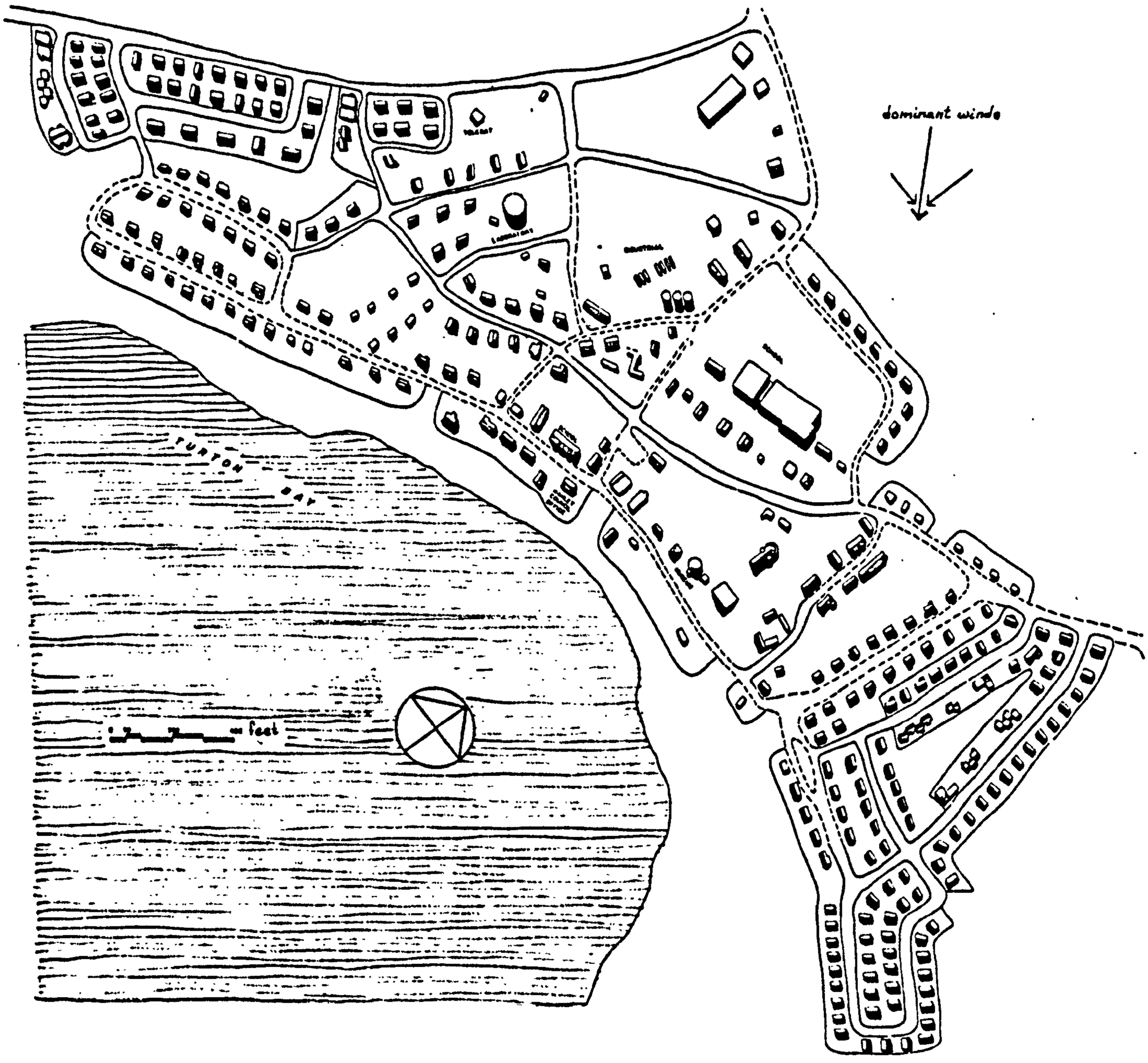


Fig. 143. Igloolik, N.W.T. (From Gerein, 1980).

Svappavaara in northern Sweden (see Fig. 144), and Fermont in Québec (see Fig. 145), the basic principle of which is the protection of the town from the dominant winter winds by a windbreak wall composed of apartments and row houses.

In the early design stages, Erskine experimented with an orthogonal plan that was designed to minimize snowdrifting by allowing the winds to blow the roads clear. See Fig. 146. However, this plan would have created conditions of discomfort because the wind would blow unobstructed along the pedestrian paths parallel to the wind. It is also not certain that snowdrifting would have been minimized because snow would accumulate whenever the wind blew from any of the other two dominant wind directions. Extensive snow-drifting studies were carried out in an open-channel water flume "snow simulator" for both the orthogonal and windbreak-wall plans (Gerein, 1980, pp. 92-94; Culjat, 1975, pp. 226-294).

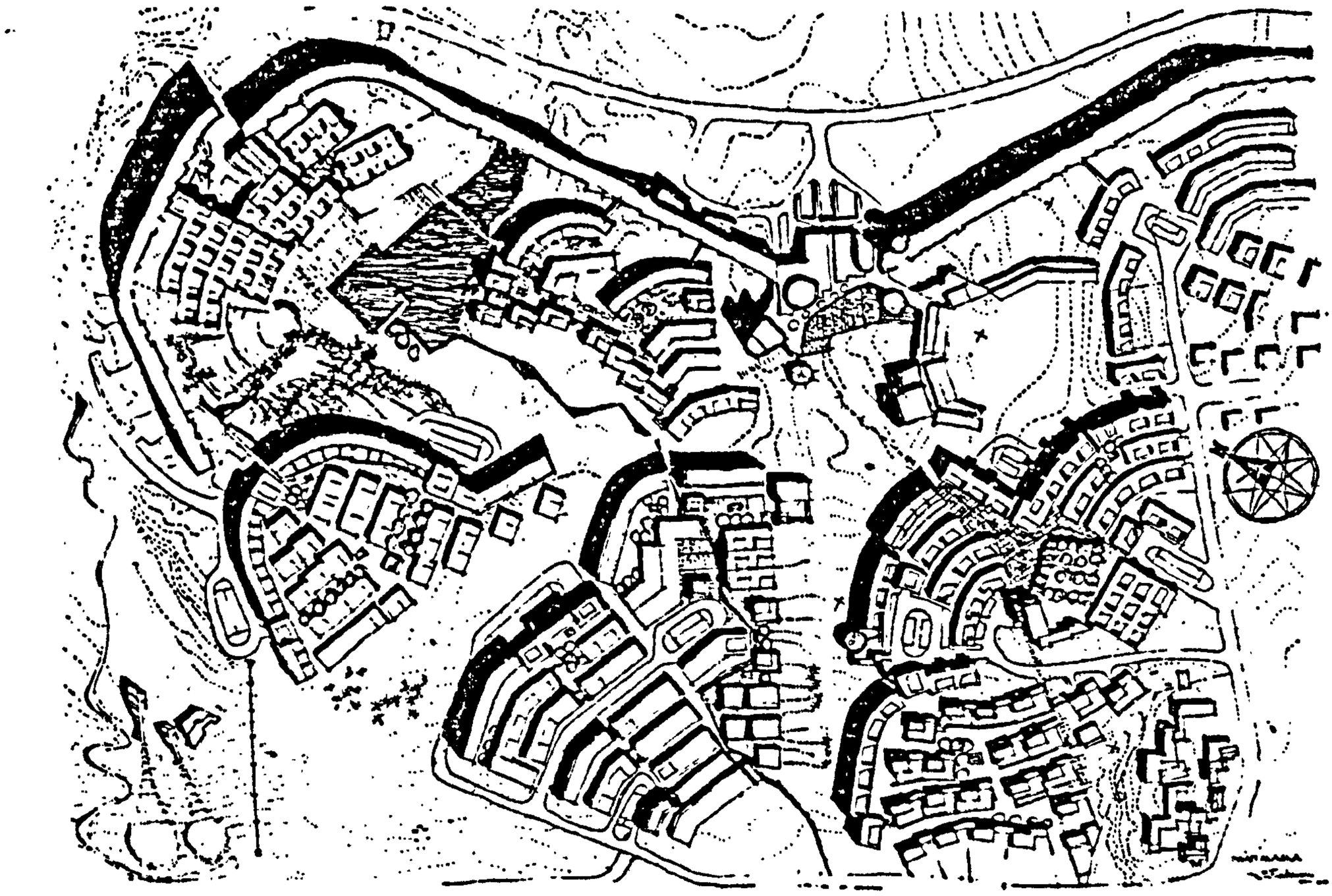


Fig. 144. Svappavaara, Sweden (From Van Ginkel Assoc., 1976).

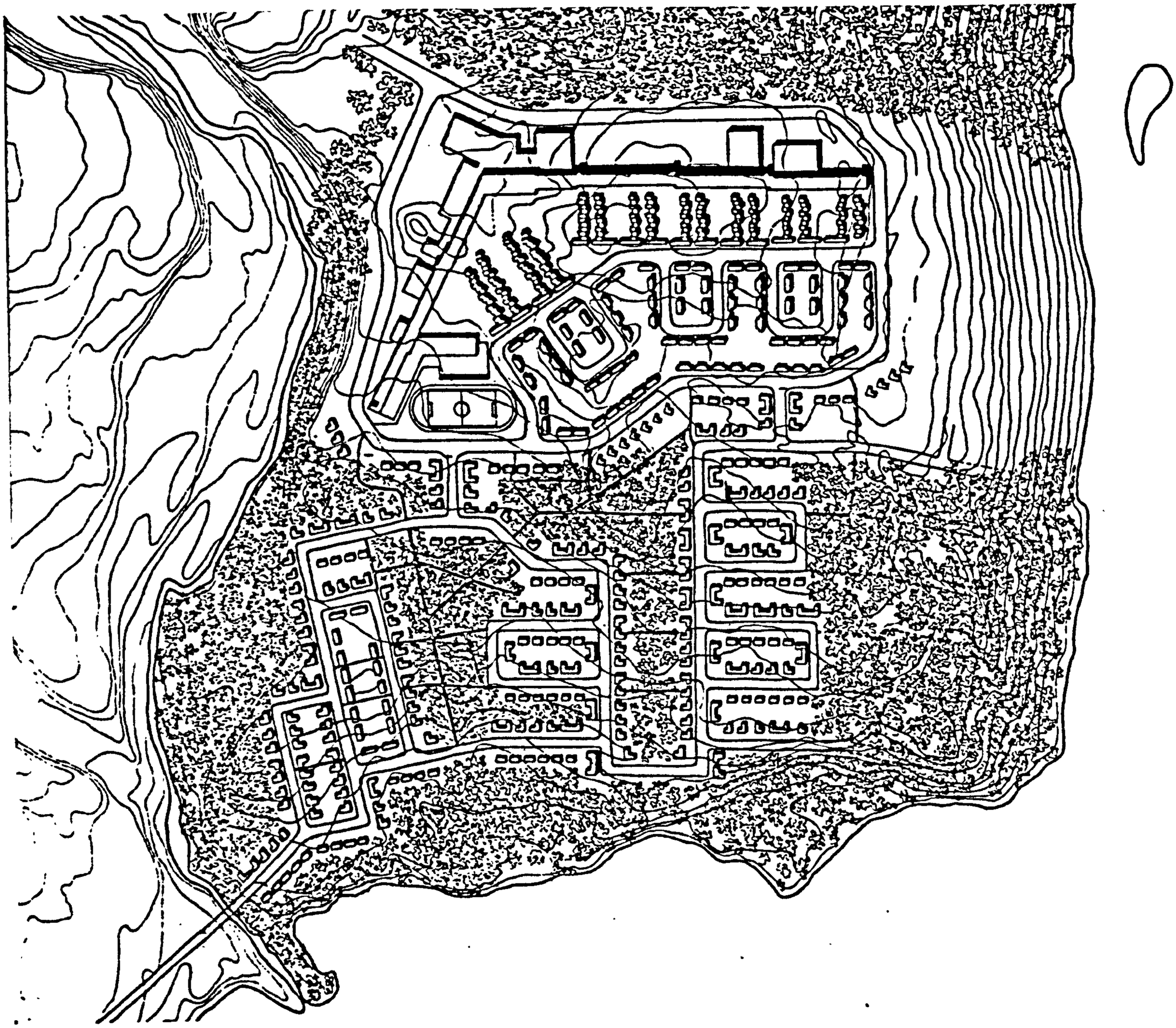


Fig. 145. Fermont, Québec (from Van Ginkel Assoc., 1976).

The plan finally adopted was based on the windbreak principle to reduce wind speed in the town, and to limit snowdrifting (through the shape and general layout of the buildings) to zones where it would not be problematic. The buildings are oriented towards the harbour and the sun, but it is not evident to what extent the shadows cast by the buildings during the various seasons affected the layout and spacing of the dwellings. Some sections through the village give the impression that solar shading was considered (Culjat, 1975, p. 208), but it is not

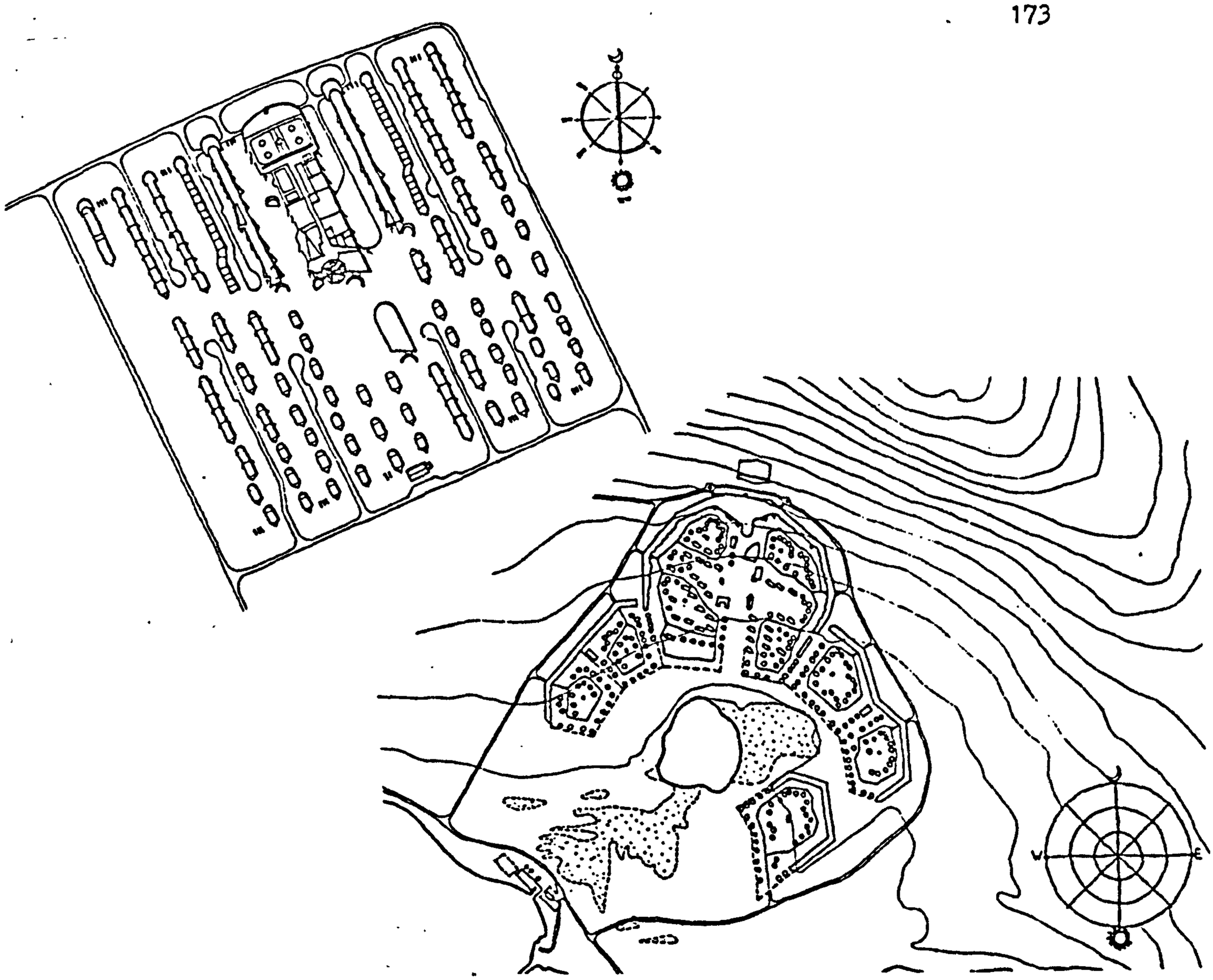


Fig. 146. Resolute, N.W.T. (Alternative plan (upper left) based on principle of self-snow clearance and Erskine's final design based on the principle of controlled snow-drifting (From Culjat, 1975).

clear just how rigorously and systematically this factor was studied. The layout gives the impression that very general notions of solar shading were employed rather than rigorous heliodon or computer shading simulations. At latitude 74° 43'N there would be a period of several weeks during the winter when there would be no daylight, and in summer no darkness. The shadows would be long even at midday at the equinoxes, and would be important even in summer because of the low solar altitude (15° 20' at the equinoxes and 38° 50' on the 21st of June, both at 12:00 noon).

With regard to the efficiency of the windbreak wall, the literature perused turned up no evidence that wind-tunnel studies were carried out to determine

to what extent the wind speed was diminished behind the wall, and for what distance the speed was reduced.

It is interesting to note that user participation had the effect of changing some of Erskine's original proposals. For example, many indoor spaces were eliminated, and the emphasis on multiple-family housing was diminished to provide detached single-family houses for the Inuit (Egelius, 1977, p. 847). However, a major discrepancy would seem to be the long distance from the houses to the sea, which as can be seen from the traditional settlement layouts and the contemporary settlements that were planned with or by the Inuit, has been as short and as direct as possible. Apparently the Inuit had a choice of dwelling and "...decided on social groupings within the housing clusters, which has ensured a continuation of the extended families and suitable relationships with friends" (Egelius, 1977, p. 847). This would seem to imply that the Inuit did not assist in the design of the layout of the clusters, but simply chose houses within a pre-determined layout.

A modified plan was proposed in 1977 at which time the population reached 175 persons. As can be seen from Fig. 147, the entire southeastern sector was dropped from the plan, while the southwestern sector has been modified reducing its length and curving the houses more towards the centre. In 1980 only part of the windbreak wall in the southeast sector had been built due to the decreased demand for multiple-family housing units and budget limitations (Gerein, 1980, p. 108). The pedestrian distances from the farthest house to the school are 500' (457m), and 1700' (518m) to the future town centre, which is far for a town of this size (see Iwujivik and Kangiqsuk).

It is unfortunate that the town has not been built as planned, because of the uniqueness of the planning approach to climatic conditions. However, the Inuit culture is one that adapts with great difficulty, if at all, to multiple-family housing (see Schuurman, "Apartment Houses for Greenlanders" 1969), and since the concept depends on this form of housing, a large white population would be required to justify the number of multiple-family housing units necessary to form the windbreak wall. Thus a cultural

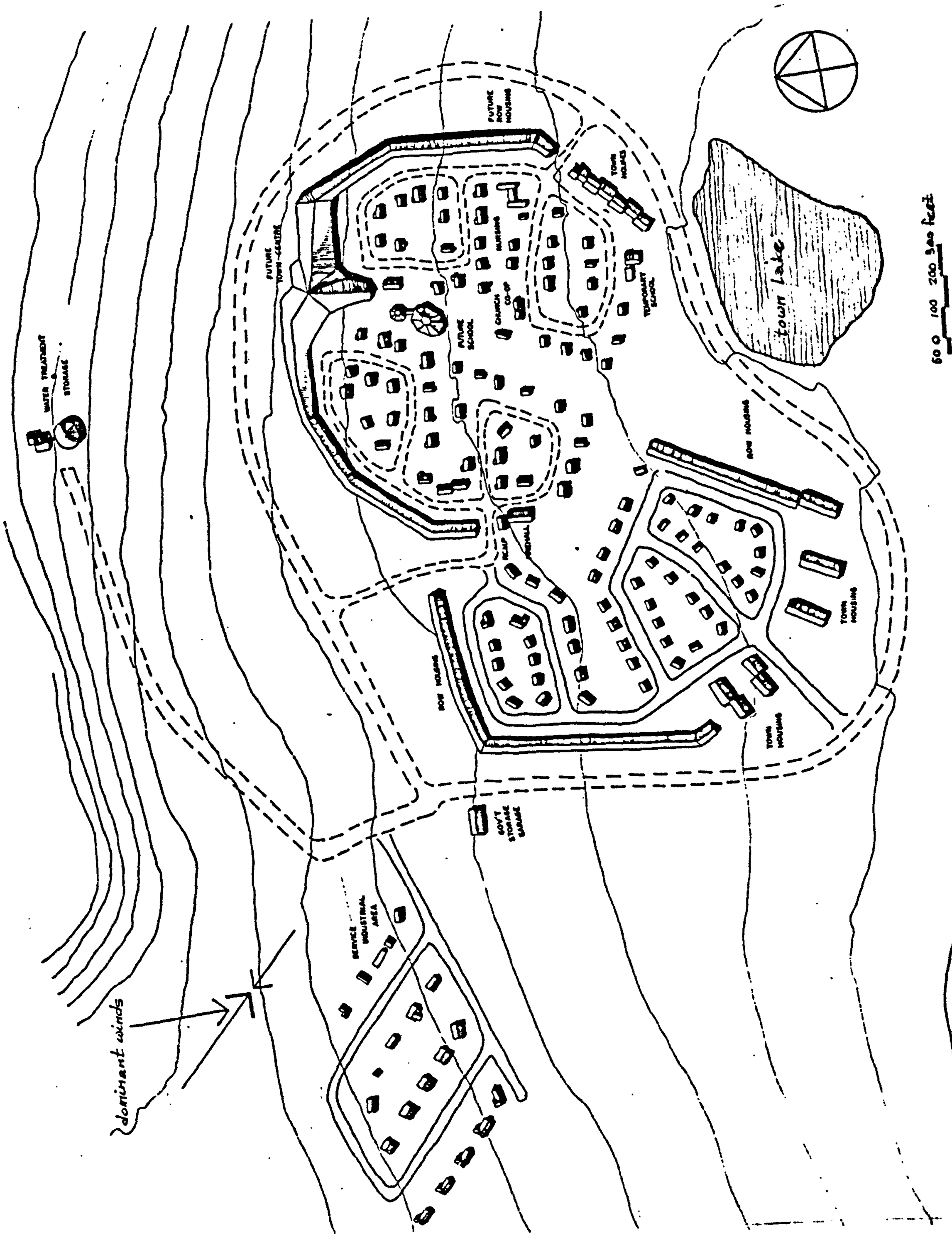


Fig. 147. Resolute, N.W.T., 1978 (Modified plan from Gerein, 1980).

factor becomes of prime importance to the realization of a planning concept based on climatic conditions.

1.5.2.14 Proposed Village At Richmond Gulf, Arctic Québec - Lat. 56°N

This village plan is included in the history of contemporary settlements even though the village does not yet exist, because it is one of the most recently-planned villages and one of the few which has employed consultation and user-participation techniques in the elaboration of the plan. Because some of the plans generated by the Inuit for this village are available, and because the planning process is elaborated in a report (Pluram, 1979), it was decided to use the site of this village for the case study demonstration of the author's proposed planning model.

The village, planned for a population of 718 to 803 residents (Pluram, 1979, p. 16), is located on the east coast of Hudson's Bay at approximately latitude 56° 30'N. As can be seen from the plan (see Fig. 148), the houses are laid out partially parallel to Hudson's Bay and the land contours, and at an angle 50° to the contours and the water's edge. The institutional, educational and commercial buildings are grouped together on the inland side of the houses and are distributed in 5 buildings, 3 of which are joined by corridors. A road runs directly from the dock warehouse and oil tank area to the Institutional-educational-commercial complex, from where it turns 90° and leads to the airport.

With regard to pedestrian distances, the furthest house (not including the group of 10 houses on the road to the airport) is 1100' (335m) from all main services, which is a reasonable distance when compared to those of existing arctic villages. However, the Co-operative store should share a central position with the school rather than being placed off-centre in the service complex, as the store has a social function in addition to its obvious importance to all the community. The recreation centre which is the hub of arctic social life for people of all ages, should be given a more prominent position in order to fulfill its role of animating community life.

Wind conditions, as analysed by the Pluram group, led them to believe

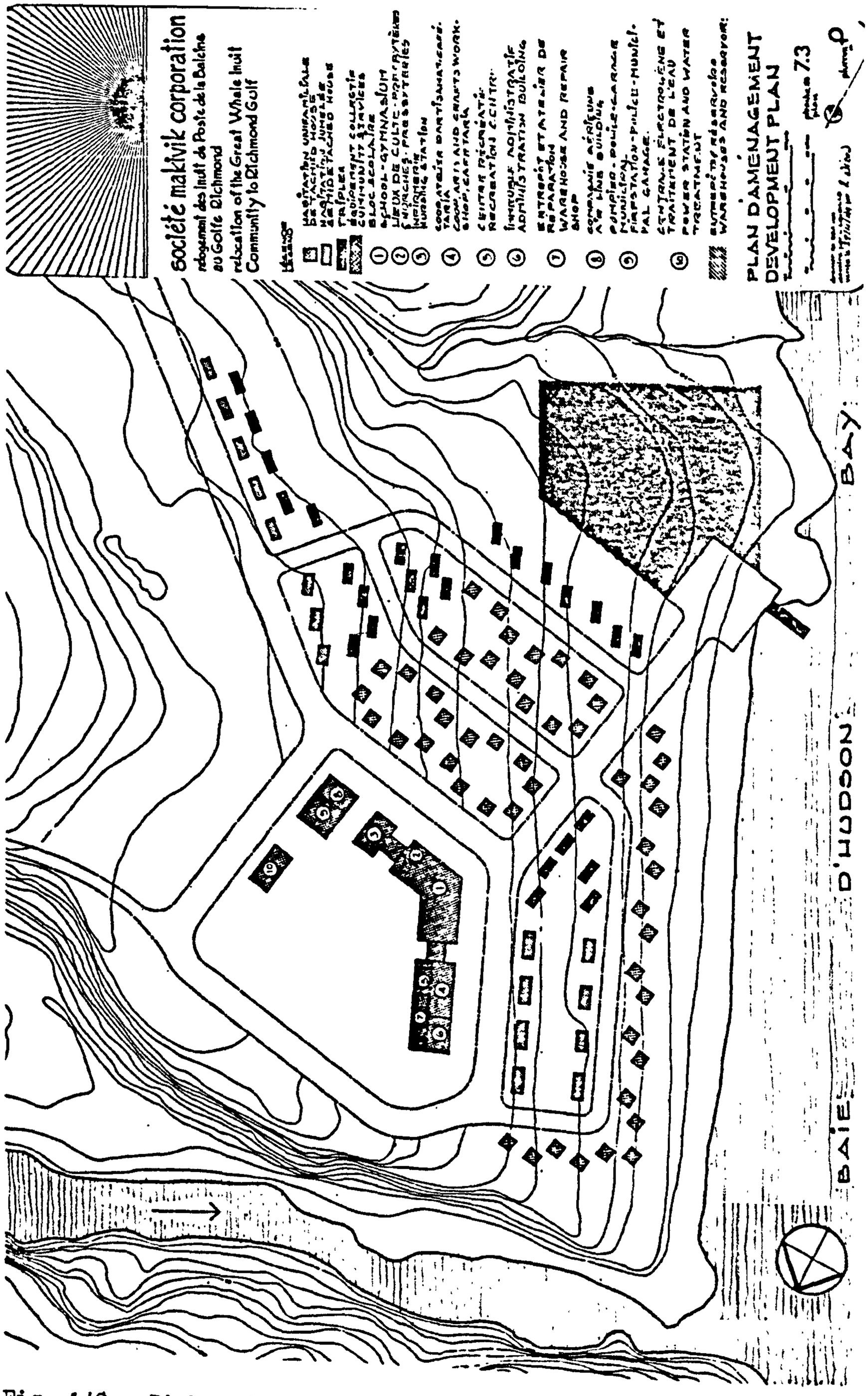


Fig. 148. Richmond Gulf, Hudson's Bay. Proposed plan for a new village (From Pluram, 1979).

that the village needed to be protected from "...the impact of the winds from the east" and they therefore located the service complex "...to shelter the village from the winds from the east" (Pluram, pp. 138, 148, 152). Wind conditions at the site were based on climatic data from Inukjuak, approximately 250km north of the site, and Kuujjuaraapik, approximately 160km to the south; on personal observations from Inuit hunters who had hunted at the site; and from site observations based on "...geomorphology and erosion." The prevailing wind from this analysis was determined to be on an east-west axis (Pluram, pp. 96, 112, 114, 508). Comparing the wind frequency and direction tables for Inukjuak and Kuujjuaraapik as used in the Pluram report, the easterly wind was only the third most frequent wind in winter at Kuujjuaraapik (second was south-east); 6th most frequent in summer and 7th most frequent direction summer and winter at Inukjuak. This would seem to indicate that the easterly winds at the site would only be the third dominant wind direction (Pluram, 1979, p. 114). The winds come from the east at Kuujjuaraapik because the Great Whale River probably channels the wind down its valley into the village. However, no such large valley exists to the east of the Richmond Gulf site. The wind data from Inukjuak would seem more appropriate to use because of off-shore islands between it and the open water of Hudson's Bay, which is a similar situation at Richmond Gulf. The author proposes that rather than coming from the east that the wind direction would more frequently blow from the west through a space between the two off-shore islands. As the dominant winds in the Arctic are from the northwest and north, the winds would probably blow along the length of the coast north and south between the islands and the coastline. Occasionally, perhaps due to the large body of water called Richmond Gulf which is east of the site at a distance of approximately 8km, the wind might blow from the east.

The Pluram report mentions that a hollow has been formed at the site at the service complex which was created by aerolian erosion (pp. 102, 104). The report also mentions that the site is windswept in winter and that snow is generally scarce or non-existant "...from the majority of the site, excepting the edges of rocky hillocks", which leads the author to believe that there are strong winds from the west, north, and south, with only occasional winds from the east, because easterly winds would leave

more snow on the west side of the hills. This description of wind conditions on the site seems to be in contradiction to the site selection criteria elaborated by the planning group which states, "preference should go to a site sheltered from winter winds..." and that although the Inuit are accustomed to the wind, the youth are less willing to accept the discomfort of strong winds and severe weather (Pluram, pp. 70-74).

The consultation with the Inuit revealed that of the 17 people consulted, 16 (over the age of 35 years), stated that violent winds were not a problem (p. 508). However, the respondent who was below 35 years of age, cited wind as a problem (pp. 486-490). Therefore, this small sampling of opinion cannot be taken as representative of the community (most of the community - 437 out of 684 are below 31 years of age). The author proposes that the wind is an important factor and has not been given sufficient consideration, and although the service complex protects the community from the east winds, this probably erroneous concept would leave the community exposed to the sweeping west, north and south winds.

Snow accumulation has not been considered very seriously in the report except to state, as does practically every planner designing for the north, that the roads should be oriented in the direction of the dominant winds in order to blow the streets clear of snow (Pluram, p. 72). However, the report states that in a large measure the plan was based on the physical conditions of the site (p. 138) and that the topography and the road network determined the zones for the detached and semi-detached housing. As can be seen from the plan (see Fig. 148), all the detached houses are oriented approximately north-south, while most of the semi-detached houses are oriented north-northwest to south-southeast, following the land contours. This would mean that for east winds, the snow would collect on the Bay side of the houses where they would not obstruct the majority of the streets.

In general, this plan because of its user-participation input, seems to have satisfied the cultural needs, although the houses in the northeast sector seem to be influenced by the position of the service complex, rather than the distance to the water. The warehouse and reservoir occupy prime waterfront land when they could be situated further inland without any

great penalty to their functioning. The village could have developed in rows parallel to the shoreline and land contours with the service complex placed more centrally with houses on either side.

This plan is one of the most culturally sensitive plans analysed by the author, although it seems quite doubtful that it has resolved the climatic constraints of wind and snow. The south orientation of the detached houses is good as is the location of the service complex behind the houses, because no large shadows would be cast on the houses. The semi-detached houses, however, should be re-oriented to take advantage of the sun. The plan of the proposed village at Richmond Gulf is an interesting example of traditional planning techniques modified by user participation, and is strong encouragement for a more elaborate and systematic use of this technique.

1.5.2.15 Utopic Arctic Settlements

Plans for utopic settlements in the Arctic are frequently proposed, although rarely constructed. They are interesting to note in a history of contemporary Arctic settlements, although they rarely concern the indigenous or permanent population. They are usually based on satisfying southerners' needs in a "hostile" environment, and are economically justified by the exploitation of some natural resource which it is supposed is in sufficient world demand and sufficiently abundant to be exploited over a long period of time to pay back the economic investment.

The first example illustrates one of many Russian projects for an all-enclosed megastructure city. It consists of a dome-covered sports or recreation centre joined to an elevated pedestrian-commercial-institutional spine which is linked to the elliptical-shaped apartment blocks. The buildings are all elevated on pilotis above the permafrost to minimize heat transfer, and are elliptical or dome-shaped to reduce wind loads and air infiltration. See Fig. 149.

The second example is a residential complex proposed for the Russian Siberian city of Norilsk containing 2000 persons. The pyramid structure has apartments in the sloping-envelope structure with a sports-recreation park in the open space at ground leve. See Fig. 150.

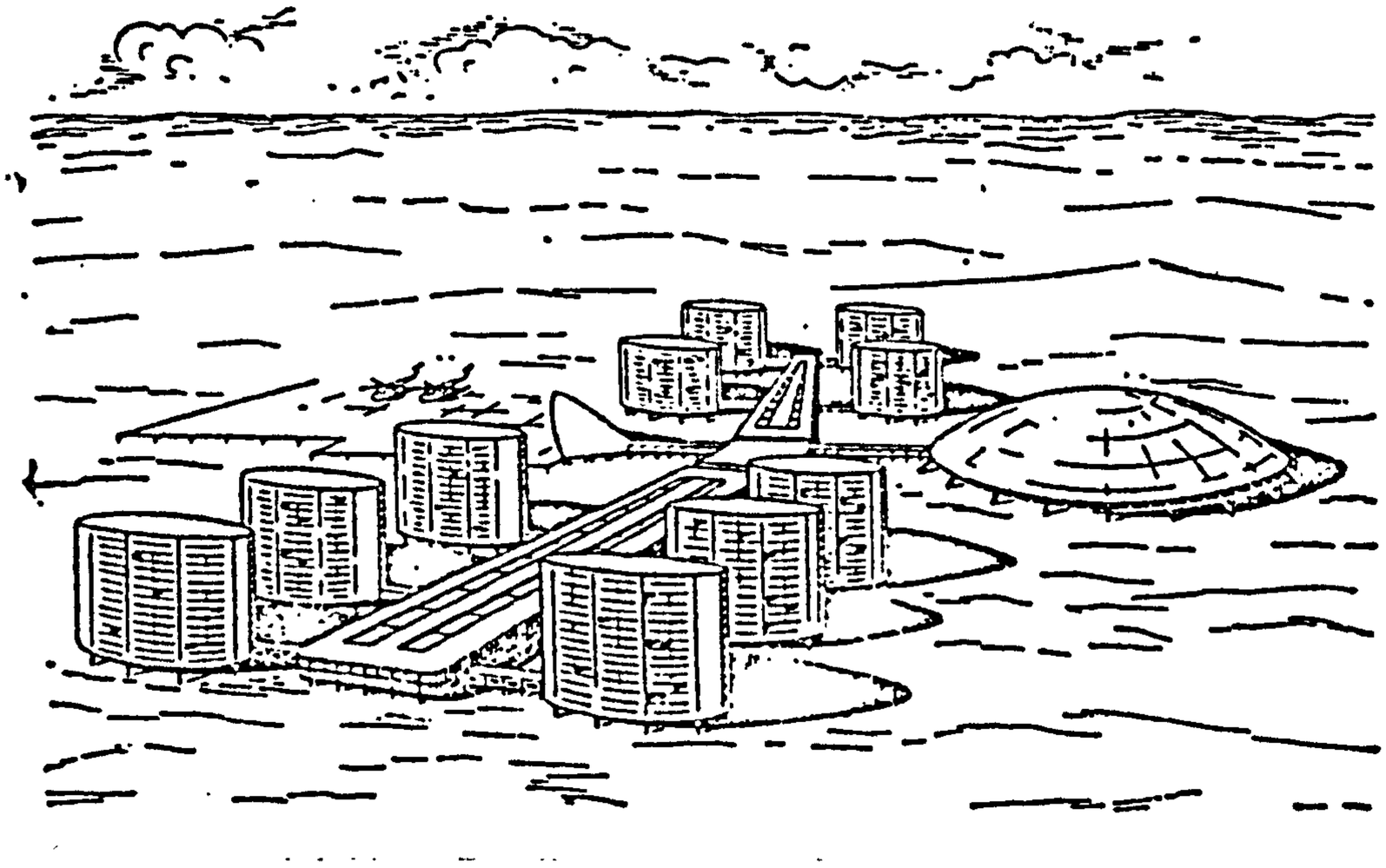


Fig. 149. Russian project - all-enclosed megastructure city (From National Research Council, 1966).

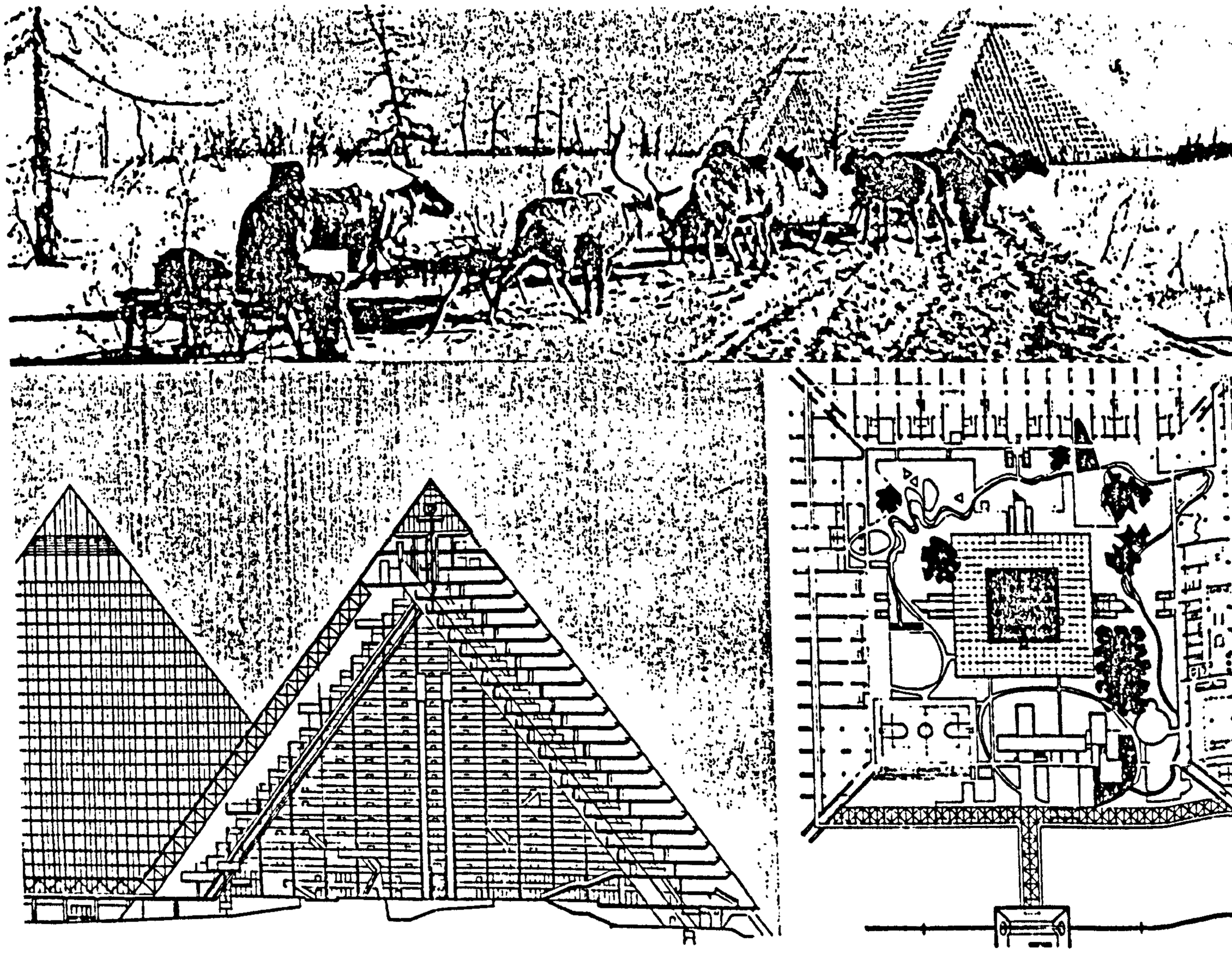


Fig. 150. Proposed residential complex for Russian Siberian city - Norilsk (From Architecture d'Aujourd'hui, 1967).

The third example is an air-inflated dome elaborated in 1970 by Frei Otto for the Arctic. See Fig. 151. It is based on an original proposal by Otto made in 1952 for a glass-covered cable-net roof over an Arctic city. The proposed climate-controlled city has a diameter of 2km and an interior height of 240m and is designed for a population of 15,000 to 45,000 people. It is suggested that its dome shape "...should be able to resist severe storms", and prevent the accumulation of snow. However a wide belt is left free around its base in which the snow would accumulate (Oleiko and Thorsteinn, 1971, p. 6).

The electricity power plant uses atomic energy and recycles the cooling water to keep the harbour ice-free and to warm the polar air at the dome's air intake. It is stated that the "outside conditions are altered by raising the temperature only as much as necessary", and that "both temperature and humidity fluctuate (but) ground frost is avoided" (Oleiko and Thorsteinn, 1971, p. 6). The avoidance of ground frost in an area of permafrost would seem to be very difficult and would, as Gerein has noted concerning domed-covered communities in general, "...upset the thermal balance of a site causing degradation of the permafrost and serious foundation and drainage problems". It is also believed that the savings in less rigorous insulation and heating requirements for the buildings would not offset the cost of the dome and the conditioning of the air (Gerein, 1980, p. 101). Otto proposed a cost for the dome of 300 to 450 DM/m^2, which converted into Canadian dollars is 1170 x .54 = \$632.00/m^2 or \$59.00 ft^2. Residential construction cost in Arctic Québec range from \$64 to \$87.00/ft^2 (Pluram, 1979, pp. 304-306), and even if the cost was reduced by 25% to take into account reduced heating equipment and insulation requirements, the total cost of the dome and houses would be from \$107 (\$59 + \$48) to \$124 (\$59 + \$65). It would therefore seem unlikely that the proposal of a city under a dome could be economically viable, unless on a long-term basis the cost of heating the dome was cheaper than heating each house individually.

Otto states that "...material studies and detailed calculations in England concentrating on the problems of urban construction and of human behaviour" have brought this proposal "...beyond the phase of

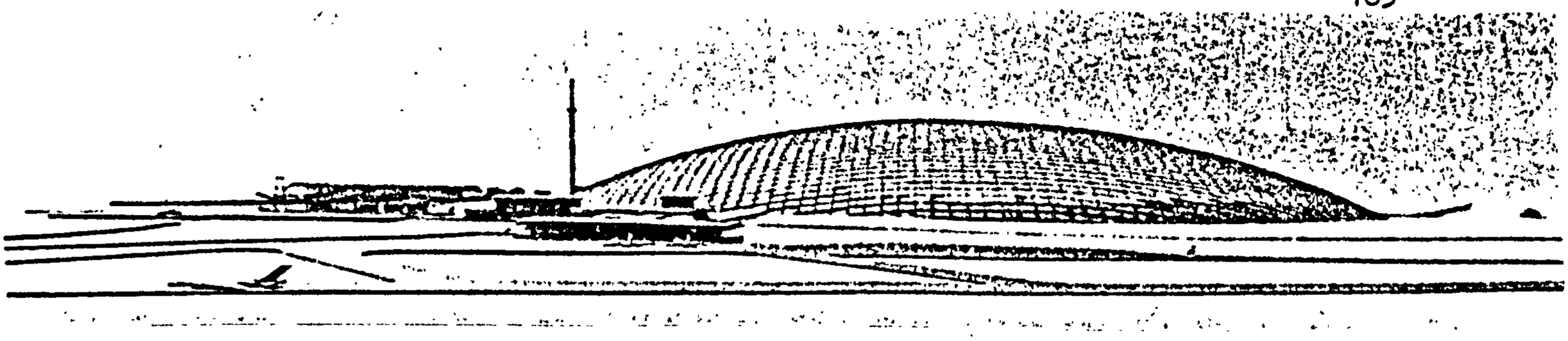
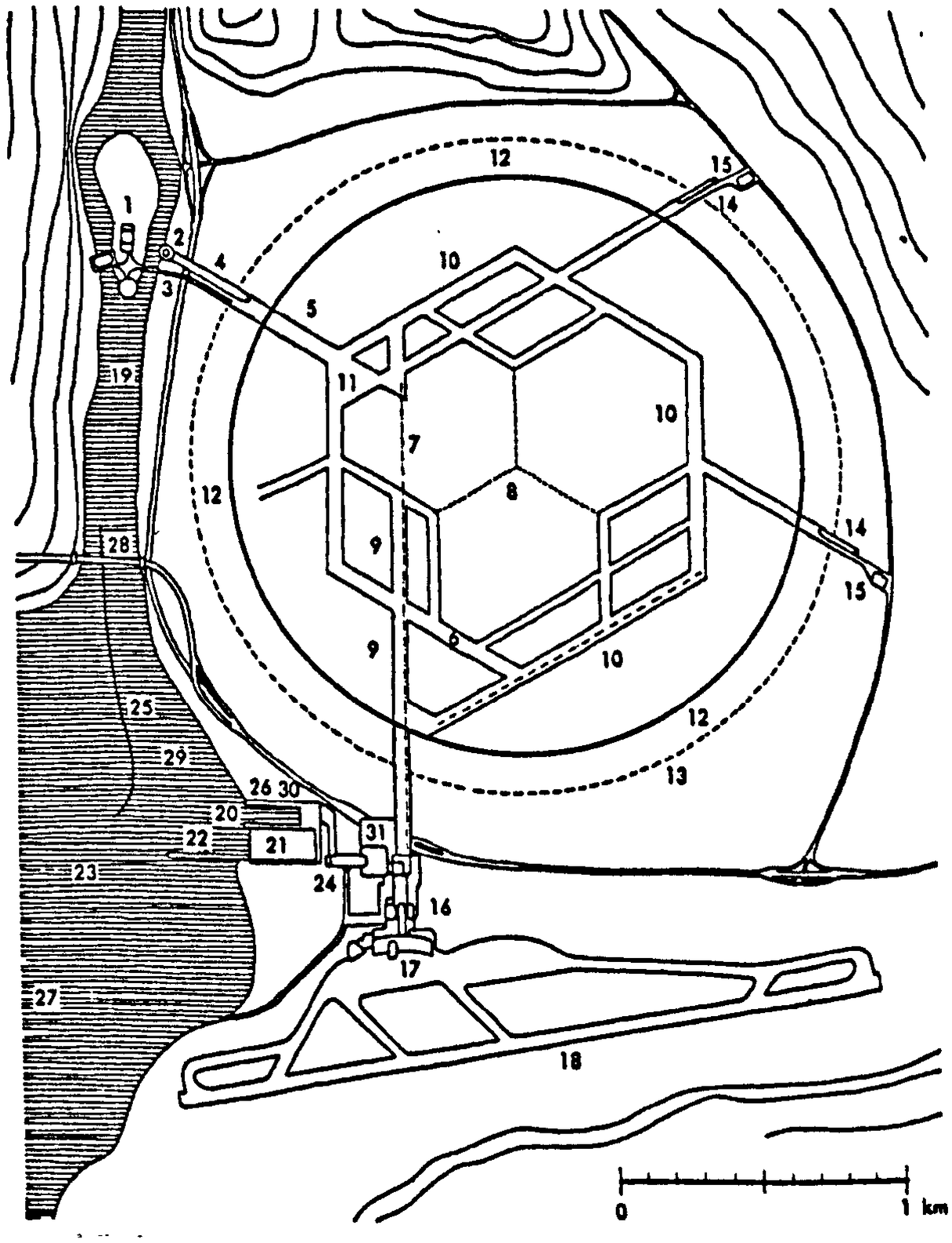


Fig. 151. Proposal for an Arctic city covered by an air-inflated dome (Oleiko and Thorsteinn, 1971).



1 Atomic power station
2 Air circulation tower
3 Tower restaurant
4 Main blower
5 Air exchange system
6 Closed supply and traffic system
7 Moving sidewalks
8 Gondola lift
9 Business district
10 Residential area
11 City center
12 Snow storage ring
13 Snow fence
14 Suction system and auxiliary pressure fans
15 Air lock and small external depot
16 External communications terminals
17 Air terminal
18 Runway
19 River
20 Harbour
21 Covered harbour basin
22 Open harbour basin
23 Anchorages
24 Passengers
25 Anchored floating guide trough for warm water
26 Oil depot
27 Water
28 Bridge
29 Warm water (ice-free port)
30 Store houses
31 Parking houses

utopian ideas and visionary projects" (Oleiko and Thorsteinn, 1971, p. 7). Gerein raises some doubts about the social implications of such projects when he states: "What are man's needs for contact with the natural environment and especially in the north where the native people have had a traditional feeling for the closeness and struggle with nature? Much of the native people's pride is in their ability to cope with the formidable northern environment." (Gerein, 1980, p. 101). Even in the case of "southerners" living in this type of city there could be psychological problems because it could result in the "...creation of a "hot-house civilization" (Zrudlo, 1971, p. 165). Dr. Selye points out that "...certain unrelieved stresses can cause the body to fail, but complete lack of stress leads to degeneration and some is needed to properly maintain the body" (in Zrudlo, 1971, p. 165). Ian McHarg believes that "...no species can exist in an environment of its exclusive creation"(in Zrudlo, 1971, p. 166) which is the case of a city under a dome. The author believes that projects such as this need much more behavioural research on the effects of a completely controlled environment before a dome-covered village for the Arctic should even be considered.

Conclusion

Numerous changes have been made in the Inuit way of life as is reflected in the settlements they now inhabit. As has been described in the section on the history of Arctic housing, the sedentarization of the Inuit had a great effect on housing, form, materials and the use of space.

Contemporary Inuit settlements have imposed a change in living patterns as demonstrated by the importance given to such services as the store, school, infirmary, etc. In the traditional culture all these services were integral to their life style and no separate buildings were needed to carry out these activities (an exception being the dance house for village celebrations). As the white culture interacted with the Inuit these services were gradually provided for by the white man and were housed in buildings. Because these buildings were permanent and relatively large in scale, their situation had a great influence on the development of the village.

With the advent of other services such as the provision of water and heating fuel, rubbish removal, electricity and telephone, even more of the tasks normally performed by each family were given over to other people. This process of abdicating control over one's daily life and environment was begun when the first wood houses were built for the Inuit. This abdication of control went to such an extent that in some contemporary settlements (for example Salluit and Ivujivik), the institutions and services took up preferred positions relegating housing to inferior sites.

However, there are a few cases in which the Inuit have been able to regain some control over their environment as is the case of Tasiujaq, Aupuluk and Akulivik. These villages were planned so that the essential relationships between the houses and the water were maintained, and the distances between the houses and the institutions were as short as possible. These are villages that were planned with the Inuit and provide a good indication of the priorities given to the location of houses and services.

Resolute is an example of a village that has given the Inuit a limited amount of control over the environment through a form of user participation in the planning process. As illustrated by the original multiple-family housing concept (windbreak wall), it seems evident that the plan was first elaborated to resolve climatic problems, and then the Inuit were solicited for their reaction. User participation as defined by this author requires the user to be formally involved in the conception of the plan, and not consulted after the fact. Erskine's plan was less successful with respect to cultural aspects because the only means he had of integrating the user's needs into the plan (without destroying the original concept) was through making minor modifications to a concept that had its beginnings in another culture. Notwithstanding these drawbacks, the plan is interesting as an example of an attempt to resolve climatic problems in the design of settlements.

The proposed plan for Richmond Gulf is an example where the Inuit have had the possibility to determine completely the design of their village. They hired planners who instituted a small measure of user participation

in the design process (based on the techniques used in the Nunaturliq Project - Phase 1). However, although the techniques were valid, a large sector of the population was not reached, so that the results could not be truly representative of the community. The Inuit in this instance had administrative control, but did not exploit planning control which would have influenced the plan to a greater degree. The climatic conditions were dealt with in the planner's typical cursory fashion, without any simulation studies or major concessions to the climatic constraints.

Nevertheless, this is the best example to date of integrating the user in the planning of a settlement that the author has been able to uncover.

From the analysis of contemporary settlements the author did not find any examples where due consideration was given in any systematic fashion to the climatic conditions and cultural factors. In general the climatic conditions have been paid lip service or completely neglected, and as far as cultural factors are concerned, they have not been treated in any meaningful way except for Resolute and Richmond Gulf. It is evident that an integrated approach to settlement planning in the Arctic is required if the cultural needs, climatic conditions, geological constraints and the technical requirements are to be coalesced into a coherent, balanced plan that gives due consideration to all these factors.

The planning model to be described in the following section is an attempt to set out a systematic procedure that will integrate all the needs, conditions, constraints and requirements through a framework of consultation and evolutionary transformation.

CHAPTER TWO

2. A FOUR-LEVEL PLANNING MODEL - THEORETICAL BASIS

From the foregoing description of the history of arctic settlements, it is relatively clear that no town or settlement in the Canadian Arctic has given consideration to all the environmental and human factors in a sufficiently coherent and systematic manner.

Most of the settlement plans have been determined more by constraints of the technical infrastructure than by climatic or cultural needs. The Arctic is not unique in this respect. In his critique of town planning techniques, James Stirling describes the planning process in the following words: "A typical sequence of new town 'rational' planning is firstly the design of sewers/services, 'part of the infrastructure', the routing of which dictates the layout of roads. This in turn, dictates the disposition of buildings and an abject environment results - particularly in relation to housing." (Stirling, 1979, p. 42) This same importance is given to the service infrastructure in the Arctic, but on a more primitive level. Unlike southern urban areas, the layout of settlements in the rctic has been more influenced by topography and road networks (Pluram, 1979, p. 238)than by other considerations, because with few exceptions, sewer networks do not exist in the Arctic.

Taking into consideration the special constraints of building in the north, the author has identified four major influences in the planning process. These influences are arranged in four levels from the most abstract technical considerations to the more personal cultural needs of the people. The proposed four-level model includes first, the geological and hydrological requirements; second, the services infrastructure requirements; third, the climatic requirements; and fourth, the cultural requirements. The first three levels involve town planners and specialists, with the final level involving the people.

The first level includes the physical constraints of the site imposed by the soil composition; the topography; water drainage; soil erosion; location of rivers, streams and swamps; and the proximity of a sufficient volume of potable water - which together govern the locational possibilities

for buildings and roads.

The second level is related to the service infrastructure, which is of two types - one technical and the other socio-institutional. These seemingly different types of services are grouped in the same level because they both have an important influence on the organization of houses and roads. The technical services (the delivery of energy, etc. and the collection of waste) require simple distribution networks and minimum distances between the point of origin of the services and the final receiving point. The socio-institutional services such as the store, infirmary, school, church, administrative offices, dock, airport, etc., by their position in the village influence greatly the movement of people and goods. Their location, as well as the amount of land they occupy, has an important effect on the distribution of streets and houses.

The third level deals with climatic factors such as solar shading, wind flow and velocity and snow accumulation. These three factors can render life uncomfortable and can make circulation difficult if not impossible in times of severe weather conditions. The layout of the settlement can modify in a positive manner any unfavourable conditions due to the climate, such as offering wind protection, the opening-up of spaces to sunlight, and the orientation of buildings to minimize heavy snowdrifting. In this way town planning can affect the well-being of the inhabitants and the efficient functioning of the settlement in a very direct manner.

The fourth level treats the cultural needs in the planning of a settlement. There are many ways in which a cultural group can use the physical grouping of buildings called a village which would differ from that of another cultural group. The layout of a village can facilitate or impede certain cultural activities, discouraging patterns of movement and use of services.

The model integrates the four different levels of requirements in a cumulative process for which the author has identified two main approaches. The <u>first</u> method is a one-step total integration process, while the <u>second</u> has multiple stages in which partial integration is carried out between levels before proceeding to the next level.

Method 1.) The plan or plans of each level produced by the relevant

specialists are superimposed. From this would emerge a plan representing the areas where the greatest concentration of superimposed lines occur. The resultant plan would be evaluated by all the participants (specialists; planners and population) for conformity to each participants particular level's requirements. A process of consultation and negotiation would be carried out to arrive at a consensus on the plan or a modified version of the plan.

Method 2.) The plan at each level is synthesized with that of the following level by the identification of conflicts and their resolution through consultation and negotiation. A new plan is produced which is the synthesis of the requirements of both levels. The following level is then synthesized with the composite plan of the previous levels and the synthesis through consultation and negotiation continues. This process repeats until the final level is synthesized. The final plan is therefore not only the product of all the sequentially synthesized composite plans, but due to the process of consultation and negotiation, the plans could take directions other than those indicated by simply identifying conflicts. It should be noted that each level that involves more than one set of requirements would arrive at only one plan for that level through the same conflict-identification synthesis process applied internally within the level.

Town planning in general does include some aspects of the proposed first, second and fourth levels. However, the third level, that of the climatic factors, is all too often treated in a summary and superficial manner. The historical description of arctic settlements poignantly illustrates this deficiency. For example, Hellers observes that economy is the major criterion in the town planning design process which results in a tendency to state climatic factors in economic terms as well (1972, p. 31-1). Taesler noted that "...with the exception of air pollution control, very little if any serious attention is paid to local or urban climatic conditions..." (1972, p. 69-1). A good example of this attitude is McHarg's study of the metropolitan region of Philadelphia which identified air pollution, linked to temperature inversion, as the major climatic influence on design, with high summer heat and humidity as secondary climatic

concerns (1969, p. 64). His Staten Island study considers only the climatic data related to hurricanes and the resultant inundation as important (1969, p. 105). This minimal concern with climate has been due in part to the lack of systematic research into the town planning-climate relationship and any comprehensive climatic method related to settlement design (Givoni, 1972, p. 18-2).

However, climatic factors in the design of buildings and cities have been at times of basic concern to man with early examples found in the remains of the Egyptian town of Kahan in 2000 B.C., and in China during the Chou dynasty. In Greece, Aristotle and Xenophon established planning principles related to climate, while the Roman Vitruvius wrote briefly about climatic considerations in planning, although he devoted more space to climatic influences on man's physiological makeup than to planning (Vitruvius, 1968, pp. 24-26 and 170-174).

In the late 1560's, South American Spanish towns were laid out according to laws which indicated that certain climatic factors had to be respected (Aynsley, Melbourne and Vickery, 1977, pp. 1-7). The industrial revolution diminished the concern with climate (Ryd, 1973, p. 55), because the process of urbanization was more concerned with proximity to natural resources, energy sources and transportation routes. However, in the late 1800's laws were passed in Germany and Sweden requiring natural light in buildings and more recently the plans of Chandigarh in India, towns in New Jersey, Corcula in Dalmatia, Kitimat in Canada and Medellin in Columbia - all considered wind flow around buildings in their layout (Aynsley, Melbourne and Vickers, 1977, pp. 9-11; and Aronin, 1953, pp. 211 - 221). However, in all these examples the integration of climatic factors into the design process seemed to be subordinate to economic and social concerns.

Of the methods proposed for designing with climate, Olgyay's is the most well known. Unfortunately, the method is more oriented to the design of buildings than town planning (1963, pp. 12-13). Some procedures in the method are based on the use of subjective values as well as climatic data. For example, in order to arrive at his synoptic orientation chart in relation to sun and wind, average wind velocity and frequency are calculated

for peak winter and summer months and with wind thermal coefficients for summer based on subjective categories (hot, warm, medium, cool, cold), are entered into an equation which gives the net yearly wind score. Solar orientation is then scored according to a scale ranging from -100 for a North orientation; 0 for Northeast; +50 for East; +100 for Southeast and South; +50 for Southwest; 0 for West; to -50 for Northwest, which is then combined with the wind score on a synoptic chart. Best orientation for sun and wind is calculated graphically by a line perpendicular to the middle of the permissable range of orientation, and the resultant optimum orientation is midway between the two orientations (Olgyay, 1963, pp. 95-97). The wind score is modified by an importance factor which gives more weight to the sun score than to wind, but which is once again a subjective value.

A more detailed procedure for calculating the temperature and radiation effects is described by Olgyay under the title of the "sol-air approach". It requires the plotting of total radiation and radiation during the under and over-heated periods on axial charts for the various cardinal directions, and the finding of the angle of maximum radiation value, measured from the nearest major cardinal point. If there is a difference in the two angles, it is divided in a ratio favouring an adjustment away from the overheated towards the underheated zones (1963, pp. 54-61). Thus he presents two different ways of determining solar orientation, one very detailed and the other more general and subjective. In the overall method the "sol-air approach" seems to be the major evaluation tool for the solar radiation and temperature impact, while the wind is evaluated separately in terms of need for protection and need for ventilation (1963, pp. 12-13).

The method is judged by this author as far too complex and does not seem to have a systematic linear step-by-step approach to the analysis of climatic data, to their evaluation and to the formulation of design criteria. The manner in which the evaluated data is presented does not facilitate the use of it by the designer when planning community layouts. The analysis made by Olgyay for community layouts (pp. 153-177) seems more readily carried out from data presented in tabular and textual form than

from the elaborate graphical means he uses for house design. The proposed design solutions in the housing layout are qualitative in nature and could have been duplicated by a sensitive designer without going through the very complex and time-consuming procedure.

The shelter design aspect of the solutions are a little more quantitative in nature, but with the exception of form, volume and orientation considerations, could have been arrived at without the elaborate calculations required by the method. His proposed solution for the cool region demonstrates the lack of quantitative guidelines for street widths and house spacing in relation to solar shading, and also the distances behind windbreaks at which wind reduction speeds of acceptable comfort levels are attained (pp. 155-159). The notion of outdoor comfort is generally left rather vague and ambigious. Olgyay's 'bioclimatic chart' (pp. 17-26) for comfort does not concern itself with freezing and below freezing temperatures and is therefore not of much use in describing possible comfort conditions as well as not considering the effect of clothing, being mainly concerned with hot climates.

Givoni has also formulated a design approach based on climatic factors applicable to hot countries, but as it is mainly concerned with indoor comfort conditions, it is therefore directed to building design rather than settlement design. Most of the design solutions presented are of a qualitative nature based on quantitative notions (1976, pp. 340-372). This method does not demonstrate a systematic approach to design, but rather a series of conclusions drawn from his 'building bioclimatic chart' (a modified psychrometric chart) which have to be elaborated according to the various principles involved such as natural ventilation, and thermal properties of materials (pp. 314-339).

A design method that is interesting in its systematic procedure is one proposed by Koenigsberger, Mahoney and Evans for the design of low-cost housing and community facilities. This divides the design process into the sketch design stage; the plan development stage; and the element design stage.

In the sketch design stage, the designer organizes the air temperature, humidity, and rain and wind data into 'Mahoney tables'. He then establishes

comfort levels for night and day based on relative humidity groups and annual mean temperature. The humidity group number, the mean maximum, mean minimum, and the day and night comfort temperatures are then entered for each month in a diagnosis table. Thermal stress is evaluated for day and night conditions for each month according to whether the temperature is above, below, or within the comfort limits, represented by the symbols H, C, and O, (respectively hot, cold and comfortable). A table of humid and arid indicators is completed with appropriate data which indicates whether air movement is essential or just desirable; whether rain protection is needed; whether thermal storage is required; if outdoor sleeping is needed, and whether there are cold season problems. The next table presents sketch design recommendations based on the number of indicator groups present in each category. These recommendations vary from general layout suggestions such as "buildings oriented on east-west axis to reduce exposure to sun" and "compact courtyard planning"; building spacing; air movement; openings; walls; roofs; outdoor sleeping; and rain protection recommendations (Koenigsberger, Mahoney and Evans, 1971, pp. 23-31).

In the plan development stage, activity patterns are analysed and compared to daily temperature fluctuations with the day and night comfort zones overlaid. The plan can then be laid out to provide comfort for the periods when the space is occupied. Unlike the previous stage, this one is mainly analytical and does not propose solutions or recommendations, although the chapter devoted to this stage does give many examples of plans and sections as well as general "design tools" for open spaces for various types of climate (Koenigsberger, Mahoney and Evans, 1971, pp. 43-58).

The element design stage employs the same type of table for design recommendations as the previous stage, and uses the same indicator groups and totals. The element design recommendations range from the size, position and protection of openings; to walls, floors, roofs and external surface treatment (1971, pp. 59-65). See also Koenigsberger, Ingersoll, Mayhew and Szokolay for a slightly expanded version of the same method (1974, pp. 237-265).

The method is interesting because of the way it uses the climatic data,

requiring little transformation to establish comfort limits, thermal stress indicators, and design recommendations. The passage from indicators to recommendations is direct, but the recommendations are a little too general for detailed planning, although they are sufficiently orientative for the sketch design stage. The detailed studies would have to use quantitative and environmental simulation techniques to arrive at more precise layout recommendations. It would have been useful to have more quantitative recommendations at this level with regard to height and spacing for solar shading and air movement for natural ventilation. For settlement design, the notion of outdoor comfort should be related to the combination of physical activity, air movement, and solar radiation to be of any real value. The method is interesting because of its simple and straightforward procedure, but it is related more to the provision of indoor comfort conditions, as well as having been formulated for hot countries. A method which is more comprehensive in relation to activity, clo values, solar radiation and wind velocity and adapted to arctic climatic conditions would be of great use especially in the design of settlements.

Ralph Knowles, in his Owens Valley study developed an ecological method which includes climatic factors in an integrative procedure (1974). He defines what he calls "stress domains" which include ambient air temperature, incident energy, precipitation, and mountain-valley lateral-thermal winds as well as geology, surface water, ground water and topography (p. 64, 65). Knowles assigns stress values to each domain ranging from one to three for maximum variation of the stress. For example, the maximum variation of incident energy over a single interval has a stress value of one, and ground water has cyclic variations in the height of the water table which occurs at one and 30-year intervals and varies daily due to evaporation resulting in a stress value of 3. There seems to be a high degree of subjective evaluation at this level. A further analysis of the valley produces an upper and lower limit of the surface to volume ratio (S/V) for a building based on a unit cube of 6.25 feet, which is the smallest useful building increment achieved by dividing the smallest land increment of 100 feet. The largest building increment is 400 feet

and is related to the largest flat land increment (3,200 feet) on the valley floor (pp. 68,69).

Knowles then establishes solar shading limits in relation to slope and orientation for the four cardinal directions and in slopes of 2.5; 5; 10; 15; and 30°. He arrives at height to area ratio (H/A) which establishes the maximum height of construction that can be built on a site so that it does not cast a shadow on adjacent sites (Knowles, 1974, pp. 71-76). He then divides the land into increments according to the maximum dimensions allowed by the H/A ratio from the slope-orientation stress domain (pp. 77-80). Network analysis is used to establish a set of values which indicate the degree of optimization required for a site depending on the vector values obtained which is used to set out the acceptable range of S/V values (pp. 86-102). This is done for the slope-orientation construct to establish the range of H/A values acceptable for the site.

At the organizational level, sites can be selected for more detailed study according to the surface to volume (S/V) range, the height to area (H/A) range, and the ratio of the incident solar energy at the winter solstice to the incident solar energy at the summer solstice (E_W/E_S). The increment of development involving one or several buildings must, in combination with S/V and H/A values give a ratio of $E_W/E_S = 1.0$. If this ratio for insolation is not achieved, this "...will be considered grounds for not building" (p. 115). Knowles then gives a case study example which illustrates the possible subdivision of a site by dividing the original H/A pyramid into smaller pyramids with the same H/A ratio. He analyses the modification of the E_W/E_S ratio according to the number of pyramids or facets added to the original volume which thereby allow an unacceptable ratio to be transformed into one that is acceptable (pp. 140, 141, 160-164). Various increments of densification are explored with their corresponsing range of S/V and E_W/E_S values, which illustratas the latitude of the possible building volume diversification while respecting an acceptable range of S/V and E_W/E_S values (pp. 176-186).

This method has been developed as an ecological approach to planning by integrating climatic, geological and hydrological factors in the development

of his main design control tool, (the S/V, H/A and E_w/E_s ratios). This author feels that this method is far too complex to be of use to designers and planners at the scale of the design of a settlement. The amount of time that would be involved in the determination of the values of the points and joining lines in the network analysis system employed, and the optimization procedures described before arriving at the very useful control tools (S/V, H/A, E_w/E_s), seems to be exaggerated for the degree of real accuracy that would be achieved in a procedure that has many subjectively weighted values at various stages. The author feels that a simpler manner of arriving at the same control tools would be far more realistic. McHarg also integrates social values in his method, which is lacking in Knowle's work. Nevertheless, the treatment of the climatic factors in Knowle's design approach is noteworthy, even though it needs simplification in order to be of practical use.

Arens (1972) proposed a design method which integrates climatic factors and comfort notions in a systematic manner. His eleven-step procedure begins with the identification of design parameters; independent and dependent variables; the relationships among parameters and variables; the prediction of independent variable values; the identification of constraints governing dependent variables and design parameters; the identification of values of design parameters and of expected values of dependent variables; the investigation of the consistency of values; relationships and constraints; and finally the comparison of and selection from alternative sets of parameter values (pp. IV-84 to IV-88). These eleven steps are described for 2 processes: 1.) "...making a site climate from ambient climate and physical planning" (the design process), and 2.) "...determining comfort from the site climate" (comfort criteria), (p. IV-84). The method requires a detailed case study to verify the need for eleven steps.

Arens actual case study as presented in the text does not illustrate every step of his eleven-step procedure. The analysis process is graphically represented on a plan of the case study site and gives a good visual indication of the climatic conditions, while the wind-flow direction and wind-strength contours also present a clear picture of the wind

conditions. The shade diagrams given for two different times of day along with the contour lines representing the degree of shading time averaged over the complete day is useful when combined with the wind conditions. Arens employs comfort curves for sun and shade using average seasonal wind speeds and temperatures, adopting a typical clo value for clothing and the season of year considered, thereby establishing the discomfort zones along the pedestrian path (see Figs. 13a and b, pp. IV-89 to IV-91). The case study does not illustrate all of the eleven stages of the proposed design procedure and the choice of climatic data is based only on average conditions, when data for extreme conditions should be used as well in order to establish the range of comfort. When designing for cold climates, it is important to know whether a pedestrian zone has any areas of comfort under extreme temperature and wind conditions.

The procedure described by Arens is of interest but needs further development. Arens was more concerned with the relation of building performance to climate, rather than outdoor comfort, the latter aspect being of major interest to northern planners. Also by using existing buildings in his case study, Arens does not illustrate clearly how his procedure can be utilized as a design tool in the planning of new settlements.

The various design methods referred to above, all have some drawbacks or disadvantages such as the lack of radiation and wind speed data in the comfort tables developed by Mahoney, and the general lack of concern for outdoor comfort as seen in Givoni's and Arens' procedures. Therefore, this author felt the need to develop a design procedure that would permit architects and planners to integrate climatic factors into the design process in a manner that would not require large amounts of time and complex data computations, while still retaining a level of precision that would be acceptable for preliminary planning needs.

The preliminary planning stage of settlement design requires a sufficient degree of precision so that major design decisions can be taken without the danger of committing serious errors. For example, in relation to climatic conditions, such as solar shading, wind flow and velocity and snow accummulation, an error will not usually result in the total

malfunctioning of the settlement design. An error in the solar shading requirements may result in a certain degree of discomfort with regard to this phenomenon, but does not necessarily affect comfort in relation to wind flow and velocity and snow accummulation. In extreme arctic or antarctic locations, unfavourable solar shading conditions could result in the impossibility of melting snow deposits near buildings which could eventually result in structural damage (Melbourne and Styles, 1967), but at latitude 65°N this is unlikely.

With regard to wind flow and velocity, an error in relation to this factor could result in structural failure or even in destruction of the building, but it is assumed that during the initial site selection, sites with dangerous wind conditions and wind exposure would be eliminated, or if this was impossible, structural stability and superior wind resistance would be built into the buildings. Therefore, an error in the comfort aspects of this factor would not necessarily adversely affect the village. This factor, however, is also related to snow accumulation and any inaccuracy in the determination of wind-flow patterns and velocity could result in large snow deposits, preventing easy circulation and possibly causing structural damage to buildings. However, excessive snow accumulation in roadways can always be removed, and buildings could be designed to minimize snow accumulation on roofs, or roofs could be constructed to resist even heavier snow loads, thereby minimizing the level of precision needed in the prediction of wind and snow conditions, but the costs involved could be egregious.

There is also the paradox that in zones where wind speed is reduced and where comfort conditions are likely to be met, these are also zones where major snow accumulations would occur (Schneider, 1962, p. 14; Mellor, 1965, pp. 22, 24). This indicates a possible conflict between the wind and snow requirements in relation to comfort and thus an error in the consideration of wind factors may not negatively effect snow-drifting. However, there is a point where some of the requirements must be met through design solutions, otherwise the town layout would have so few advantages that there would be no point in building it.

Therefore, climatic simulation devices are needed that would give

reasonably accurate predictions of the performance of a particular layout so that various alternatives may be rapidly explored. The time frame for the preliminary design stage in relation to the total design process, is often quite short and therefore any simulation procedure must be expeditious, a factor which could result in a lower level of precision. As has been pointed out above, achieving a high level of accuracy would not necessarily create serious problems, therefore not justifying the use of expensive, precise and long simulation procedures. Therefore, simpler simulation procedures which architects could use without specializing in this field should be acceptable. This is similar to Jones' second criterion for design project control (1970, p. 57); to the fourth stage of Page's cumulative strategy which states that "tests should be no more precise than is necessary to discriminate between acceptable and unacceptable solutions" (Jones, 1970, p. 151), and to Popper's statement that "...there is no point in trying to be more precise than our problem demands" (1963, p. 28).

The design approach or model proposed by the author has similarities to other methods, especially in its process of diversifying the number of solutions. For example, one of the more promising approaches of the synthesis of the divergence-convergence procedure is that of Dewey which includes a stage involving the cultivation of a "variety of alternative suggestions" (Broadbent, 1973, pp. 178-180). In the author's model, this divergence is achieved through having specialists at four different levels produce plans or layouts based on the criteria or requirements of their area of specialisation. The author's proposed model also includes the aspect of many people "...working simultaneously in parallel" which is part of the synthetic group approach to design, but also includes the face-to-face group approach for the final evaluation of ideas (Broadbent, 1974, pp. 356-357). The author's approach also has some similarities to Page's Cumulative Strategy. The identification of aims or objectives, the determination of external factors that would prevent the attainment of the aims, and the definition of the criteria or requirements to identify unacceptable solutions (Page's first 3 stages) are carried out simultaneously in the author's four-level model by each specialist group. Tests

by means of the formulation of plans are proposed which fulfill the criteria or requirements of each level or sub-level which is similar to Page's fourth stage in his cumulative strategy.

The present author's model does not deal with individual solutions for each criterion or requirement, but rather proposes a solution for a group or category of requirements, thus stages 5 and 6 of Page's strategy are not applicable to the model to be proposed. Stage 7 which deals with "design conflicts by seeking ways of combining sub-solutions to eliminate conflicts", is similar to the phase in this author's proposed model where the plans would be combined to eliminate the conflicts and to produce one solution which would satisfy all the major or most important requirements. As Jones observes, Page's strategy "...provides good control over desicion making and is a suitable procedure for the collaboration of specialist designers at the early stages of a large project" (Jones, 1970, pp. 149-155). This author's four-level model provides a procedure which would integrate all the various specialists into a collaborative framework.

The proposed four-level model has also some similarities to the 'system transformation method' described by Jones in which the existing system and its faults are identified; reasons for these faults are ascertained and a search for ways of modifying the system to remove the faults is made. It should be made clear at this point that Jones is describing a method of modifying an existing system, whereas the author's proposed four-level model is concerned with transforming the product (town plans) rather than the system itself. For example, Jones was concerned with finding an "evolutionary pathway that would allow existing components to evolve into the new ones" (Jones, 1970, pp. 316-322).

The author's proposed method also bears some resemblance to the argumentative method of planning (described by Kreimer, Polydorides and Wormhoudt, 1978, p. 166), in that when the specialists present their plans they must also "...defend the explanatory system that guides them in identifying discrepancies and select strategies, as well as stating their expectations regarding the outcome of the specific course of action they are advocating." The argumentative method also requires a "plurality and diversity of

view", a requirement which the four-level model fulfills through the diversity of specialists and the variety of plans thereby generated. Another advantage of this model is that, factual knowledge is not only essential but expanded at each level as conflicts between opposing plans can only be resolved when the proponents of a plan are required to produce factual support for their solutions. This corresponds to the third advantage of the argumentative method. Increased cooperation is the fourth advantage of the method and comes about through the "non-committed" participants' better understanding of the "assumptions, value-systems and possible flaws of the system arrived at. They will be more willing to cooperate in carrying out the decision taken." In the context of the design of arctic settlements, the "non-committed" participants would be those whose plans were modified greatly in the synthesis process. In the past, the Inuit have been the participants who have had to accept plans that they did not necessarily like.

The variety of points of view, according to the argumentative method, "...provides an enriched set of criteria to be applied in the evaluation stage" (Kreimer, Polydorides and Wormhoudt, 1978, pp. 166-168). This would certainly be true in this author's proposed method, because each specialist would develop his criteria or requirements to a more refined level because he would be obliged to test them through the elaboration of a plan.

This diversity of points of view and solutions is part of Popper's description of the "method of trial and error" which if highly developed "begins to take on the characteristic features of scientific method." The method of trial and error requires that 1.) "sufficiently numerous theories (or solutions) should be offered"; 2.) "that the theories (or solutions) should be sufficiently varied"; 3.) "and that sufficiently severe tests (plans in this author's method) should be made. In this way we may ...secure the survival of the fittest theory by the elimination of those which are less fit" (Popper, 1963, p. 313).

The method Popper describes is the basis for understanding the dialectic triad "thesis, antithesis and synthesis". In the dialectic triad, unlike

the trial and error theory, some aspect of a theory put forward is likely to be kept. "This valuable element of the thesis is likely to be brought out more clearly by those who defend the thesis against the attacks of their opponents, the adherents of the antithesis. Thus, the only satisfactory solution of the struggle will be a synthesis ...in which the best points of both thesis and antithesis are preserved" (Popper, 1963, p. 315). In this author's proposed method, antithesis is not necessarily a concientious seeking of opposite solutions to every thesis or primary solution, but rather antithesis occurs naturally by solutions which resolve conflicting requirements such as those of wind protection and snow accumulation.

Problem solving by trial and error results in new problems, which according to Popper's tetradic schema takes the form of $P_1 \longrightarrow TS_1$ to $TS_n \longrightarrow EE \longrightarrow P_2$ where P_1 is the original problem; TS_1 and TS_n are the tentative solutions; EE is error-elimination and P_2 is the second problem which is generally different from the first (Popper, 1972, pp. 121, 144, 176, 242, 243, 287-288; and Popper, 1963, pp. 406, 407). The second problem in the context of arctic settlement design could be the emergence of new problems related to climate and to user expectations as these factors have not been considered in depth in previous planning strategies. The proposed design model, therefore hopes to solve most of, if not all of the present problems, but may raise new problems by the very procedure it utilizes. It is hoped that the new problems can be resolved within a modified or transformed version of the model proposed.

The author's proposed model is therefore not patterned after any existing strategy or method, but has stages or sub-procedures that are found in a variety of existing design methods or theories.

2.1 THE FOUR-LEVEL MODEL - REQUIREMENTS

2.1.1 Level One - Geological and Hydrological Requirements

These criteria are related to the topography and the geological nature of the site, the sources of potable water and natural drainage patterns.

The topography of the site can be analysed in terms of its slope. McHarg in "Design with Nature" (1969, p. 144) suggests high compatability between suburban residential and urban construction for slopes of 0 - 5%; high compatibility for suburban residential and medium compatability for urban construction for slopes of 5 - 15%; and medium compatability for surburban and low compatability for urban types for 15 - 25%. (Russian figures for the arctic 2 - 6% is suitable, 6 - 15% is partially suitable - NRC., 1972, p. 95). Since most Inuit villages can be classed as suburban construction, then acceptable slopes would be from 0 - 15%.

The geographical aspects of the site include an analysis of the soil and rock composition to determine suitability for foundations. For instance, certain silty soils and clays have poor stability and low resistance to compressive forces while gravelly sand, stony sandy loams and crystalline rocks are good foundation material. (See NRC., 1972, p. 95 for Russian examples of criteria.) Because most of the houses in the north do not have foundations anchored into the soil, gravelly sand and stony sandy loams are suitable foundations, but for larger buildings such as schools, infirmary, stores and garages; foundations on rock would be advisable. If housing in the arctic moves away from single detached houses to grouped housing such as duplexes, triplexes and even perhaps a limited form of terrace housing and apartment blocks, more permanent foundations on rock would be appropriate. This type of housing may permit the use of rocky sites and steeper slopes if the other criteria can be satisfied, thus opening a broader choice for new village sites and expansion zones for existing villages.

Soil erosion is related to slope, soil composition and wind conditions and would be considered within these criteria levels. Erosion is also related

to natural surface drainage systems including rivers, streams and swamps which impose limitations on the use of a site. (NRC., 1972, p. 95 for Russian criteria). Roads should run parallel to the slope of the land to avoid blocking natural water run-off, which could cause flooding, resulting in the destruction of the roadway and foundations uphill from the road blocking the water (Environment Canada, 1979, p. 2-21).

The location of the sources of potable water, their volume and distance from the zones of acceptable slopes and soil composition is of great importance. A potable water source that is available summer and winter in the volume required by the village plays an essential role in the choice of a site. The level of high water in rivers and streams due to melt-water runoff, high and low tide levels and flood lines are also important factors that would be evaluated to determine suitable building sites.

2.1.2 Level Two - Service Infrastructure Requirements

These requirements include two types of service; technical and socio-institutional. The technical services are the distribution of water, heating fuel, electricity, telephone, and the collection of sewage and refuse. The socio-institutional services are comprised of the stores, school, infirmary, government offices, airline offices, church, community hall, radio station and the snowmobile workshop.

The technical services are dependent on the mode of supply and collection adopted. Due to permafrost conditions, the most common means of distribution and collection is by some form of vehicular transport such as tracked vehic which require a road system. The road system depends on the soil conditions, slopes, natural drainage patterns and groundwater conditions. A less common means of distribution and collection, due to its cost, are piped systems. These are usually buried in the earth in heated, insulated pipe casings and rely greatly on suitable soil conditions and slopes, but unlike road systems can be independent of housing layout. Above ground piped systems have been used to minimize the transfer of heat to the permafrost which can cause severe differential movement. These systems have the same disadvantages as road networks plus the

conflicts created where the road and the above ground piped systems meet, requiring the road to pass over the pipe system, or for the pipe system to pass above the road. Either solution for resolving the conflict has disadvantages. Of the underground systems, the single pipe recirculation type has been strongly recommended for the Arctic (Environment Canada, 1979, pp. 2-22 to 2-26). However, the underground piped system has the danger of rupturing because of possible differential movement. Quite often piped systems distribute heat from a central heating plant to several buildings, eliminating the problems of fuel distribution and frozen pipes. This has, of course, the great disadvantage of disrupting all services at once if the pipe breaks.

The telephone and electrical line networks impose restrictions on settlement layout, but less than the water, sewage, refuse and fuel networks. Electrical and telephone lines are more economical if laid out in straight lines with short distances because of the need for pole bracing and transformers. The line may be laid out in an irregular manner if other more important criteria so dictate. Low voltage secondary runs should not be longer then 400' (122m) with transformers at the centre of the load (Lynch, 1971, pp. 184, 185).

The surface distribution network for vehicles and pedestrians must be considered in relation to the socio-institutional infrastructure which affects the pattern of movement of people and goods from the airport and dock to warehouses and the village in general. Goods which enter each year by boat during the short ice-free summer must be brought in by the most direct manner possible to warehouses, stores, oil storage reservoirs, building sites, school, infirmary, etc. The road network is dependant, as previously mentioned, on soil conditions, topography and slope. This indicates a strong relationship between service infrastructure requirements and the geological and hydrological requirements.

The location of the dock and barge landing area (which serve as the entry point to the village for the yearly supply of goods such as houses and construction materials, food, fuel, consumer items, etc.,) is important because the off-loading directly from the boat to the dock requires a deep-sea dock, or if conditions are unsuitable a shallow water dock and

landing beach for barges. The location of a dock to accomodate ocean-going vessels for direct off-loading from ship to dock would require a deep water harbour which is a rarity for most Inuit villages. A beach easily accessible from the water for cargo barges is of prime importance with a permanent or floating dock being secondary. The location of the beach and dock is dependent on water depth at the shore line or slope of the beach, tidal variations (some villages have 14 metre tides), spring flood levels and ice movement along the shore during "break-up".

The airstrip is the major entry point of people into the villages with the exception of some local traffic between villages by boat in summer and by snowmobile in winter. All contact, however, with the "south" and distant villages is by aircraft. Aircraft are also used for the transport of perishable goods and special consumer items not brought in by ships. This same mode of transport is used for export of local goods to the south as well as locally caught fish and game which are shipped from one village where there is an abundance to another where there is a scarcity.

The situation of the airstrip requires a relatively flat, well-drained site with no serious crosswinds or turbulence and should be as near the village as possible to minimize transportation distances. In some villages distances to the airport of 2 to 3 miles have been accepted for summer traffic if shorter distances in winter are possible because the aircraft can land on the ice directly in front of the village. (Every Inuit village is on the edge of a body of water.) Crosswinds and turbulence have to be analysed for both locations.

The location of the fuel depot, generating station, garage, warehouses, store, post office, administrative offices, school, infirmary, church, community centre, airline office, radio station, water station and refuse field would be situated according to the frequency of use and relation to the dock and airport.

The size of the settlement and neighbourhood units or grouping of houses is another aspect at the second level which needs definition. Alexander gives examples of the number of people that define the hierarchical levels in a town. As these figures apply to the North American urban

context they can only give an impression of the range of people involved. His figures are presented here with this note of caution with regard to the arctic context for the Inuit culture.

Alexander defines various levels of social and political entities along with their corresponding population figures. He suggests 5,000 - 10,000 people for a community or small town; 500 - 1,000 people for a neighbourhood[1]; 30 -50 people for house clusters; and 1-15 persons for a family (1977, p. 4). In another study for a Peruvian village, Alexander established an upper limit of 1,500 people and a lower limit of 50 for neighbourhoods (1969, pp. 57 and 59). These figures developed for a different cultural context give an indication how culture can affect the definition of social units.

Doxiadis provides another set of figures for the scale of communities. He suggests 9,000 people for a small town; 1,500 for a neighbourhood; 250 for a small neighbourhood; and 40 persons for a dwelling group (1968, p. 30). There is a general confusion in the use of the terms 'house clusters'; 'neighbourhoods'; and 'dwelling group'; but by the degree of agreement in the various authors' figures (30-50; 50; and 40 persons) it would seem they were intended to designate the same type of social unit.

Lynch adds to the confusion of the definition of the size and meaning of a neighbourhood. He states in an early work that 'true' neighbourhoods (ie. "areas within which people are on friendly terms partly because they live close to one another") range from 10 to 40 families in size (Lynch, 1971, p. 321). In the North American context this would be from approximately 35 to 140 people (3.5 people/family - Bigué and Pageau, 1980, p. 80), and in an Inuit context from 60 to 240 persons (6.2 persons/family - Bigué and Pageau, 1980, p. 58). In a more recent work Lynch describes a neighbourhood of the 'very local unit' type ("within which people are acquainted with each other by reason of residential proximity"),

1 It is interesting to note the similarity of the dimension of 300 yards which Alexander proposes as the maximum distance across a neighbourhood containing 400-500 persons (1977, p. 84) and the 300 X 25 yard dimensions of the Inuit settlement containing 21 dwellings and approximately 120 people, that Jenness describes (1922, p. 76).

as containing 15 to 30 households (1981, p. 246), or 53 to 105 persons in the North American context and 90 to 180 persons in the Inuit context. Later on in the same text he gives a figure of 20 to 30 families for a 'social' neighbourhood (ie. "where people are acquainted by reason of living nearby each other"). He then states that "the proper size of the neighbourhood has been widely debated" and suggests a number between 50 and 5,000 people (1981, p. 402).

There does not seem to be, therefore, any criterion for the establishment of the size of a neighbourhood or house cluster. Most arctic villages whose population is predominately Inuit, vary in size from 66-800 people in Arctic Québec (Bigué and Pageau, 1980, p. 57) and from 11 - 1,000 persons in the Northwest Territories (Hamelin, 1979, p. 52), while administrative centres, the white population of which is relatively large (100 whites or more), vary from 800 to 1,100 in Arctic Québec (Bigué and Pageau, ibid.) and from 264 - 3,065 people in the Northwest Territories (Hamelin, ibid). It is evident that according to Alexander's and Doxiadas' upper figure for neighbourhood size, most arctic villages or settlements would be classified as neighbourhoods.

For the determination of the size of an interacting social unit which in the Inuit context would consist of a kin-related group or clan, it would be more appropriate to base the size on historical cultural data. McCartney describing the analysis of 120 Thule winter sites,observes that in the smaller sites they varied from 4.4 to 14 houses while at larger sites the number of houses varied from 12 to 50. On the other hand Taylor (in McCartney, 1980) observes that in general they varied from 6 to 30 houses. McCartney proposes 4 to 5 houses for a Thule winter site arriving at a settlement size of 40 - 50 persons (McCartney, 1980, pp. 525, 526). Hall, in 1865, mentions coming across a village of snowhouses inhabited by 43 Inuit (in Mathiassen, 1927, p. 6). Other authors, notably Mathiassen (1927, 1928), Boas (1974), and Jenness (1922) have observed that traditional snow and stone house groups were generally made up of a minimum of 2 and a maximum of 8 houses, while larger groups of 14 to 32 houses were less common.

Analysing the number of inhabitants in a longhouse, which often made up

the entire village, gives another indication of the size of traditional house groups or social units. Thalbitzer (1979, pp. 11 and 186) gives a figure of 32 and 38 persons to a one-house settlement in east-Greenland, while Schledermann (1976, 27 snd 29) mentions a maximum of 40, and an average of 20 people per longhouse. Williamson noted that traditional Inuit camp groups rarely exceeded 7 to 8 families, while in the Keewatin district specifically, they rarely exceeded 10 - 15 families (1974, p. 41). If we take 7 houses, (a figure between the 6 houses proposed by Taylor and the 8 proposed by Boas, Jenness, Mathiassen and Williamson), it would seem to be a reasonable figure for the smallest social unit. Therefore, this unit would be made up of 43 persons (7 X 6.2 persons per household - Bigué and Pageau, 1980, p. 58), which is coincidentally the same number of persons observed by Hall and close to the figure proposed by Doxiadis for a 'dwelling group'. The author, therefore, proposes the grouping of houses into small kin-related or otherwise determined social groups of 6, 7, or 8 houses.

2.1.3 Level Three - Climatic Requirements

2.1.3.1 Comfort Requirements

The determination of what constitutes the notion of comfort in the arctic context is essential to the elaboration of requirements to counter the adverse effects of climatic conditions. It would be unrealistic to require that people be comfortable regardless of the degree of climatic stress. Climatic conditions being severe in the arctic, suggest the idea of protection or defence, that is, keeping safe by avoiding hypothermia and frostbite. Therefore, outdoor spaces will be evaluated in terms of the degree of comfort they provide and the protection they afford. Another aspect of comfort is related to "psychological well-being" brought about by sunshine (Ne'eman, Cruddock and Hopkinson, 1976, p. 237) and reduced wind speeds, factors for which criteria are difficult to determine.

2.1.3.1.2 Thermal Comfort

Factors normally considered in thermal comfort are 1.) the air dry bulb temperature; 2.) relative humidity; 3.) temperature of the skin; 4.) radiant

temperature of surrounding surfaces; 5.) velocity of air movement; 6.) amount and type of clothing worn; 7.) amount of physical activity and the degree of acclimatization to climatic conditions (Univ. of Mich., 1965, p. 96).

1.) Air dry bulb temperature - This study will use average daily, average maximum daily and average minimum daily temperatures for four months representing the four seasons. The temperatures for the coldest month (February), the warmest month (July), and the transitional months (May and October) are used. See table 7 below (taken from table 1 in section 1.2.2).

Table 7. Seasonal Temperatures - Lat. 65°N

	Feb.	May	July	Oct.
Average mean daily temperature	-29°C	-7°C	7°C	-8°C
Average max. daily temperature	-25°C	-3°C	11°C	-5°C
Average min. daily temperature	-33°C	-10°C	3°C	-10°C

2.) Relative humidity - Although absolute humidity is low, Steadman states that in regions with low temperatures, the effects of wind and temperature dominate those of humidity and solar radiation (1971, p. 674; see also Arens, 1972, pp. AII 1:1 and 1:2). Thus, relative humidity does not enter into the wind chill calculations and thereby is not included in the calculation of the clo values required to maintain thermal comfort (see Auliciems, de Frietas and Hare, 1973, pp. 8-0). In a study carried out in the U.K. under summer conditions, Humphreys noted that the choice of clothes to be worn was not influenced by humidity (1977, p. 140). It has also been indicated that discrimination between 30 and 70% relative humidity can be made at temperatures near freezing. However, this discrimination increases with higher temperatures (Sargent and Tromp, 1964, p. 28). Therefore, the author eliminates relative humidity from comfort considerations because of its minor importance at the low temperatures of the arctic.

3.) Temperature of the skin - This factor will also be eliminated because of the difficulty of correlating skin temperature with that of the

ambient air. However, Steadman has included values for skin temperature in his calculations of clothing thickness related to comfort (1971, pp. 676 and 679). On the other hand, Auliciems et al. do not use skin temperature directly in their calculation of clo values (1973, pp. 8-9). Brown and Page point out that the skin temperature of the hand is higher for Inuit than for Caucasians (1969, pp. 175-176) indicating that there are cultural differences in skin temperature.

4.) Radiant temperature of surrounding surfaces - This factor will be excluded because of the low radiation values in winter (see table 6 in section 1.2.5.4) and the frequent high winds at latitudes of 55°N and higher.

5.) Velocity of air movement - This factor is one of the most important in comfort considerations because the amount of heat carried away from the skin is directly proportional to the square root of the wind speed and the temperature gradient between the skin and the air (Sargent and Tromp, 1964, p. 28).

The wind chill index which integrates the dry bulb temperature and wind velocity gives a relatively good indication of comfort concerning these two parameters, and because it is valid only at temperatures at freezing and lower (Siple and Passel, 1945, pp. 177-179), it will be used for the winter (Feb.) and the two transitional months (May and Oct.).

Wyon has pointed out that the wind chill index is not reliable because it considers the cooling of exposed flesh and not the whole body exposure, nor does it consider clothing and activity levels (1974, p. 24). Steadman's modification of the wind chill index is quite comprehensive, taking into account as it does, dimensions of the average person (surface area and diameter), resistance of clothing, skin temperatures, activity, heat loss through lungs, wind speed, effective wind speed for moving persons and a precision of the amount of clothing resistance for hands, feet and leaving the face uncovered (1971, pp. 675 - 678). Steadman takes the radiant temperature of the surroundings to be equal to the air temperature, supporting this author's decision to ignore this factor. However, he does note the effects of solar radiation in a very general manner when he observes that "full sunshine" will raise the ambient temperature

approximately 14°C in calm periods and approximately 7°C in strong wind (1971, p. 682). The temperatures given are for a clothing thickness of 1 cm. and a direct insolation value of of 240 cal m^{-2} sec^{-1} which is the average value at all but very high altitudes. It would have seemed a natural extension of the parameters in his modified wind chill index to have included the effect of solar radiation.

Steadman's nomograms give clothing thickness in mm. related to temperature and wind-speed and wind-chill isopleths in cal m^{-2} sec^{-1}. This manner of presenting the data is not very meaningful for designers and planners. As Maravelias observes, there is a need for climatic descriptors that are more qualitative in nature than the conventional climatic descriptors and which require a semantic dimension (1978, pp. 52, 190, 193).

Monteith describes a temperature/heat-flux diagram which integrates temperature, wind and solar radiation using a graphical analysis technique to solve the heat balance equation of natural surfaces (1973, pp. 162-170). He gives an example applied to man, based on a study by Chrenko and Pugh in the Antarctic, which illustrates the temperature gradient from the outside air through a sweater to the skin for the side in sun and the side in shade. The information is not in a form useable by designers because no comfort criteria are established.

The work by Penwarden presents an excellent method for relating wind, temperature, solar radiation and clo values to comfort. He gives comfort curves for strolling in sunshine and shade generated by an equation that integrates the body core temperature T_b; air temperature T_a; metabolic rate of heat dissipated by means other than evaporation k; thermal resistance of body tissues R_b; thermal resistance of clothing R_c; solar heat input per square metre of body surface S; and wind speed u. The equation is:

$$T_b - T_a = \frac{M}{A_{Du}} R_b + k \frac{M}{A_{Du}} R_c + k \frac{M}{A_{Du}} + S \quad 4.2 + 13_u^{0.5} \quad -1$$

(Penwarden, 1973, pp. 263-266 and Penwarden and Wise, 1975, p. 41).

However, Penwarden's comfort curves were produced with U.K. data and were only drawn for clo values of 0 - 1.5. Arens generated similar curves using slightly different values with a maximum clo value of 3 (1972,

tables II-17 to II-20), which for a metabolic rate of 150 w/m^2 in full sun is comfortable at -20°C in calm wind conditions. Since the average daily temperature in February is -29°F and the average wind speed in winter is 5.5 m/s, comfort curves with higher clo values are needed as well as with the radiation values appropriate to latitude 65°N.

This author decided to construct comfort curves based on Penwarden's equation and data relevant to latitude 65°N. Appendix II-A contains the calculation of the radiation data for sun and shade conditions. The metabolic rate of heat production chosen is 125 w/m^2 which is the equivalent of the effort in level walking at 0.9 m/s (2mph), which seems a reasonable average figure when considering the variety of ages and the different seasons requiring a difference in effort to maintain the same walking speed. The clo values chosen are extended to 5 which is beyond the maximum suggested by Auliciems, de Freitas and Hare (1973, p. 15) and Sargent and Tromp (1964, p. 26). See Appendix II-B for data used in Penwarden's equation.

The curves produced by this data are given in Appendix II-C for metabolic rates of 125 and 100 w/m^2 (the latter equivalent to strolling or slow walking 0.6 m/s or 1.3 mph was used by Penwarden in his calculations). For a metabolic rate of 125 w/m^2, 4 clo are needed to maintain thermal comfort in February at a temperature of -33°C and a wind speed of 10 m/s, while a metabolic rate of 100 w/m^2 requires clothing with a 5 clo value to maintain comfort at the same temperature and wind speed.

These curves provide the designer with an indication of the severity of the conditions but do not indicate at what level and to what degree protection is needed. The work of Auliciems, de Freitas and Hare which gives a series of "clopleths" superposed on a map of Canada (1973, pp. 18-29) with the maximum clo units necessary to maintain thermal comfort, also has this same limitation (although they do not make a difference between sun and shade conditions, they do give clo values for day and night conditions related to temperature differences). The curves generated by the Penwarden equation, however, do give an indication of the importance of providing areas in sunlight. For the month of February at a metabolic

rate of 125 w/m^2 at a temperature of -25°C and a wind speed of 5.5 m/s, 3.5 clo are needed in the shade which is reduced to almost 3 clo in the sun. For the month of July the clo values are 1 clo for sun and almost 1.5 clo for shade for a temperature of 7°C and a wind speed of 5.3 m/s. Thus the difference between comfort and discomfort is a measure of additional clo. Taking a standard clo value for each season gives a better comparison, but does not reflect reality, as people vary their clo values relative to the climatic conditions. For an interesting study on people's choice of clothes in relation to climatic phenomena see Humphreys, 1977. He observes that man maximizes environmental comfort by "...choosing clothing appropriate to the microclimate (or) by choosing a microclimate appropriate to his clothing." (p. 142).. Without a statistical analysis of what constitutes average clothing for the average person for the various seasons, it would be difficult to propose typical seasonal clo values. Thus the comfort curves in sun and shade are used to support the opinion that shading of public areas and pedestrian paths should be avoided.

However, with regard to the establishing of comfort requirements, the windchill nomogram will be used. This indicates at what wind and temperature conditions exposed flesh will freeze and how long it will take to freeze. See section 2.1.3.3.

Wind pressure on human beings can cause discomfort when snow, hail, rain or dust are present in the wind. The frequency of occurrence of these phenomena when wind is blowing, is difficult data to obtain from meteorological stations and will not be considered. The effort encountered by people walking in strong winds has been compared to the equivalent effort in climbing slopes (Penwarden, 1973, p. 262), but wind speed related to comfort will be based on Davenport's table of comfort related to wind (1972, pp. 8-4 to 8-6). Difficulty of movement in strong winds will be considered in relation to the values proposed by Hunt, Poulton and Mumford (1976, p. 25).

6.) Amount and type of clothing worn - This factor has already been explained in the factor on wind velocity and has been integrated into the comfort curves constructed using Penwarden's equation.

7.) Amount of physical activity and degree of acclimatization - The amount of physical activity has been selected for Penwarden's equation and is integrated into the comfort curves. The metabolic rate of 125 w/m^2 is the equivalent of level walking at 0.9 m/s (2mph) which should be realistic for the pedestrian paths and for children playing in front of the store and the school.

With regard to the degree of acclimatization, because this study is concerned with the Inuit population, they are considered to be completely acclimatized to the arctic environment. However, there is much conflicting evidence on the adaptation of the Inuit as a race to the arctic environment. Some studies have shown that the Inuit perspire less than Caucasians in areas normally covered by clothing (Schaeffer, Greidanus, Leung and Hildes, 1975), and that at low ambient temperatures they have twice the blood flow and greater skin temperature of the hand than white men (Brown and Page, 1968, pp. 175-176). In contradiction to these studies are the results of other studies and observations which suggest that cultural adaptation is a more important factor in acclimatization and adaptation, than changes in regulating mechanisms (Hinnant, 1964, pp. 38-52; Milan, 1962, p. 315; Washburn, 1963, p. 683), and that non-acclimatized races can develop phenotypic changes similar to the characteristics of inhabitants of extreme climates (Sargent II and Tromp, 1964, pp. 4 and 53; Stefansson, 1913, pp. 75 and 79). It has also been noted that acclimatization to heat has been demonstrated, but not to cold (Mackworth, 1956, p. 20). The evidence seems to point to the Inuit possessing capabilities of resisting the discomfort of lower temperatures, but that they would nevertheless freeze at temperatures similar to those at which Caucasians freeze. Therefore, the wind chill values for freezing flesh will be used in this study. For discomfort due to high wind velocities, the author proposes to use a Beaufort number $\frac{1}{2}$ higher than the Davenport figures adjusted for low temperatures. The Pluram report observes that the majority of the people they interviewed stated that strong winds were not a problem, however, the one person who did consider the wind a problem was the only person below 35 years of age and who had spent some time in the "south", and therefore may represent the younger generation's attitude (Pluram, 1979, pp. 486-490 and 508).

Therefore, the Davenport Beaufort numbers will be used for the space in front of the store and playfround, where younger people tend to gather, but one lower Beaufort number will be used on the pedestrian paths where the older people would be the major age group.

2.1.3.2 Solar Shading Requirements

The difference between comfort in full sun and in shade can be noted from the comfort curves in Appendix II-C. If we take 3.5 clo in February with the typical winter wind of 5.5 m/s, a person would be comfortable (middle line) in full sun at a temperature of -33°C, while in shade the person would be comfortable at -29°C, a difference of 4°C. Steadman suggests that sun can raise the ambient temperature by approximately 7°C in a strong wind and 14°C under calm conditions (1971, p. 682) which if transposed to arctic conditions would seem to support the 4°C difference in temperature indicated by the comfort curves. However, as Steadman (1971, p. 674) observes, at low temperatures, the effects of wind and temperature are more important than those of solar radiation and humidity. Nevertheless, the psychological aspects of climate are important and the imagined comfort in sun, which can be related to a set of expectations, probably dominates the actual physical realities (Arens, 1972, p. II-6).

Support of the psychological reaction to climate is given by a Norwegian study which noted that the minimum comfort temperature in autumn was 11°C, while in spring the minimum temperature for comfort was found to be 9°C (Bjørkto in Culjat, 1975, pp. 73, 74) indicating that a cooler temperature was acceptable in spring than autumn because of the adaptation to the generally lower temperatures that precede the onset of spring. A Swedish study shows the difference in the number of people outdoors on a cloudy and sunny day in February, one day apart, which emphasizes the importance of solar radiation in stimulating people to go outside (Carlestam in Culjat, 1975, pp. 76-77).

From the foregoing studies it is clear that it is important to ensure that the pedestrian paths and public gathering places are not in shade during the principal hours of activity from 9:00 am to 4:00 pm. For the period of May 6 to August 7 (midway between the equinox and the summer solstice)

for a space of 15.2 metres (this is the minimum distance given for a road right of way - Lynch, 1971, p. 140) between buildings 2 storeys (7 metres) facing each other on a north-south axis at latitude 65°N at 12:00, a minimum of approximately 35% of the space is in sunlight. For the autumn equinox at 12:00 this space has just begun to be totally in shade, while on Sept. 14 and 7, 2% and 4% respectively of the space is in sunlight. It is proposed that for the period of May 6 to August 7, that at least 30% of the space between buildings facing each other which form a major pedestrian path must be in the sunlight from 9:00 to 15:00. Any public gathering place or playground must be completely in sunlight during the same hours.

Solar shading becomes less important in winter because of the air temperatures which can vary from a mean daily temperature of -29°C, a mean daily maximum of -25°C, a mean daily minimum of -33°C, to the corresponding values of -18°C, -14°C, and -2°C, for the month of November. (The midpoint between the winter solstice and the equinoxes are November 6 and February 5.) These low temperatures and the low solar altitude make for very uncomfortable conditions in the winter. The solar angle at noon on the winter solstice is 1°30' at latitude 65°N which indicates that there may be approximately one hour of sunlight at this period. On November 6 and February 5 the solar altitude at noon is 13°10'; at 10:00/14:00 is 10°; at 9:00/15:00 is 6°10'; and at 8:00/16:00 is 1°10'; therefore the space never receives sunlight at noon and would have triangular portions of the space lit at 8:00/16:00 and 10:00/14:00 periods in varying percentages depending on the east-west dimension of the buildings. If the spacing east-west between groups of facing buildings is 13.7 metres (the distance suggested to minimize the spread of fires between buildings - unofficial directive from the Department of Indian Affairs and Northern Development), then the space between groups of buildings would have 6% of the area in sunlight at 9:00 to 100% at 12:00, the average being 52% of the area (see Dwgs. 1,2 and 3 in appendix II-D). Therefore, it is proposed that a pedestrian space between buildings should have an average of 50% in sunlight between 9:00 and 12:00 and 12:00 and 15:00 on November 6 and February 5 and that public gathering places or playgrounds be 100% in sunlight during the same hours.

By adhering to these requirements, a certain degree of physical comfort would be assured in summer and psychological comfort in winter. The fulfillment of these requirements would ensure that each building would receive direct solar radiation on at least one facade all day long for the summer, thereby permitting the use of passive solar heat gain and diminishing energy needs in summer. In winter each facade, with the exception of the north, would receive some sun and provide "psychological warmth".

2.1.3.3 Wind Protection Requirements

Many authors and planners have observed that in cold climates the wind is one of the major climatic concerns in planning (Olgyay, 1963, p. 156-159; Givoni, 1972, p. 18-6; Sargent and Tromp, 1964, p. 80; Cooper, 1968, p. 153; Erskine, 1964 and 1968; Egelius, 1977; and N.R.C., 1972, p. 13). However, outdoor comfort in relation to wind is extremely difficult to determine as the variety in proposed comfort limits illustrate. Davenport suggests that for people walking fast at 10°C or warmer, winds of 9.3 m/s (Beaufort number 5) are perceptible, and at 12.4 m/s (B.N.6) are tolerable, but for strolling the velocities drop to 6.7 (B.N.4) and 9.3 m/s (B.N.5), (Davenport, 1972, p. 8-6). Penwarden proposes 5 m/s as the limit for comfort in the wind and 10 m/s as being "definitely unpleasant" (1973, p. 266; Penwarden and Wise, 1975, p. 41). Melbourne suggests an acceptable wind gust speed in pedestrian areas would be 15 m/s if it occurs not more than 1% of the time (in Aynsley, 1974, p. 92). Jackson suggests that "control of walking begins to be impaired" at 8 m/s, at 12 m/s it is "difficult to walk steadily" and at 14 m/s progress is generally impeded and balance in gusts is difficult (1978, p. 257). Arens uses 7 m/s as his "cut-off point" for thermal comfort relationships (1972, p. II 99), while Hunt, Poulton and Mumford propose 6 m/s as the comfort limit in a steady uniform wind, 9 m/s in a non-uniform and gusty winds, with 15 m/s being the limit for ease or control of walking under steady and gusty wind conditions (1976, p. 25). However, they caution that at temperatures below 15°C a wind-chill factor must be introduced (p. 26).

Davenport's wind comfort criteria, as has been stated, was produced for temperatures of 10°C and higher, but he states that the comfort level

would be reduced one Beaufort number for every drop of 20°C if the table was to be used for lower temperatures (1972, p. 8-6). If we reduce the criteria by 1/2 a Beaufort number for summer when average daily temperatures vary from 0 to 7°C, a full Beaufort number for spring and autumn (temperatures of -7 and -8°C) and two Beaufort numbers for winter (-24 to -29°C), the wind criteria would be adapted to the arctic context. If, however, an adjustment is made for the Inuit being acclimatized to the arctic conditions, the author proposes shifting the comfort level upwards 1/2 a Beaufort number which gives:

Table 8. Modified Davenport Comfort Levels in Beaufort numbers (B.N.) and wind velocity in m/s

		Summer	Spring and Autumn	Winter
Walking fast (0.9 m/s)	perceptible B.N. (m/s)	5 (9.3)	4.5 (8.0)	3.5 (5.5)
	tolerable B.N. (m/s)	6 (12.4)	5.5 (10.8)	4.5 (8.0)
Strolling (0.7 m/s)	perceptible B.N. (m/s)	4 (6.7	3.5 (5.5)	2.5 (3.4)
	tolerable B.N. (m/s)	5 (9.3)	4.5 (8.0)	3.5 (5.5)
Standing, sitting for short periods	perceptible B.N. (m/s)	3 (4.4)	2.5 (3.4)	1.5 (1.6)
	tolerable B.N. (m/s)	4 (6.7)	3.5 (5.5)	2.5 (3.4)

The velocities of 5.5 and 8.0 m/s for fast walking in winter are similar to those proposed by Penwarden (1973) and by Jackson (1978), while the summer velocities of 9.3 and 12.4 m/s resemble the limits suggested by Hunt, Poulton and Mumford (1976) and by Jackson (1978). Since the average winter wind velocity is 5.5 m/s it would be probable that according to the modified version of Davenport's comfort criteria, comfort could be achieved most of the time in winter in fast walking situations. The maximum observed hourly wind speed is 29.5 m/s, but as is indicated in the climatic statistics for the Canadian arctic (Dept. of Transport, 1967, p. 8) less than 20% of the winds are of the 8.9 to 13.0 m/s range and less than 10% are stronger than 13.0 m/s. There would therefore be winds of the 29.5 m/s class less than 10% of the time.

Taking into consideration the remarks concerning the need to introduce a

chill factor for temperatures below 15°C (Hunt, Poulton and Mumford, 1976, p. 26), it was decided to compliment the modified Davenport comfort figures with freezing indications contained in a wind-chill nomogram (see Fig. 152).

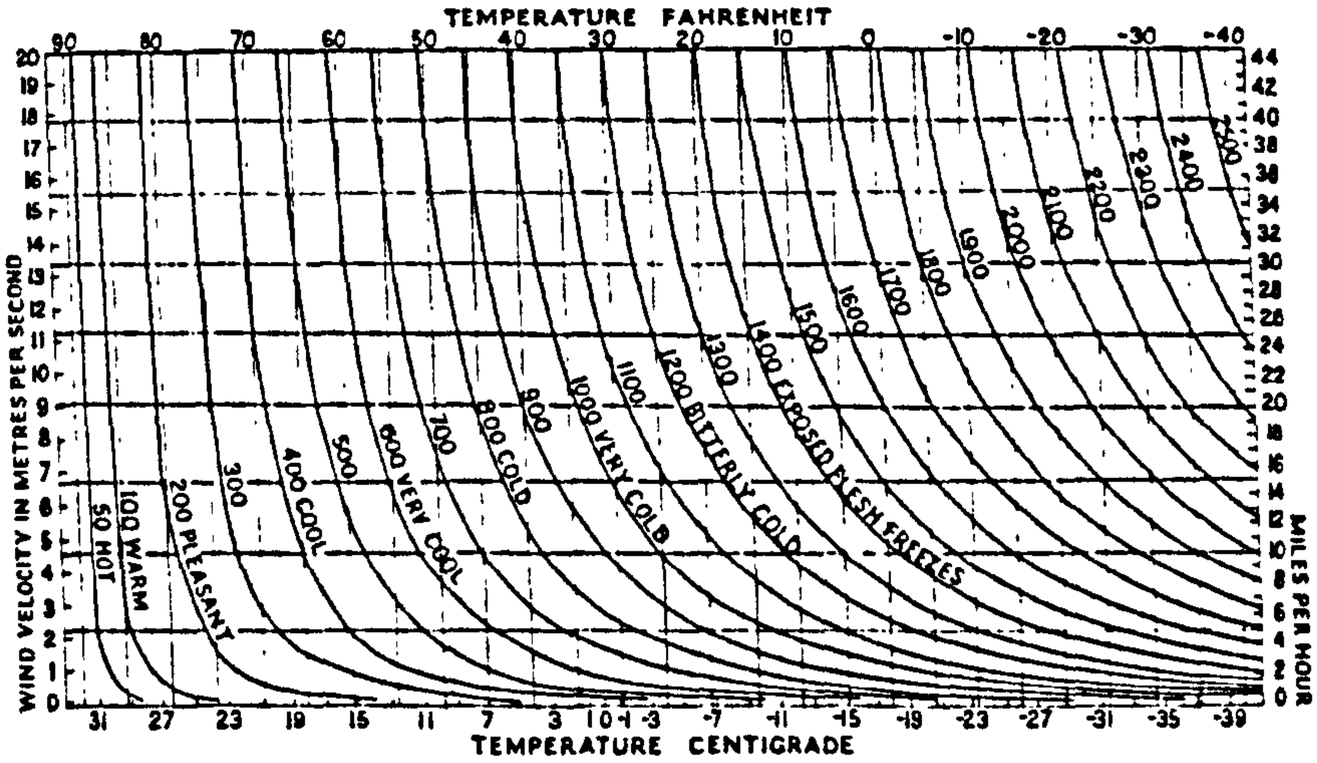


Fig. 152. Wind-chill Nomagram (from Baird, 1964).

Using the 5.3 m/s wind velocity and the average daily temperature range of 0 to 7°C for the summer season and entering these figures on the wind-chill nomogram, the resultant wind-chill values range from 700 to 900 kcal/m^2h which is in the 'cold' range. For spring and autumn, the wind velocities are 5.5 m/s (12.2 mph) and 6.3 m/s (14.0 mph) respectively (see Appendix I-G), and the average daily temperatures are -7 and -8°C giving a wind-chill value in the 1,100 range, which is qualified as between 'very cold' and 'bitterly cold'. In winter, the wind velocity of 5.5 m/s combined with the average daily temperature range of -24 to -29°C, gives a wind-chill value in the range of 1,650 to 1,750 which is well above the 1,400 level where exposed flesh freezes, but lower then the 2,000 level where exposed areas of the face freeze in one minute and travel and life in a temporary shelter becomes dangerous (Sater, 1963, p. 156). A reduction of the wind by 50% would still result in a wind-chill value at the level where exposed flesh freezes. Therefore, a major design effort is needed to reduce the wind-chill values for winter to a point where they are not dangerous.

Arens observes that "...the difference between the relatively immediate temperature sensation and the mean body temperature lag extends to as much as 5 minutes depending on thermal difference" and that "...a designer could expect significant response of vasoconstriction in cold spaces that take more than a minute to traverse" (1972, pp. II-15 and II-16). The wind-chill value for winter is within the 'freezing of exposed flesh' threshold, but below that for the 'freezing of flesh in one minute'. If we use the 5 minute figure, which is the time between immediate temperature sensation and the mean body temperature lag as the length of time it would take for exposed flesh to freeze in winter at lat. 65°N, then this would give an indication of an acceptable maximum pedestrian distance when correlated against walking speeds of 0.9 and 1.33 m/s. The walking distance for flesh to freeze would then be 270 and 399m (0.9 or 1.33 x (5 x 60)) which is near the 250, 300 and 400m distances proposed by the Russians for townsites in climate subzone I (mean January temperature of -13 to -40°C, wind velocity 5 m/s and higher), subzone II (-32 to -48°C and winds 1 to 2 m/s), and subzone III (-24 to -32°C and winds 1 to 3.5 m/s) respectively (N.R.C., 1972, pp. 13, 20, 94, 101). The temperature range for latitude 65°N is from -25 to -32°C with a wind of 5.5 m/s which situates this document's climate in the Russian subzone I, giving some credence to the distances of 270 and 399m. Therefore, it is proposed that at least 50% of all houses in the settlement be within 270m of the store or school and that no house be further than 400m from an indoor public space.

With regard to wind protection, most studies have concerned themselves with agriculture needs, and as a result, much of the wind reduction devices have been vegetative shelter belts and windbreaks. One such study noted that the wind speed behind shelter belts was reduced by 61 to 89% of the undisturbed speed at leeward distances of 0.5 and 5 times the height of the shelterbelt (W.M.O., 1964, p. 7). Another study noted that for a solid wall, the wind is reduced 75% at a distance of 13 times the height of the wall at 0.1 times the wall height above the ground (W.M.O., 1964, p. 11). The studies by Nageli and also by Panfilov (in Caborn, 1957, pp. 10-11) on shelter belts indicate that a 75% reduction of wind speed is achieved at a distance of approximately twice the height of a dense shelter

belt and at a height above the ground of 2.2m (idem. p. 20).

Brooks gives wind reduction values of from 15 - 40% of the free wind speed ie. a reduction of 60 - 85%, at a leeward distance of 3 - 4 times the barrier height and notes that "these ratios appear to be almost constant, irrespective of the height of the windbreak and the strength of the wind" (in Aronin, 1953, p. 190).

Therefore, the figure of 75% reduction of free wind speed seems to be a reliable value, but the distance behind the shelter belt at which this value occurs, varies from 0.5 to 13 times the height of the windbreak. Since most of these studies were concerned with the protection of crops, the height above the ground where the wind reduction is measured is quite low, as in the case of the solid wall mentioned above where the 75% reduction occurs at 0.1 times the wall height. With one and two-storey buildings of 4 and 7m high the 75% reduction would occur at heights above the ground of 0.4 and 0.7m respectively at distances of 52 and 91m from the wall. The study by Nageli seems more useful in work for pedestrian comfort because he gives wind-reduction figures for heights more related to humans. See Fig. 153. For heights of 2.2 and 1.1 m, he observes a

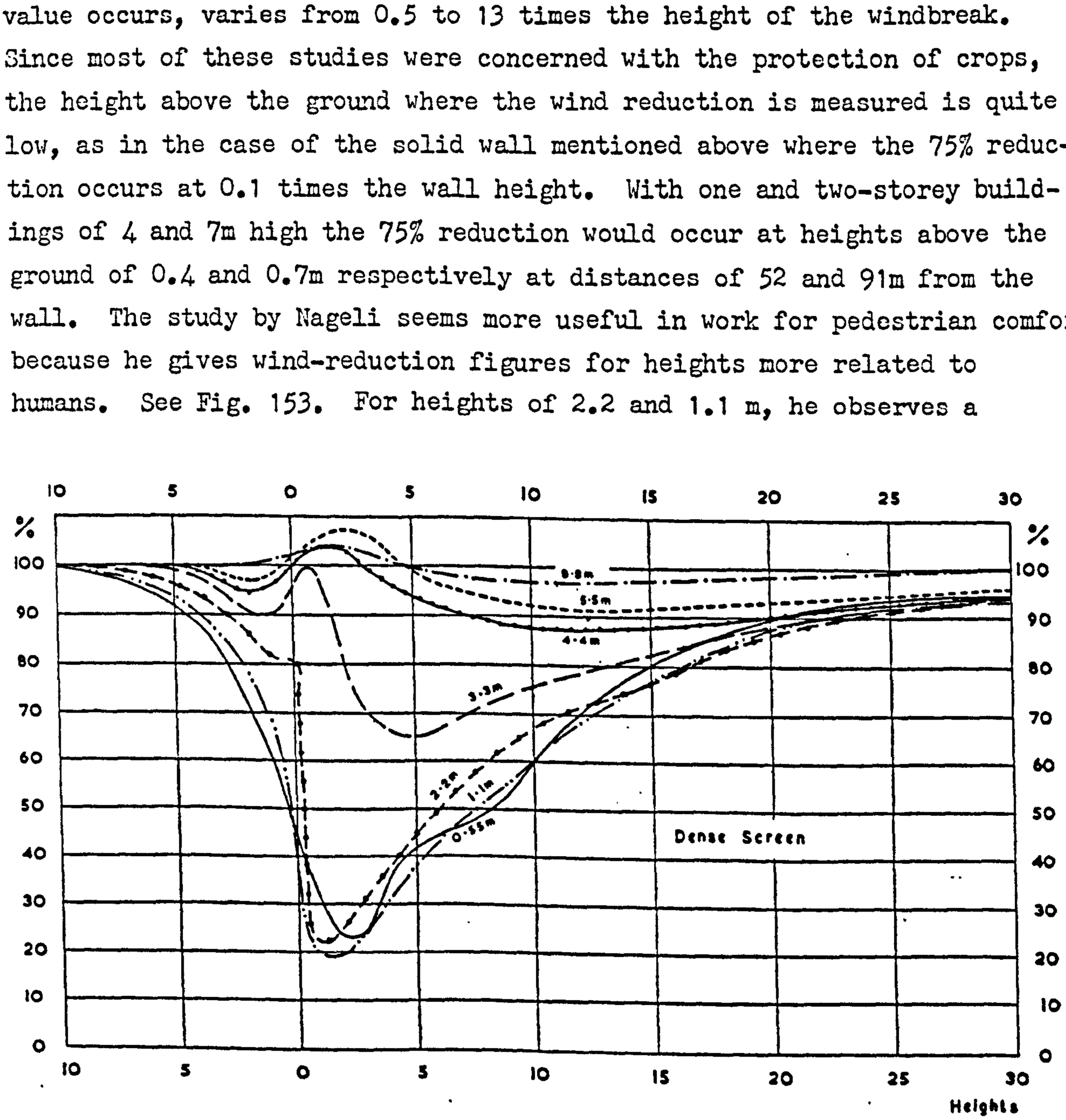


Fig. 153. Wind Reduction in % behind Windbreaks 2.2m in ht. (from Caborn, 1957).

reduction of 25% of the free wind speed at respective distances of 2 and 3 times the windbreak height (in Cabon, 1957, p. 20), which would be 8 and 12m from a one-storey building and 14 and 21m from a two-storey building. It would seem that for leeward distances of 12m for one-storey buildings and 21m for two-storey buildings, wind speeds would be reduced to 25% of the free wind speed.

Evans gives the dimensions of eddy zones to leeward of different building shapes, which give a designer an indication of the zone of influence of different building sizes and shapes which could help in making preliminary choices of building proportions and roof types (1972, pp. 12-1 to 12-13). Unfortunately Evan's work does not give any wind reduction values and therefore cannot be used to determine outdoor comfort distances related to wind.

An interesting study by Smith and Wilson on wind reduction in walled enclosures gives average wind-reduction figures for various enclosure widths, lengths and heights which could be useful in the determination of the size of and degree of wind reduction behind windbreaks and buildings (1977, pp. 223-230). This study presents less wind reduction information than that by Hassan (1974) which gives wind-reduction figures in the form of an 'exposure profile' which is determined from the measurement of wind at four different heights and up to 10 different rows of points in each direction (pp. 234, 306, 307). Hassan's study is very rigorous, but the author found the information presented by Smith and Wilson easier to use at the level of precision required by the proposed planning model.

Although Smith and Wilson's information was generated with scale models of walled enclosures, it is felt that the data will be useful for groupings of buildings that do not form an enclosed area if we use the data generated for width to height (W/H) ratios at a ratio value one lower than actual building dimensions. This should minimize to a certain degree the side wind conditions due to the lack of side walls. For example, if a house has a W/H ratio of 2 (8m/4m), then the author proposes to use the W/H ratio of 1, which for 0^{o} wind orientation should be reasonably accurate. For 30^{o} and 60^{o} wind orientations, 0^{o} wind orientation data should again be used with the reduced W/H ratio value in the zone behind the building in

a direction parallel to the wind, as there are no side walls to modify the wind flow.

In the case of 'protective-wall' type buildings , similar to Erskine's buildings at Fermont and Resolute Bay, the wall enclosure data could be used directly without reducing the W/H ratio because the buildings form a partial enclosure on three sides and the individual houses form a permeable fourth wall. See Figs 154, 155 and 156 for graphs showing the effect of length on average speed for orientations 0°, 30° and 60°.

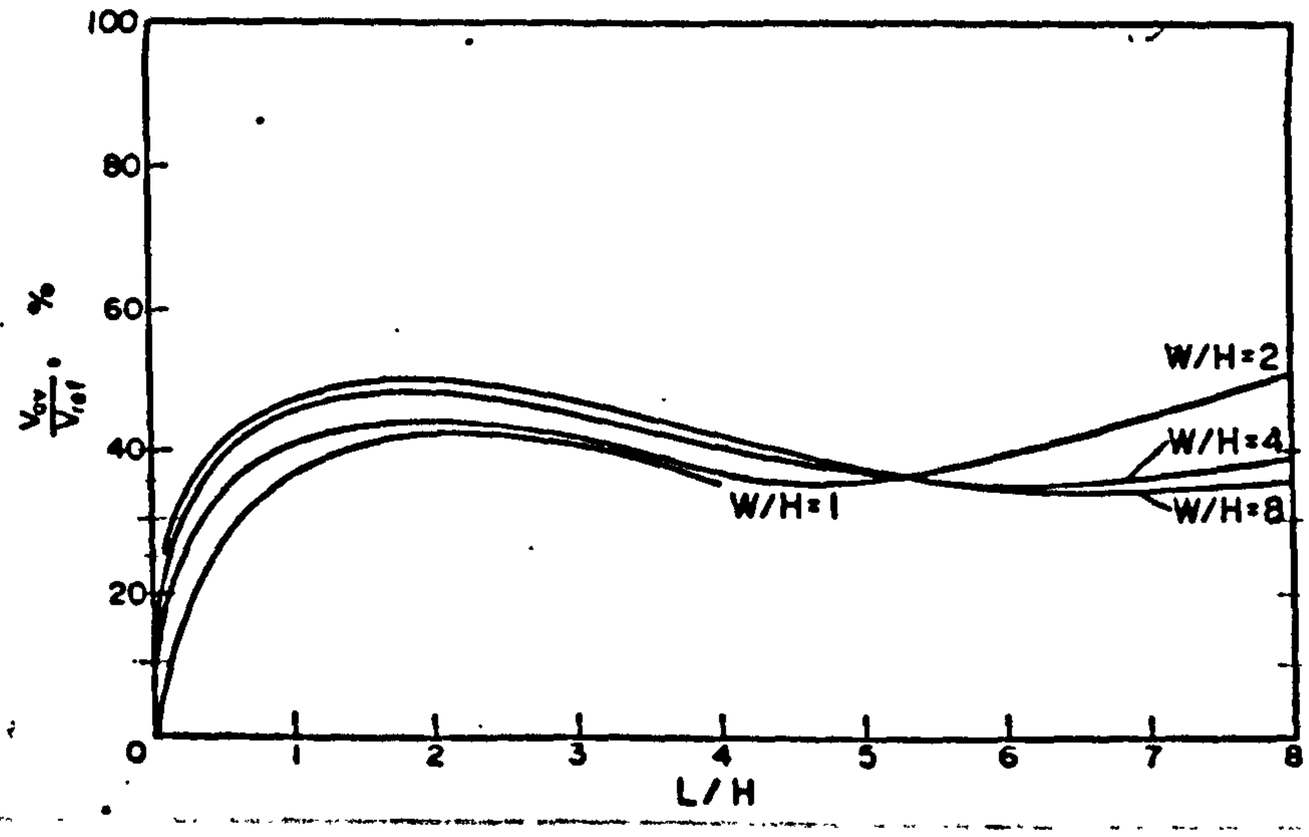


Fig. 154. Effect of length on Average Wind Speeds at 0° orientation for Walled Enclosures (from Smith and Wilson, 1977)

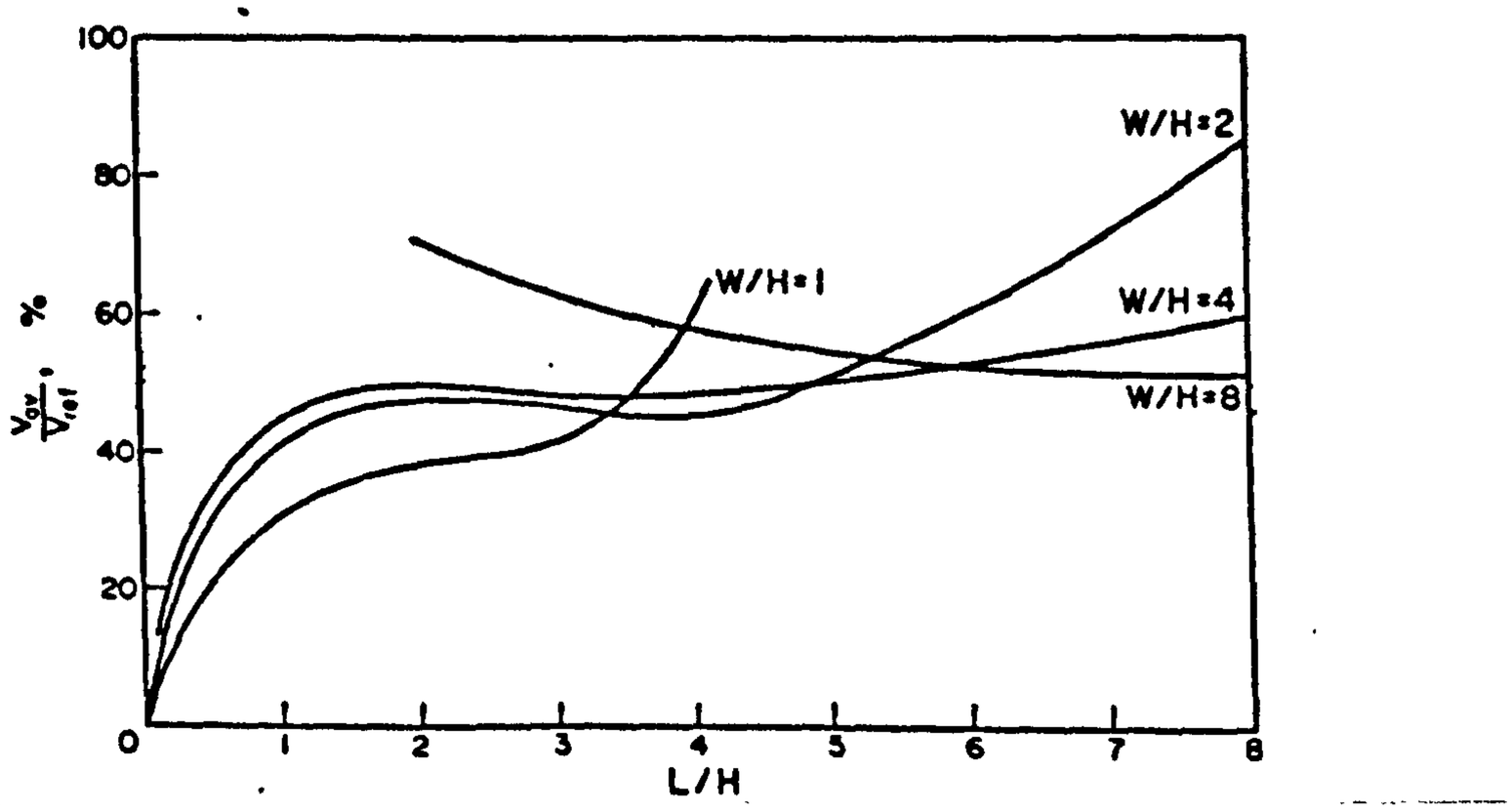


Fig. 155. Effect of length on Average Wind Speeds at 30° orientation for Walled Enclosures (ibid.)

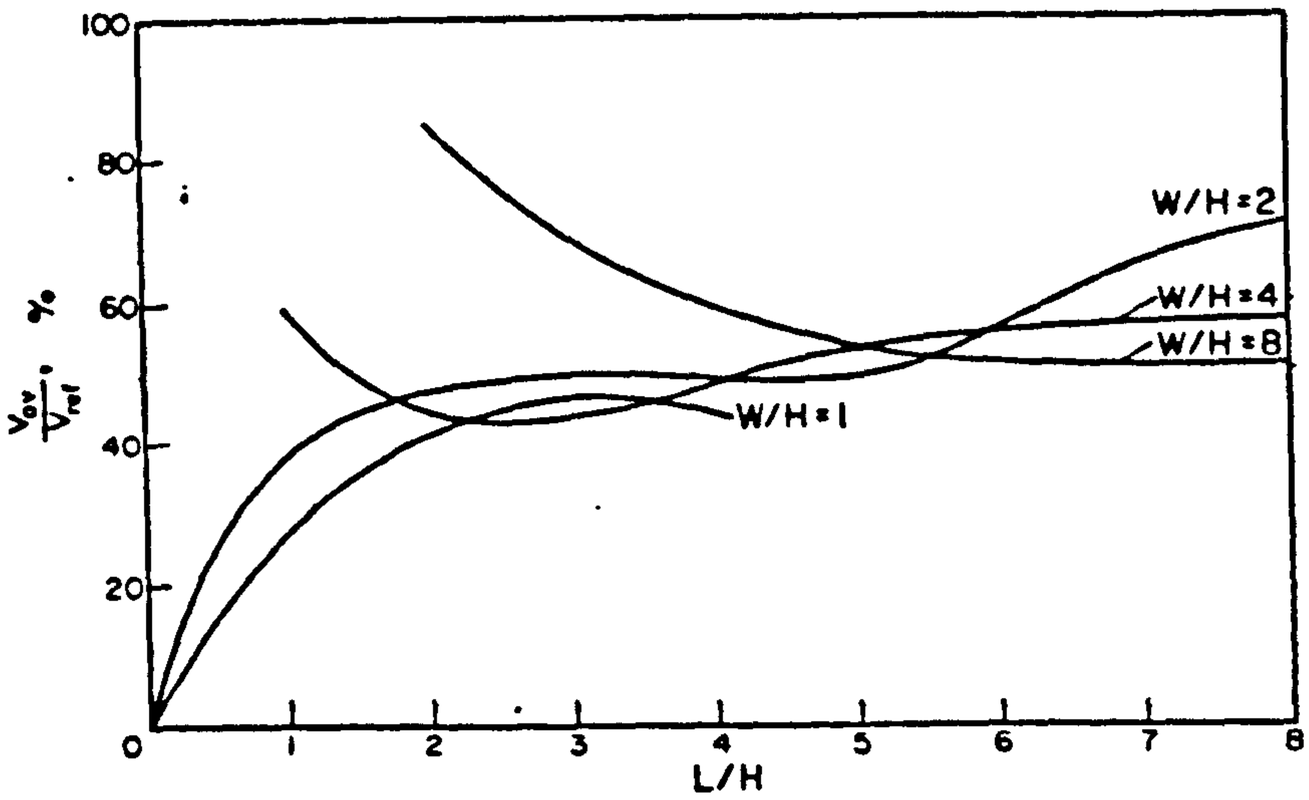


Fig. 156. Effect of length on Average Wind Sppeds at 60° orientation for Walled Enclosures (ibid.)

Using these assumptions, to achieve reduced wind speeds of 25% of free wind speed, the distance between one-storey houses for a W/H ratio of 1 would have to have a length to height (L/H) of 0.5 or 2m which is unrealistic. The next lowest wind speed on the curve is 35% at an L/H ratio of 4 or a distance between buildings of 16m, which is close to the 15.2m distance given for the road right-of-way. For two-storey buildings, of 7m height, to achieve a wind speed of 35% of the free wind speed, the W/H ratio of either 4 or 8 (giving widths of 28 and 56m), could be used at L/H ratios of 6 to 6.5, or distances between buildings of 42 and 45.5m.

Since the reduced wind figures of 25% by Nageli were measured for dense vegetative windbreaks, they cannot accurately represent reduced wind velocity for detached single buildings. The same is true, to a lesser degree for Smith and Wilson's data based on walled enclosures. The author proposes a design reduced wind velocity figure of 30% be accepted behind buildings (half-way between Nageli's 25% and Smith and Wilson's 35%) spaced at a distance between buildings of 14m for detached one-storey buildings, 33m for detached two-storey buildings (half-way between Nageli's 12 and 21m and Smith and Wilson's 16 and 45m) and 45m for two-storey 'protective-wall' type continuous building, for the design of wind

protection-oriented settlement layouts. These proposed figures require verification in further wind tunnel studies, but for the purposes of the proposed planning model will be accepted as a reasonable approximation of reality.

Applying the above suggested wind reduction figure of 30% to the average winter wind conditions of 5.5 m/s would give a wind speed of 1.7 m/s in the wind-protected zones mentioned above. This is slightly above the 1.6 m/s comfort limit given for standing and sitting for short periods (see table 8). The maximum observed hourly wind speed is 29.5 m/s with an average gust speed of 38 m/s (an infrequent occurence) which if reduced to 30% would give velocities of 8.9 and 11.4 m/s. Thus the maximum observed hourly wind speed is near the limit of comfort of 8.0 m/s (tolerable) for fast walking in winter, while the average gust speed (11.4 m/s) would be outside the comfort limit. If we use the figures of 8.9 and 11.4 m/s with the winter temperature range of -25 to -33°C to determine the wind chill from Fig. 152, we arrive at a range of wind-chill values of 1,800 to 2,100 which are in the zone (2,000) where exposed flesh freezes in one minute. If we take 0.9 m/s as the speed people would walk, then they would be able to travel 54m before their faces would freeze (this would occur less than 10% of the time). Using the 1.7 m/s average reduced wind speed and the same temperature figures in the wind-chill nomogram gives values of 1,300 to 1,400 which is the value at which exposed flesh freezes, the 5 minute, 400m maximum pedestrian distance from the furthest house to the closest indoor public space would still apply. However, for the 8.9 and 11.4 m/s wind speeds, the maximum distance before freezing exposed flesh is reduced to 54m. Therefore, it is proposed that the distance between houses or between the nearest house and public buildings should not exceed 54m.

If the wind velocity figures are close to acceptable in winter, then in summer there should be no major problem. The speeds of 8.9 and 11.4 m/s are within the 9.3 and 12.4 limits proposed for summer. For spring and summer only the 11.4 m/s (average observed gust speed) is above the limit of 10.8 m/s, which suggests that wind comfort conditions would be met most of the time.

Another advantage of wind protection other than outdoor comfort is the effect on a building's heating load and the indoor environment. From a study made by Woodruff (Olgyay, 1963 p. 99) on shelter belts and their effects on the heating loads of protected houses, it has been observed that an unprotected house in a 20 mph. (8.9 m/s) wind has a heating load 2.4 times that at 5 mph (2.2 m/s) at the same temperature. Olgyay describes another study by Stoeckeler, William and Ross (p. 99) which demonstrated that of two identical houses, the protected house consumed 22.9% less fuel than the unprotected house. The study noted that if the protected house had protection on 3 sides, an estimated 30% less fuel would have been used (also in W.M.O., 1964, p. 108). Thus the buildings leeward of those facing the dominant winds would also consume less fuel, an added benefit to providing protection for the pedestrian. <u>If the site does not provide natural shelter from the dominant winds, the windward buildings could either have artificial protection in the form of stone walls or earth berms</u> recalling perhaps the medieval walled citics, a rather appropriate image in the hostile arctic environment.

2.1.3.4 Snow Control Requirements

The accumulation of snow is a complex phenomenon in which a great many parameters are continucusly interacting. These parameters are: particle size, density, speed and direction, relative humidity gradient near the snow surface, air temperature, total insolation, saltation processes, erosion, melting, evaporation, sintering or age hardening, surface roughness, creep and turbulent diffusion (Isyumov and Davenport, 1974; Jumikis, 1970; Kind, 1974; Kobayashi, 1972; Martinelli, 1973; Mellor, 1965). From the number of parameters and their interaction, it is evident that there are many difficulties in wind tunnel and water flume simulation of drifting snow (Mellor, 1965; Krasinski and Anson, 1975; Kind, 1974; Schneider, 1962; Calkins, 1974a; Calkins, 1975). It has been observed that snow deposited at the beginning and the end of the winter may vary greatly due to different wind directions (Adam and Piotrowski), different particle size, density and relative humidity as well as the sintering process.

The arctic conditions are such that snow accumulation is more influenced

by wind velocity and the saltation, creep and turbulent diffusion processes than by the other factors listed above (Mellor, 1965). The arctic being a desert, relatively speaking, has relatively little snow that falls as precipitation. Most arctic settlements are in proximity to large bodies of water which when frozen over create a drier climate and become immense reservoirs of snow which are transported by turbulent diffusion to the settlements. The frequency of high winds in the arctic contributes to the formation of extremely large and dense snowdrifts. These conditions result in an environment that is quite different from 'southern' locations regarding the simulation of snow accumulation, and therefore simulation would involve fewer of the previously mentioned parameters which would be more common to areas with higher precipitation and humidity.

The architect and planner involved in planning settlements in the extreme climatic conditions of the arctic, require information concerning the 'performance' implication of planning decisions before they become 'frozen'. They need indications of microclimatic conditions created by buildings in terms of sun exposure, wind protection and snow accumulation (Gordon, 1965, pp. 12). They also need information that will guide their design decisions in the preliminary design phase before the final layout is made so that they will be able to evaluate the probable consequences of using various types of layouts. Once alternative layouts have been generated they can be evaluated in simulation tests and the layout plan which has the best performance would be retained (Gerein, 1980, p. 93; Morrisson, Hershfield, Theakston and Rowan, 1974).

When dealing with problems related to snow, the planner only need know the locations on or around obstacles where major snowdrifting would occur. The amount of snow accumulated is not important[1], however, the location of drifts due to various wind directions is (Calkins, 1975, pp. 1,3;

1 It is unlikely that snow accumulation can be predicted with accuracy with present simulation techniques (Schneider, 1962, pp 58-59; Mellor, 1965, pp. 34-38; Kind, 1974, pp. 27-29; Adam and Piotrowski; Calkins, 1974a, pp. 1 and 3; Gerein, 1980, p. 94).

Calkins, 1974b, pp. 1, 5-15, Frenette, 1979, p. 34). Some studies have attempted to "measure" the amount of snowdrifting reproduced in water-flume simulation techniques (Morrison, Hershfield, Theakston and Rowan, 1977; Morrison et al, 1974, figs. 2-8; Culjat, 1975, pp. 193-200, 226-233, 289-290; Krasinski and Anson, 1975, pp. 5-8, 16-24), while others used qualitative measures such as low, average, heavy, very heavy and extreme (Frenette, 1979, p. 38) and still others only tried to determine the snowdrift patterns and their "areal extent" (Calkins, 1975, pp. 4-6; Calkins, 1974b pp. 5-15). The latter two approaches seem the most realistic given the similitude limitations with present simulation techniques.

Schneider proposes two approaches to dealing with snowdrifts:

> "1. The object may be given a form such that no deposits at all can occur, or artificial means can be provided so that the snow is blown over the object to be protected or is conducted past it.
>
> 2. By the erection of obstacles or by suitably altering the shape of the ground the wind velocity is decelerated so that the driving snow is precipitated. In this case sufficient space is allowed in the design of the protecting installation for the snow to be deposited." (1962, p. 15).

This corresponds generally to the two possibilities for town layout proposed by Erskine: 1.) to orient the buildings and streets in the dominant wind directions so that the streets would be self-clearing with the snow collecting behind the buildings and not in the streets; 2.) to use a perimeter building, which would act as a snow fence, along with secondary snow control devices in order to avoid heavy snowdrifts in major open spaces around detached single-family dwellings and on roads (in Culjat, 1975, pp. 224-226).

In order to make initial layouts, some guidelines are required to direct the shape of and distances between buildings. The work by Finney on snow fences gives a possible direction to the formulation of the guidelines based on the relationship between drift formation and the eddy length. He states that "the solid barrier produces a drift that does not extend to the end of the eddy area except under very low velocities" (in Calkins, 1975, p. 6). Thus, if the eddy length can be determined,

the approximate length of a snowdrift can be estimated. Calkins gives an interesting correlation between snowdrift area and shape in relation to the width of a building, but it is specifically related to a building with one sloping face (1975, p. 7).

Using Evans' table relating building length, width, height and roof form to eddy length and using a unit dimension of 4m (height of a detached single-family dwelling) we find that for:

Single family dwellings -

- a flat roof building 1 unit high by 2 units long and 2 units wide has an eddy 2 units long (8m).
- a 4/12 double-slope roof building, 1 unit high by 2 units long and 2 units wide has an eddy 2.5 units long (10m).
- a 2/12 single-slope roof building 1 unit high by 2 units long and 2 units wide has an eddy 2.5 units long (10m).

Institutional buildings -

- a flat roof building 2 units high by 4 units long and 1 unit wide has an eddy 8.25 units long (33m) - size of a store, school module, small infirmary.
- a flat roof building 2 units high by 8 units long and 1 unit wide has an eddy 11.75 units long (47m) - large store, etc. for larger settlement.
- a flat roof building 2 units high by 28 units long and 1 unit wide has an eddy 18.5 units long (74m) - perimeter protective-wall type building.

See table 9 for the complete table (Evans, 1972, p. 12-3).

<u>The above eddy dimensions for the selected building sizes and types should be used as a first approximation of the length of the snowdrift, to guide the preliminary layout. The layout should then be tested in a wind tunnel or water flume</u> depending on the complexity of the buildings and their arrangement (Schaerer, 1972, p. 146-2; Calkins, 1974b; Frenette, 1979; Adam and Piotrowski; Theakston, 1970, p. 229).

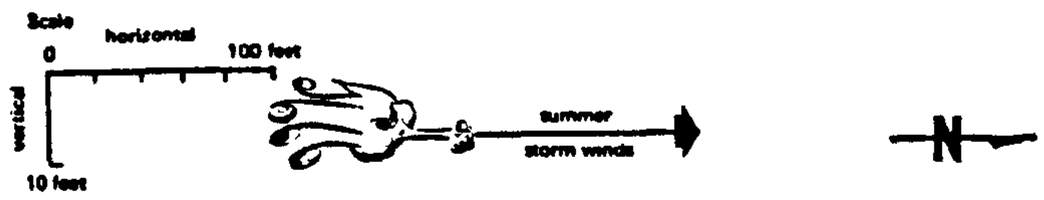
Works by Roots and Swithinbank (1955) and Stehle (1969) on snowdrifting in Antarctic research stations provides some interesting general guidelines for building groupings and layout. Roots and Swithinbank suggest

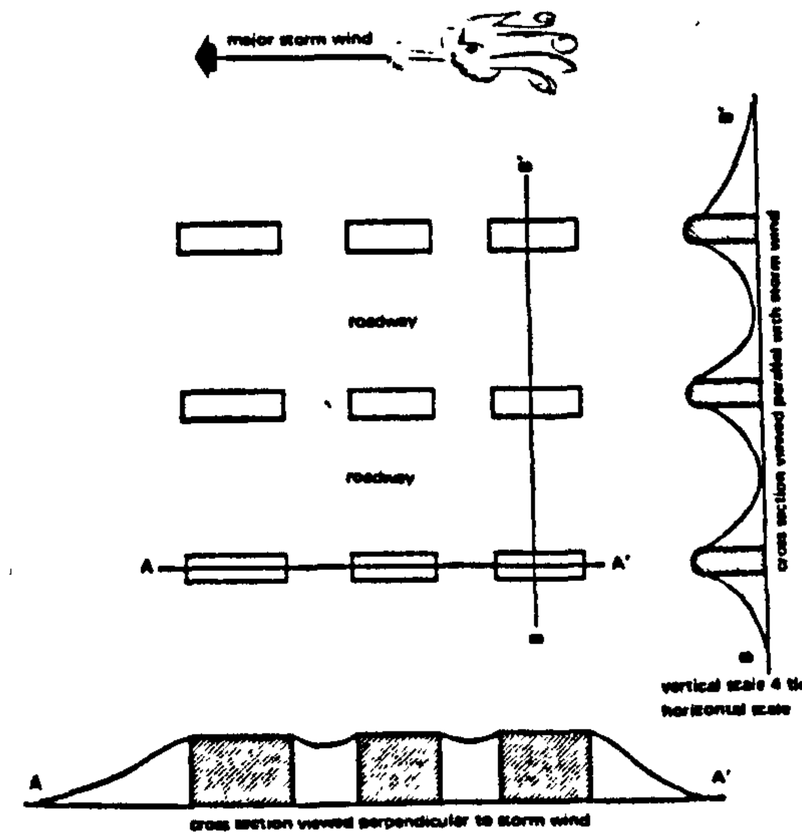
Table 9. Eddy Dimensions for Various Building Dimensions and Roof Shapes (from Evans, 1972).

DOWNWIND EDDY DIMENSION (IN UNITS)

LENGTH (L) ↓	BUILDING TYPE AND ROOF PITCH → W=1 H=1	2 1	3 1	W=1 H=2	1 3	W=1 12/12	1 8/12	1 6/12	1 4/12	W=2 12/12	2 8/12	2 6/12	2 4/12	W=3 12/12	3 8/12	3 6/12	3 4/12	W=2 3/12	2 2/12	2 1/12	W=2 3/12	2 2/12	2 1/12
2	2½	2	2¼	5¼	6¾	3¼	3¼	2¾	2¾	2¾	2½	3	2½	3	2½	2½	2½	3	2½	2½	2½	2¼	2¾
4	3¾	2¾	3¼	8¼	11½	5	4¾	4¼	3¾	5¼	4¼	4	4¼	6	4¼	4½	3¾	5¼	4	3¾	4¼	4	4
8	5¼	3¾	4¼	11¾	16½	9	7¼	6¼	6½	9¼	8¾	6¾	6¼	10¾	8	6	6¼	8¼	7	6½	6½	6	3
12	7¼	5¾	8½	15¾	18¾	11¼	8¾	7¾	7¼	11¾	10¼	8½	7¾	10¼	10¼	8¾	8½	10¼	8¾	7¾	8¼	8	5¾
16	8	6	8¾	16¼	18¾	13¼	10¼	8¾	8¼	13¼	12½	10	10	15	12½	11¼	9¼	11½	10¼	10¼	11	9½	8½
20	8¼	6	6½	17¼	20¾	13¼	10	10¼	8¼	14¼	13	12¼	11	16¾	14¼	12½	11¾	13	11¼	11	11¾	10¼	8½
24	8¾	7	8½	18	20¾	14¼	11¼	11	8½	15	14¾	13	12½	17¾	15¼	13	12¼	14¼	12½	12	13¾	11	9
28	8¾	7¼	8¼	18½	21¼	16	12	12¾	9½	15¼	15¾	14	13¾	18½	16	15	12¾	15	13¼	13	13¾	11½	9½

that in order to keep buildings as free as possible from snowdrifts caused by the "coalescence of drifts, with (the) consequent engulfment of one object in the drift of another", objects should be sited independent of each other at a spacing not less than 30 times their height and in a line perpendicular to the wind (1955, p. 386). Stehle proposes a distance of 25 times their height and that "if more than one line of buildings is necessary, place the rows of buildings in a train arrangement with the row parallel to the winter storm wind." He also suggests that a space of at least 60' (18.3m) be left between rows for ease of snow clearing (1969, p. 119). See Fig. 157 for a plan and sections of a proposed layout, and a section through a layout with the rows perpendicular to the wind. (See also model studies of similar layouts in Strom, Kelley, Keitz and Weiss, 1962, pp. 36-45.) Lufkin and Tobiasson also recommend orienting buildings parallel to the wind to minimize drifting, but also to diminish lifting "due to the airfoil effect of the gable roof"(1969, p. 15).







Generalized cross section of Williams Field showing drift accumulation after 1 and 2 years of accumulation.

Illustrative layout of multi-building camp and expected drift pattern.

Fig. 157. Building Layouts Perpendicular and Parallel to the Wind (from Stehle, 1969).

Roots and Swithinbank observed that a snowdrift behind objects placed parallel to the wind was "many times longer than that produced by a line (of objects) across the wind" (1955, p. 384) which suggests that buildings placed perpendicular to the wind could be used without producing large drifts or the coalescence of drifts, if the distances between rows perpendicular to the wind are sufficiently long or if successive rows were parallel to the wind. Strom, Kelly, Keitz, and Weiss (1962, p. 41); Roots and Swithinbank (1955, p. 381); Stehle (1969, pp. 113-115); Mellor (1965, p. 55); Schneider (1962, p. 46); Hogbin (1970, p. 8) all point out the variability of snow storm wind directions which creates some doubts about the probable efficiency of layouts parallel to a single wind direction.

Empirical observations by Roots and Swithinbank, of a 4.5 X 4 X 4m hut oriented with one face into the wind, indicated that the resulting snow windscoop reached 1/3 the height of the hut and then seemed to remain in equilibrium (1955, pp. 382, 383). They therefore recommended that to create a windscoop which would keep a large object free of snow, a cube-shaped object whose windward face was a minimum of 3 X 3m should be used. They, however, point out that a windscoop zone "is not a protected

region, but a place of accelerated wind velocity... not suitable for a door...and the object causing the windscoop becomes the centre of a locally intensified storm" (1955, pp. 386, 387). Thie is an excellent description of the environment created on the windward side of a building which indicates the very limited possibilities for the use of this unobstructed space. An emergency exit could however, be placed in this space, but the cubic proportions recommended for the windward face could impose design complications.

Stehle mentions model tests which indicated that snowdrifting could be reduced by orienting buildings 45° to the storm winds. In addition he suggests that the long axis be parallel to the winter storm wind when the summer and winter winds are at 45° to each other (1969, pp. 118, 119). Adam and Piotrowski in aheir study also recommended orienting houses with their corner into the wind, but suggest more detailed testing is needed.

Raising buildings above the ground surface is another method that has been proposed by many authors for minimizing snow accumulation around buildings. Roots and Swithinbank suggest a clearance of 2m under a platform supporting goods stored outside (1955, p. 387); Stehle describes tests that propose 2' to 4' (0.6 to 1.2m) (1969, pp. 118, 119); Strom et al. used models with 5' and 10' (1.5 and 3.1m) elevations above the ground (1962, pp. 36, 41); Melbourne and Styles' Antarctic study proposes 8' to 10' (2.4 to 3.1m) as an upper limit and 4' to 6' (1.2 to 1.8m) as a lower limit (1967, p. 150) and later they specify that ground clearances should be more than 8' and in no case should they be less then 5' (Styles and Melbourne, 1968, p. 8); Mellor reports a free space of 19' (5.8m) (1968, pp. 8, 24); Adam and Piotrowski used 5' clearances under houses; Morrison, Hershfield, Theakston and Rowan show a 2' (0.6m) elevated space providing snow clearance (1977); and Tobiasson describes an installation with a 3' (0.9m) clearance (1968, p. 133). Comparing all the above figures, <u>it would seem that a 5' (1.5m) clearance under buildings would ensure that snow accumulation would be minimized</u>. This seems reasonable when one considers that most of the snow transported in a storm is limited to a depth of 150cm above the surface (Schneider, 1963, p. 11), Although Mellor gives a region of 100m for turbulent diffusion, a common transport mechanism in polar regions (1965, p. 6), Jumikis gives a figure in the lower 10's of cm

for 90% of the snow transported (1970, p. 213) which is mainly by the transport mechanism called saltation.

Roots and Swithinbank noted that to reduce snowdrifting a group of objects should be low as possible, streamlined with their upper surface smooth and with the windward face "relatively blunt, but rounded" (1955, p. 386). Mellor supports the notion that streamlining may reduce drifting when he states "... it seems clear that all but the most elaborately streamlined structure must create drifts..." (1965, p. 64). The Australians experimented with horizontally and vertically rounded leading edges on buildings in an attempt to accelerate wind under an elevated platform and around the sides of a building to reduce wind pressure and vibration due to turbulence (Melbourne and Styles, 1967; Styles and Melbourne, 1968; and Brown, DeMole and Gamble, 1968), as well as minimizing snowdrifts.

Snow fences of a variety of types have been used to keep highways clear of snow (Hogbin, 1970; Schneider, 1962; Mellor, 1965), and they have also been proposed for snow control around buildings (Mellor, 1965, p. 64; Schaerer, 1972, p. 146-4; and Adam and Piotrowski). The fences used varied from collector and blower to deflector-type fences. Stehle describes the results of using two 5.5'(1.7m) high triangular-shaped snow walls upwind from a 5.5' high U-shaped snow wall, which led him to suggest that "orientation and placement of buildings are generally more reliable means of minimizing drift accumulation than is the use of snow fencing (or snow walls). Adam and Piotrowski were also negative about the usefulness of snow fences for protecting settlements from excessive snowdrifting. Snow walls with earth dams are proposed by Schaerer (1972, p. 146-4) and Schneider (1962, p. 25), but as with snow fences their utility in settlement planning is doubtful and requires much more experimental verification before they should be recommended.

In order to keep snow from accumulating around houses which are elevated above the ground, the slope of the sides of the gravel pad, (which insulates the house from the permafrost) should be such that large amounts of snow do not gather on the windward or leeward slopes. Finney proposed slopes of 1:4 in which "... the flow disturbance was acceptably slight and the drifts formed were not severe..." and that "1:6 slopes created very

little separation (in Mellor, 1965, p. 54). Experiments by the U.S. Army reported by Mellor, indicated that drifting ceased once side slopes were reduced to 1:9 (1965, p. 54). Schneider proposes slopes of 1:5 for roadways in flat terrain and for hillside cuts no steeper than 1:6 (1962, p. 58). Finney's experiments led him to recommend a slope of 1:6.5 for cut sections, which he found to be the threshold for accumulation and was independent of wind speed or slopes steeper than 1:6.5 (in Mellor, 1965, p. 54). This author proposes foundation gravel pad slopes of 1:6 for buildings elevated less than 5' (1.5m) above the ground and 1:4 for buildings elevated 5' or more above the ground due to the acceleration which would occur under the building at 5' clearances (see wind speed figures in Melbourne and Styles, 1967; and Styles and Melbourne, 1968).

When dealing with snowdrifting problems in the Arctic, there are two main layout types to consider: 1.) a protective-wall building perpendicular to major winter wind directions, with successive buildings laid out;
a) in a series of protective-wall buildings parallel to the first, or
b) as a series of separate detached buildings in rows parallel or perpendicular to the wind. 2.) detached separate buildings oriented parallel to the wind.

The distance between the protective-wall building and the successive buildings whether they are protective-wall or single detached buildings; whether oriented perpendicular or parallel to the wind; would be based on the Evans eddy dimension table (table 9). Using this table, the minimum spacing of houses in the same row would be 10m. The author therefore proposes to maintain the present distances of approximately 14m between houses in arctic settlements in order to minimize the possibility of the coalescence of drifts between buildings in the same row whether perpendicular or parallel to the wind.

The distance across back yards or across streets should exceed the 10m threshold distance (table 9) because studies on solid fences or impermeable shelterbelts have indicated that snow accumulates in a region varying from 2 to 5 times the height of a fence or wall (W.M.O. 1964, pp. 61 and 143). For a single-storey house (4m high) this would give a snowdrift 8 - 20m long and 14 to 35m for two-storey buildings (7m high). However,

the 8 and 14m figures are lower than those determined from table 9 (10 and 33m) which the author proposes to use. Therefore, the author recommends a range of house spacing across back yards and across streets of 10m to 20m for one-storey buildings to avoid drift attachment from one building to another and 33 to 47m for the spacing between two-storey buildings and other buildings (see table 9 for eddy dimensions for two-storey buildings 4 and 8 units long and 1 unit wide).

It is proposed that if a protective-wall building is used perpendicular to the wind, then the second row of buildings should be laid out as separate buildings in rows parallel to the wind. If a second continuous perimeter-type building is laid out leeward of the first, it should be located at a distance of 74 to 100m[1].

It is recommended that square or nearly square buildings be turned at 45° to the storm winds, and that whenever single detached buildings are used that they be designed as near as possible to a square in plan.

A major design objective should be that all entrances to public buildings, houses, garages, warehouses, etc should be protected from snow accumulation. Snow in combination with wind creates drifting snow conditions with snow accumulating often in undesirable quantities in inconvenient places, blocking entrances, windows and roadways. The drifts can form a pattern of ridges and valleys so closely spaced that pedestrian movement is rendered difficult and tiring, especially for older people. When the ridges and valleys of snowdrifts are very close together (which often occurs when the dimensions of the buildings and the spaces between them are small), the gradient of the snow drift could attain 40%. Lynch (1971, p. 152) suggests sidewalks should have a maximum slope of 15%, which is far less than the

1 The last figure is inspired from the experiment by Styles and Melbourne (1968, p. 8) in which the second continuous row of elevated buildings, 100.6m from the first, created low wind velocities which they concluded would result in snowdrifting. Because the test buildings were elevated 4 to 10' above the ground, the wind flow would be different from buildings with no free space under them. Thus the 74m eddy dimension would probably be a reasonable minimum and the 100m a reasonable maximum distance for buildings with no under-side clearance.

slope observed in one sector of Povungnituk[1].

With regard to vehicular movement, Lynch (p. 152) states that a 17% grade is the maximum a large truck can negociate in low gear. It is obvious that with a 40% grade that not even a tracked vehicule could traverse such a snowdrift. However, with the 13.7m space (more than a threefold increase of distance over the Povungnituk example) now recommended between buildings, the gradient would approach 18% using the same drift height of 1.8m at the centre of a building 10.7m long. Since under extreme conditions snowdrifts can reach the peak of a building 4.6m high (see Bigué and Pageau, 1980, p. 36 for a photo of a snowdrift attaining the height of the roof peak), the figure of 1.8m is not exaggerated. If this condition arises, delivery time by vehicles is prolonged, extra strain is put on vehicle motors, and eventually the snow has to be ploughed, which can be costly if it is required after each snowstorm.

1 The observations were made by the author during a visit in 1976, and the slope was calculated by measuring the observed snowdrift height (1.8m) at the centre line of a house (4.9m long) and drawing a line to the ground at the midpoint of the 4m space between the buildings.

2.1.4 Level Four - Cultural Requirements

According to the dictionary definition, culture is "the way of life of a people", but the way of life of a people involves many aspects of man's activities and beliefs. Rapoport indicates the importance of culture to housing form when he affirms that: "The specific characteristics of a culture - the accepted way of doing things, the socially unacceptable ways and the implicit ideals - need to be considered since they affect housing and settlement form...". Elaborating this notion he states that: "The (living) environment sought reflects many socio-cultural forces, including religious beliefs, family and clan structure, social organization, way of gaining a livelihood, and social relations between individuals." (Rapoport, 1969, p. 47).

The religious beliefs of the Inuit are very closely tied to the symbolic aspects of their house, a point well illustrated by a shaman's description of a snow house which was recounted to Saladin (1978). The shaman recounted that the woman is the home that temporarily shelters human life and the snow house is the development of this principle on a human scale, but is also a microcosm of the universe. The raised platform on which most activities are carried out represents the earth; the floor is the shoreline; the entrance is the moon on the horizon; the window is the sun; the small platform for storing meat is the sea and the game it contains; the vault of the igloo is the universe; and the chimney aeration hole is the stars. This description also points out the close relationship between Inuit religious beliefs and their way of gaining their livelihood. With the adoption of the white man's technology, food, and some customs, the Inuit are beginning to lose the notion of symbolism and their indigeneous religious beliefs.

Family and clan structure is also changing in many communities. As a result of the greater contact with the white culture by the Inuit at school and in their travels to the south, different ideals and aspirations are evolving amongst the young Inuit which are creating differences between the elders and the youth. The youth are attracted to consumerism, styles and trends of the white culture, and are abandoning many aspects of their

traditional way of life in dress, music and leisure activities. Because of various forms of social assistance provided by the government, hunting is no longer the major occupation of father and son, and the closeness that once existed between them is being eroded. The youth segregate themselves from the elders when their music and other activities are in conflict with those of the family. The segregation may take the form of closing themselves off in their rooms, or by moving out to tents set up near their houses.

The social organization and social relations between individuals seems to have suffered fewer changes. There still exists a central gathering place in each village where they come together to discuss, dance and amuse themselves. However, the advent of radio, telephone and television has changed the nature of community consultation which now can be done directly from one's home by listening to the discussions on the radio and telephoning one's opinion to the radio station. On the level of individual families there is still much visiting amongst relations and friends.

At this level, it is proposed that the cultural requirements be determined through the integration of the future users in the planning process. Designers and clients are beginning to admit "...that expertise does not reside entirely in the designer but rather in all those whose interests are affected by a design problem" (Sanoff, 1977, p. 167), and that "...by involving in the design process those who will be affected by its outcome, may provide a means for eliminating many potential problems at their source." (Cross, 1972, p. 6). Lynch observes that: "A highly decentralized decision process, in which the immediate users of a place make the decisions about its form, is a powerful ideal. It reinforces their sense of competence, and seems more likely to result in a well-fitted environment, than if they are excluded." (Lynch, 1981, p. 44). The latter aspect is especially true when dealing with a different culture. Eastman noted (1972, p. 52) that when dealing with users who have "...different cultural and behavioural patterns from those of the architect..., the architect's own value system and intuition will lead him to false conclusions and result in the imposition of his values on the users." The author feels as does Alexander (1975, p. 40), "...the daily

users of buildings (and towns) know more about their needs than any one else" and just as in Alexander's example of the Ph.D. students in the "Oregon Experiment", (1975, p. 48) there can be no doubt that one group of specific users (the Inuit in this case) knows more about the needs of another group of the same specific users (other Inuit in the same village), than does a group of planners or designers (from the south). Jones points out that "...there is a growing demand that all the people who are affected by a new design participate in the making of critical decisions"(1970, p.71; and Jacobs, 1961,p. 441).

Fathy, on the other hand believes in limiting the scope of participation and in his work in Gourna in Egypt, he held that the design of the villages is the domain of the government and its specialists (1973, p. 33). This is a common attitude among planners such that when consultation on the design of a village does take place it usually involves the specialists (urban designers and planners) consulting the leaders of the village, then designing the village, to return only for comments and modifications on the plans. The input of the people is minimal and involves making minor modifications to the plan presented by the specialists. An example of this type of planning is described by Tanguay (1975).See also the "General Development Plan for Baker Lake, N.W.T."(1977, pp. 3-7) which admits the need for community input but does not structure the consultation in any systematic and meaningful way. Cavdar suggests that the typical planning process by only informing the users of the outcome of the decisions taken by the planners and administrators, condemns them "...to be more objects of the planning process; for the masses to become the subject of the entire process an unobstructed and dialectical media of communication must be attained" (Cavdar, 1979, p. 163).

The author believes that planners and designers should become "...technical advisors, providing a vast and subtle range of methods," as Nuttal (1972, p.20) suggests, and as Lynch (1971, p.259) proposes, they should act as specialists "...in creating form possibilities, predicting their effects, and explaining how they can be technically accomplished, but his basic role is to disengage himself by communicating the necessary techniques of design and analysis and thus allowing the client to invent and build his own world." They would work "...to reveal hidden needs and possibilities..." and would "...promote and monitor specific environmental experiments so that new

possibilities are opened up for the user, who can then, by his response to the experiment, clarify his requirements both to himself and to others" (Lynch, 1971, p. 260). The model the author proposes, would employ a form of user participation that would permit the formulation of town plans based on requirements as expressed by the Inuit. Therefore the cultural requirements, rather than being only a series of formalized written goals or needs, would take the form of a plan generated by the Inuit through a user participation method. It is interesting to note that an historical precedent existed in the United States for user participation at the scale of a community. The Oneidans, a communistic society that existed between 1848 to 1880, had amongst other social innovations, involved the community in the design of buildings and the form of places as well as rooms, decorations, etc. Lynch notes that "...sketch proposals could be made by anyone, and they were heatedly discussed until all were in accord" (1980, p. 68).

Planning a settlement or town is a difficult task because a town is like a living organism that evolves over time while responding to a multitude of forces. Alexander notes that a town grows as a result of a myriad of small changes and additions and and is not controlled by one person or group of persons (1979, p. 496). Town planners with their team of specialists frequently produce plans that inhibit any creative input by the future inhabitants. Alexander proposes the use of patterns agreed upon and controlled by a hierarchy of groups involving the individual, the family, clusters of families, neighbourhoods, communities and the town, each being responsible for the patterns affecting their level of the town space (1979, pp. 505,506). Alexander and Poyner feel that to ask a client or user what he needs, can produce deceptive responses because "...people are notoriously unable to assess their own needs"(1970, p. 309). They suggest that asking questions about needs or outside observation will be fruitless in uncovering a client's real needs. They believe that a need is an active force of someone trying to do something and is in reality a tendency (p. 309). They base the formulation of patterns from the uncovering of tendencies of 'trying to' actions and identifying the tendencies that are in conflict and resolving the conflicts (pp. 315-321).

However, problems with the pattern language have been raised by several authors. Duffy and Torrey, for instance, bring out the fact that each pattern is culture-based and is therefore difficult to transfer from one culture to

another (1970, p. 264), a problem which would require the generation of a pattern language for each cultural group, resulting in something more akin to user design participation. Protzen has more fundamental criticisms of the pattern language. He identifies four major weaknesses of which the three most important are: 1) the superficiality of the evidence supporting the patterns; 2) the evidence presented by other studies, supporting certain patterns, are taken uncritically at face value; 3) supporting evidence for a pattern is based on what Protzen calls a "consensus theory of truth" (1978, pp. 193,194). He criticizes it mainly because it is an "all-encompassing theory" that cannot be refuted in part because each part or pattern is supported and cannot exist without other patterns upon which they depend, therefore the pattern language as a whole must be refuted (1978, p. 194). The author has rejected the idea of trying to formulate patterns suitable to the Inuit because their culture being one that is in rapid transition the patterns produced for this generation could be obsolete or erroneous for the next succeeding generation.

Alexander expresses doubts about participation being feasible when employed in projects serving more than 100 people (1975, p. 64). The author believes that in the Inuit context, even though a village may exceed by 7 to 8 times Alexander's limit of 100 persons, the Inuit are nevertheless able to identify with parts of the village, such as their own neighbourhood; the school; infirmary; store; church; etc., and to understand it as a whole. They feel that all these parts belong to them in a user's sense and would therefore be strongly interested in their location within the village. Because of this and the fact that the placement of their houses in relation to the water and the public services affects their everyday actions, it is necessary that the Inuit be involved in the design of their village.

Many authors have mentioned the problem of communication that exists between architects or planners and clients or users (Dluhosch, 1973, p. 223; Bayazit, 1980, p. 17; Broadbent, 1973, p. 220). Broadbent suggests that scale models would help designers communicate with users more directly and more efficently (1973, p. 221). Scale models have been used in various user participation projects (Spring, 1969, pp. 404, 591; Editors Neuf, 1973, p. 64; Nunaturliq project, 1974; Editors Prog. Arch., 1974, p. 96; Herrou, 1980; Schmidt, 1980) and their use is widely accepted. The author proposes

integrating the users into the design and decision-making process through the use of a scale model of the village.

Scale models for user participation in the design of villages are not as common as models for the design of houses. Houareau (1973) describes personality tests using village models and a user participation example with Navajo people is described in Architectural Forum (1972, pp. 54-57). One recent planning study in the Arctic describes ways of integrating input from the community through consultation with maps, reports, etc. but rejects the use of a scale model early in the planning phase because of the planner's need for a consensus on overall community goals first. The planners saw the model not as a design tool but rather as a means for explaining their zoning by-laws and plans (N.W.T., 1977). The users never really have a direct hand in the design process and it becomes the usual lip-service to user participation.

The use of scale models would encourage and facilitate user participation in the design of the settlement. It is felt that the use of a scale model for solliciting information from a population is more accurate than most other methods that have been employed to obtain users' needs. Interviews and questionnaires have many problems as several authors have pointed out (Siddal, 1972, p. 95; Dluhosch, 1973, p. 223; Jones, 1970, pp. 217, 222-224). Broadbent notes that although many people believe that the verbal response given by a person expresses what he thinks, this is not always true (1973, p. 120). Anthropologists working with the Inuit on the Nunaturliq project discovered that often the respondent was giving an answer he thought the interviewer wanted to hear. Levin observed that "...the questionnaire,... tends to reflect the conceptual framework and attitudes of those who draw it up rather than those who fill it in" (1972, p. 35) which emphasizes the misconceptions and errors that can creep into a user participation project depending on the methods used.

There is also the problem of the uncertainty or indeterminacy principle coming into play. Briefly, it states that the act of observing a phenomenon changes its behaviour such that at the end of the period of observation it is no longer the same as when observation began (Popper, 1959, pp. 218-220; Broadbent, 1973, pp. 69, 71, 150, 151). Broadbent also notes that people's prefcrences change "...they adapt, habituate and otherwise begin to prefer

conditions which they did not envisage preferring until they had experienced them" (1973, p. 122).

In the user participation process proposed by the author a scale model of the site would be used with the total number of houses required as well as all the service buildings, such as the store, infirmary, school, warehouses, etc., at a scale of sufficient size that would allow the easy manipulation of the pieces and would permit the whole family to gather around the model. The population would be divided into family or kin-related groups which are small enough to consult easily on the design of the village. The plans generated in this way would be classified into typical plans and would be presented to the community at large where votes would be cast for the various alternatives. The plan receiving the most votes would be used in the final synthesis with the plans generated by the specialists. The user, therefore, would have an input into the generation of a typical plan and a vote on the final selection thereby being intimately involved in the decision-making process. The village plan generated by the scale model, unlike Alexander's pattern language procedure in which plans are produced by small acts and "...a history of happy accidents" (1979, pp. 509,510), would give the direction of the development of the settlement from the agreed upon starting point - the plan accepted by vote. This plan, however, could change as cultural changes develop and are expressed through this same form of consultation and participation. This is important for a culture in transition such as that of the Inuit. Fathy has pointed out the difficulty of designing for communities in the process of change (1973, p. 53) and Cavdar has observed changing patterns of use due to cultural evolution (1979, p. 162). It is therefore important to provide a procedure which allows changes to be integrated into the development of the settlement plan so that it can be modified to suit future needs.

The author feels that a scale model that allows the Inuit to design their own settlement would be far more accurate in interpreting their needs because the intervention of the specialists would be absent from this phase of the synthesis process thereby minimizing their influence on the population's response. The community would also become aware of individuals' priorities and criteria for a village layout by seeing the plans produced by other Inuit, aiding them to accept plans not completely based on their requirements.

It is proposed that through the use of a scale model village and a process of consultation, preliminary plans would be generated which after classification would enable categories of typical plans to emerge. The features that are common to all categories of plans would be identified as "constant" elements that would have to be included in the final plan. The plans representing each category of plan would include these "constant" elements, thereby ensuring that the fial plan, chosen by vote, would also include them.

Thus the requirements of this level cannot be determined in advance, as they will be uncovered during the user participation process and is therefore dependent on it. A number of cultural requirements could be determined through interviews, questionnaires and participation observation[1] but this would not have the validity of the direct involvement of the user in the actual design process and therefore the user participation with the scale model would be the major means of identifying cultural requirements.

1 Planners observing the use of the village while living in it as the users do. (Liberakis, 1973, p. 231; Zrudlo, 1980, p. 272).

2.2 PLAN SYNTHESIS AT THE FOUR LEVELS

2.2.1 Level One - Geological and Hydrological Factors

The requirements which have been elaborated by specialists such as geomorphologists, geographers, ecologists, engineers, etc., would in this phase be used to rate the various factors according to site gathered data as discussed in section 2.1.1. Using a method similar to that employed by Ian McHarg - the hand overlay method - (1969, pp. 33-41) or Alexander and Mannheim's developed version of the 'sieve map' (in Broadbent 1973, p. 287), each factor would be transformed into a map with tones ranging from white for the best correlation with the requirements and black for the worst, and various tones of grey for the values in between. Thus, a slope of over 15% and a soil condition of clay and silt would be laid out as black zones on their respective maps. When all the factors have been mapped out in this manner, they would be superimposed on each other and the lighter areas would indicate the most appropriate zones for housing, roads, service buildings, etc. See Fig. 158 for the organizational diagram.

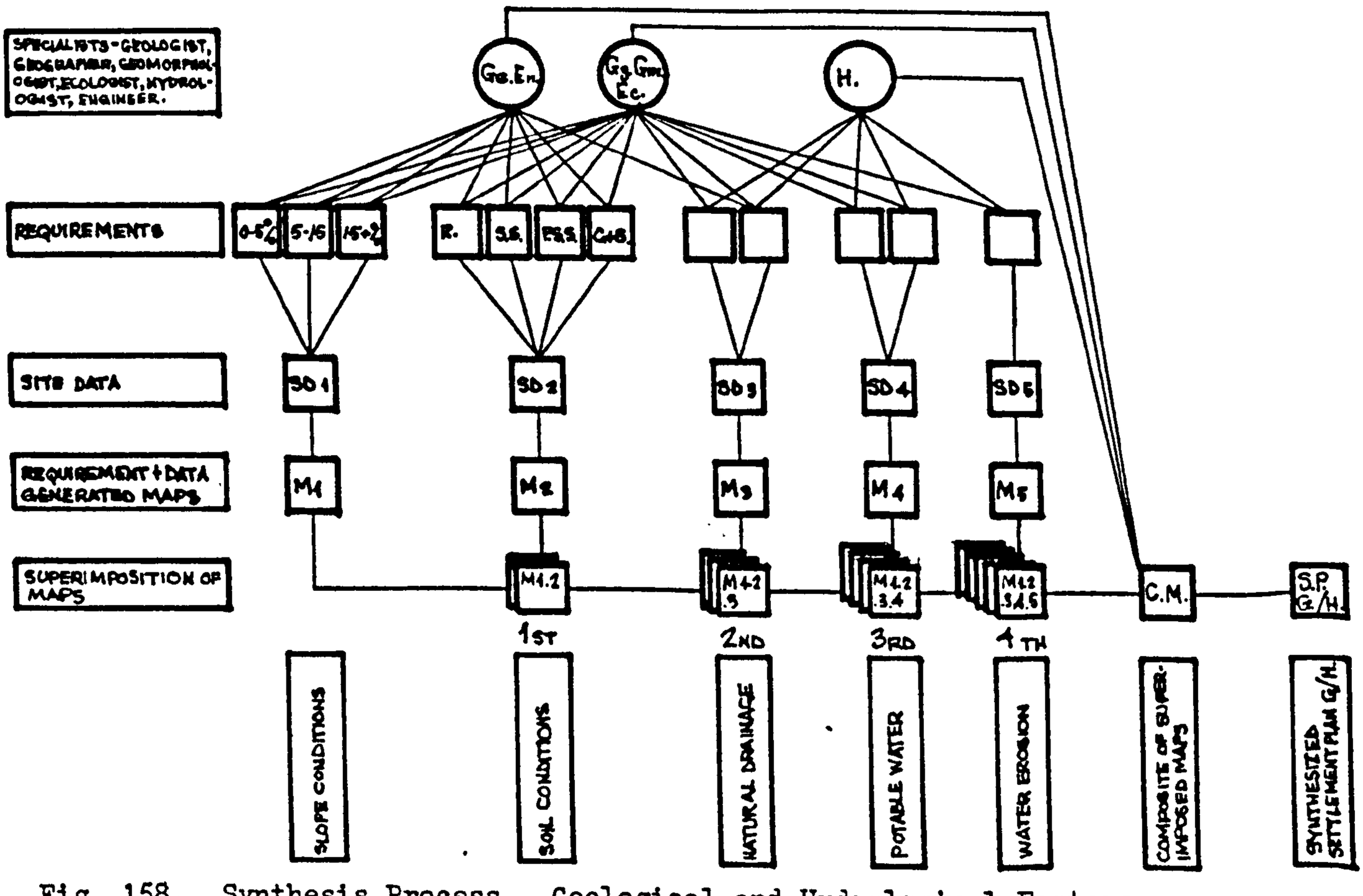


Fig. 158. Synthesis Process - Geological and Hydrological Factors

The synthesized settlement plan would be based on the requirements of this level alone without the influence of the technical, social, climatic or cultural aspects. The settlement plan would reflect the best layout satisfying the geological and hydrological requirements only. Therefore the roads, housing and service building locations would be determined by the contour lines; minimum slopes; nonexistence of low-lying undrained land; noninterference by streams and rivers; suitable soil stability to support housing and larger service buildings; etc. The plan could be said to be generated by the geological and hydrological requirements and the physical conditions of the particular site.

2.2.2 Level Two - Technical and Social Service Infrastructure Factors

2.2.2.1 Technical Infrastructure Factors

This level has two types of requirements with two types of specialists being involved. The technical service infrastructure would require municipal and civil engineers who would elaborate the requirements and analyse the site conditions in relation to the requirements. They would lay out the road network and house location based on the most efficient and economical system for distributing electricity, telephone, water, heating fuel and the collection of refuse and sewage. This plan would also be generated without consideration for the social, climatic, cultural or geological and hydrological aspects. The main objective is to generate a plan that will satisfy the technical service infrastructure requirements to the greatest extent possible for the given site without any compromise, at this phase, to any other category of requirements. The only constraints that are not of the technical service type, would be the accommodation of the total number of houses and service buildings required for the various phases of implementation and expansion, in addition to the physical limits imposed by such natural features as rivers, shoreline, steep hills, etc.

The layout of the water supply line and the sewage system, if set below the ground, would be best laid out in a recirculating loop system in order to keep the water constantly in motion to prevent freezing. Electricity and telephone lines are most economical when laid out in straight line configurations from the generating station. The telephone line should be laid out in straight lines from the satellite receiving dish which would be placed

in an unobstructed location. The fuel depot or oil reservoirs should be close to the dock for ease of provisionment by a pipe line. The roads could be laid out in straight lines, in a serpentine form, in loops, in concentric circles, etc. but would be laid out in such a manner that the distribution of water, electricity and other services would have the shortest distances possible.

Thus this plan would be based on the most efficient layout of the electrical and telephone lines, the water and sewage lines if an underground piped system is used, or the road system if a vehicular distribution and collection system is employed.

2.2.2.2 Social Service Infrastructure Factors

The social service infrastructure would be the responsibility of the architects and planners. The settlement plan could be laid out on an axis running from the dock towards the airport, which are the two entry points into the village. The land airport would be used all year long by large aircraft and during the summer by all types of aircraft. During the winter, smaller aircraft of the STOL type, could land on the ice close to the village if the land airport was too distant from the village. Because there is more movement from the south to the north by aircraft than by sea-going vessels, the entry from the airport is more important than that from the dock. The shoreline, however, is an important entry interface during summer and winter for the villagers who normally arrive from the sea by boat or snowmobile.

The social services could be arranged in an order of proximity to the dock according to the quantity of supplies arriving at and the frequency of use of the dock. The warehouses for the store would therefore be situated on a main street leading directly to the dock. The store and school should, ideally, be equidistant from all the houses with the church, community centre, infirmary and administrative offices being situated relatively near the store and school. The plan of the social service infrastructure would therefore be based on the principle of accessibility and the frequency and quantity of provisionment both into and within the community.

The two plans would be superimposed and compared and any zones of conflict would be identified. Consultation would take place between the municipal and civil engineers and the architects and planners. Trade-offs and compro-

mises would be negotiated until a synthesized plan of the two types of service infrastructure plans were agreed upon. See Fig. 159 for the organizational diagram of the synthesis process at this level.

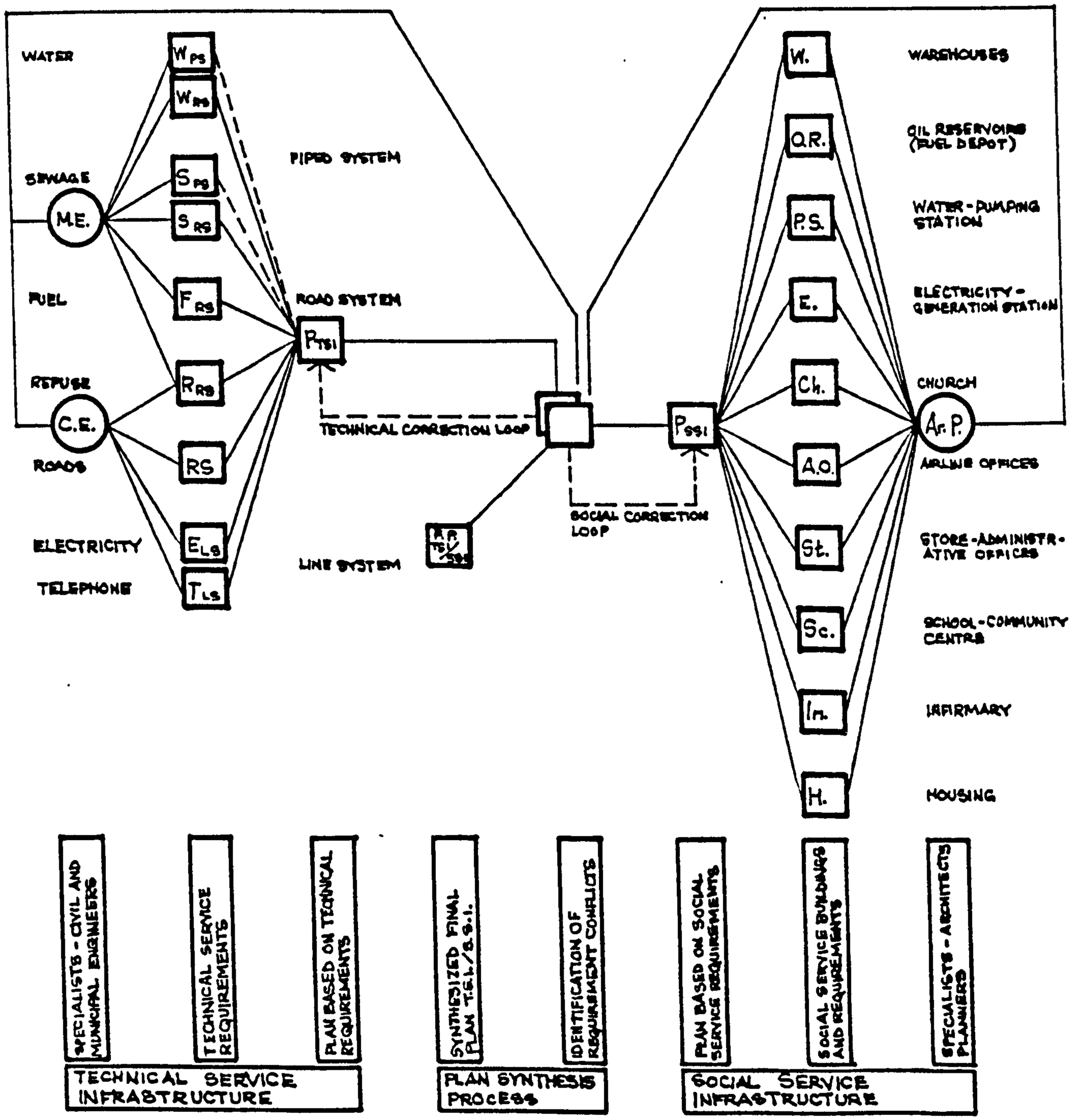


Fig. 159. Synthesis Process - Technical and Social Service Infrastructure Factors.

2.2.3 Level Three - Climatic Factors

The specialists involved at this level - the climatologists and architects - after formulating the requirements and analysing the climatic data, would generate plans and test them using various simulation techniques.

2.2.3.1 Solar Shading Factors

The sun/shade or solar shading aspects would be analysed in relation to outdoor comfort mainly for the summer. Solar shading for the winter would be considered chiefly for its psychological comfort and for its passive solar heating effects on building interiors. Plans would be made to achieve the degree of sunlight demanded by the solar shading requirements for pedestrian paths, public gathering places and building facades for the winter period and then verified to ensure that the summer requirements were also satisfied. The plan would then be checked by a simulation technique (heliodon or computer solar shading program) and modified if necessary.

2.2.3.2 Wind Protection Factors

A second plan would be made, which, based on the wind protection requirements given in section 2.1.3.3, would provide protection for the pedestrian paths and public gathering places from the dominant winds. The plan would be verified by simulation in a wind tunnel or hydraulic flume. If the speeds were not reduced to the comfort levels recommended by the wind protection requirements, then the plan would be modified and re-tested by simulation until the comfort levels were achieved.

2.2.3.3 Snow Accumulation Control Factors

The plan for this climatic factor would be laid out in relation to the dominant wind directions, bearing in mind that snow accumulates in drifts on the lee side of objects. The plan would be organized so as to minimize the problems due to excessive drifting, such as impeding vehicular movement between rows of houses, limiting the use of public gathering places and blocking entrances to buildings. Once the plan has been drawn up a model would be built of the settlement for testing in the hydraulic flume. The plan would be adjusted, modified, or completely redesigned, depending on the simulation results.

The next step in the synthesis process would be to identify the conflicting

requirements in each plan in terms of the solutions proposed in the plans at the other two levels. Conflicts between Levels 3A, B and C would then be synthesized by first modifying the portion of the plan in conflict in such a way that the plan still satisfies its requirements but would also satisfy those of the other two levels. Where this is not possible the process of consultation, negotiation and compromise would be used to arrive at a plan that would satisfy the major or most important requirements. Simulation tests would be run on the synthesized plan to ensure that the major requirements are in effect satisfied. The plan would be modified or corrected to fulfill any unsatisfied requirements and tested in another simulation test until the plan finally met all the requirements deemed essential by the specialists who produced the plans for the three levels of climatic factors. See Fig. 160 for the synthesis procedure.

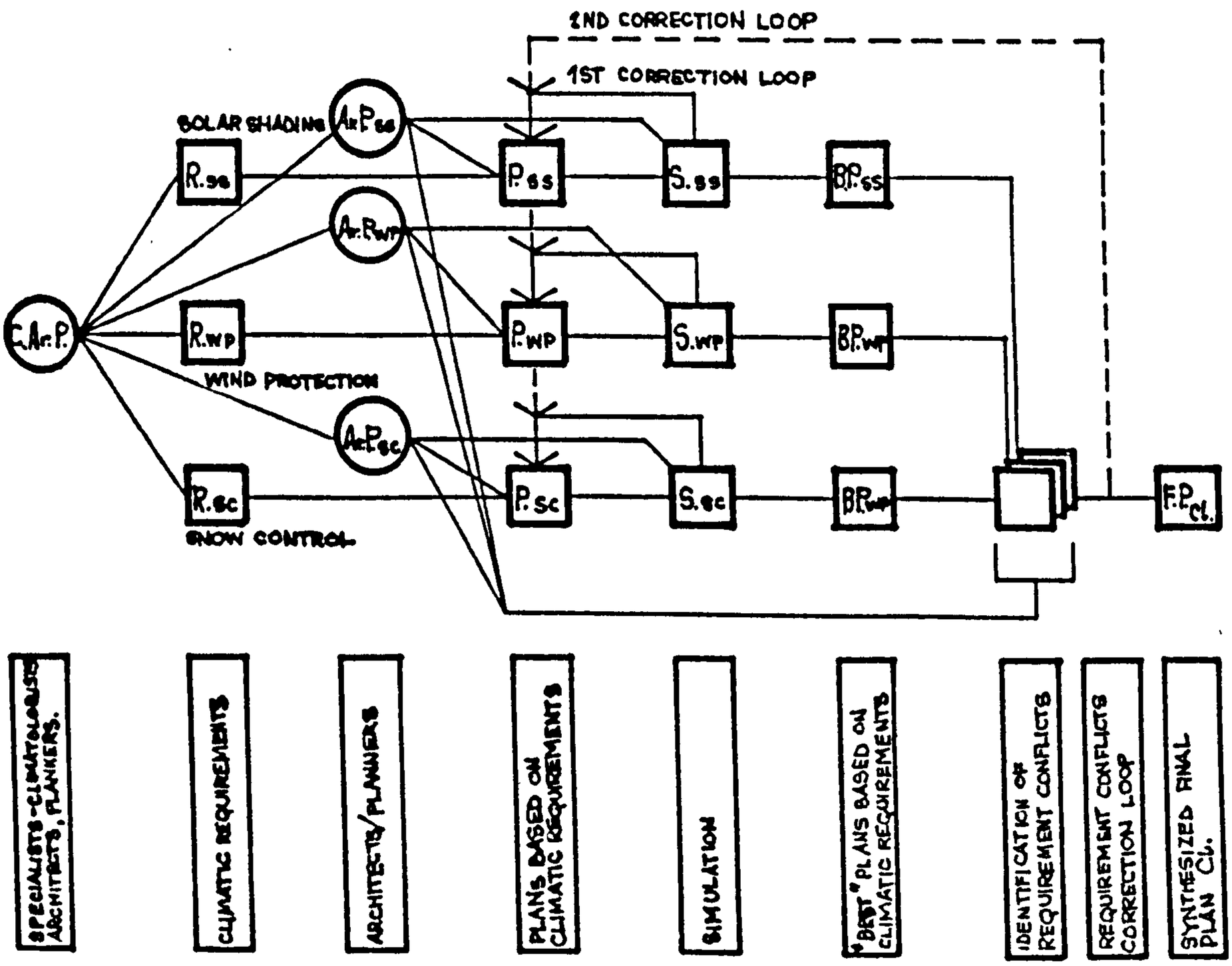


Fig. 160. Synthesis Process - Climatic Factors.

This iterative process could be shortened if the solar shading plan is formulated with the wind protection requirements in mind, which could possibly minimize the number of modifications to be made when the solar shading plan is tested for wind protection. The snow accumulation control requirements would then become the factors demanding the most modification because of the conflict created through snow accumulating in zones where wind speeds are lowest.

The author, however, believes that the decomposition of the problem into all its sub-components, their analysis and solution should be kept separate so as to not influence immediately their individual solutions. For example, the solar shading plan should consider this aspect alone without any compromise at this level to the other factors. If this is not done, there is the danger that an innovative plan for solar shading could be passed over or not emerge at all, because possible conflicts are detected with the other climatic factors. The conflicts should be eliminated at a later stage, but only after the "best" plan for the particular factor is developed.

Ideally each plan is based on a separate climatic factor and should be developed by a different member of the design team concentrating on satisfying only the needs of his climatic factor, consciously eliminating any other influences. When the plans are compared, consultation and negotiation to produce a compromise or trade-offs must be made with the spirit of defending the requirements of each particular climatic factor. This is necessary to ensure, as Alexander notes, the "...internal fitness..." in order "...to control its fit as a whole to the context outside" (1964, p. 18). Popper observes that "... many theories (or solutions) would be abandoned before their strengths were discovered if they were not defended strongly by their proponents" (1963, p. 312). However, in the author's model, once the final synthesized plan is agreed upon, all the team members would drop their partisanship for their particular plan and would support the synthesized plan.

The synthesized climatic plan (Cl.) would then be synthesized in a similar manner with the synthesized plan of the geological and hydrological plan (G./H.) and the synthesis plan for the technical and social service infrastructure plan (T.S.I./S.S.I.) thereby completing the synthesis for the first three levels.

2.2.4 Level Four - Cultural Factors

The cultural requirements would be integrated into plan form through the use of a scale model of the site with scale blocks representing the houses, as well as the technical and social service buildings. The future residents of the new village would be grouped into extended or kin-related groups. In the case of village expansion, the cultural factors may be integrated into an extension of an existing village to counteract any culturally inappropriate design. Traditionally, Inuit families functioned on the basis of regular consultation (Williamson, 1974, p. 30) so that working in kin-related groups would be natural, except perhaps for some of the people in the 18-29 age group who are often in the process of redefining their relation to traditional cultural forms.

This group composition would permit a more natural consultation amongst the people because they are consulting members of their own family with whom they can disagree without causing ill feelings. Also, by consulting the extended family, the consulting group dominates in numbers the group conducting the consultation or participation process (anthropologists, architects or planners). In the author's experience, having consulted the Inuit one by one and in family groups, the latter is preferable, because the familiarity within the group enables the responses to be less inhibited, providing the stimulus for open interaction. There is, however, the danger of a person with a strong personality dominating the consultation. This could deform the group's response, but by consulting all the family groups and making a synthesis of the plans into "typical" plans, such a deformation could be moderated in the process of synthesis.

Working with extended family and kin-related groups would bring the number of people (above the age of 18) involved in the consultation from a minimum of 6 persons (the average family in Great Whale River in 1979 had 5.7 persons (Pluram, 1979, p. 214) which corresponds closely to the 6.2 person figure in Povungnituk in 1972 (Nunaturliq, 1974, p. 121)) to an approximate maximum of 14 persons. This is based on the age pyramid for Great Whale River (Pluram, p. 41) where 5% of the population is in the age group of 56-65 years. Using the lower limit of 56 years and the assumption that no one would marry below the age of 18 and all would have four children, this would give the maximum number of people in the same family (18 years or older) to be 14. This size

of group is sufficiently large to ensure a variety of opinions and ideas, but sufficiently coherent that a consensus could be reached within the group. It is important to ensure that everyone in the group over the age of 18 is being consulted because quite often the women are left out or do not feel at ease in group discussions. This can sometimes be overcome if the model is brought to their homes where the whole family can consult informally. Another group often forgotten in the consultation is the 18-29 age group who though not usually included in the decision-making, form the group who will be making the decisions in the near future and are those whose image of their culture is the most likely to change. It is therefore important to integrate their ideas and opinions in the form of a village plan. If it is observed that they are not having an input into the kin-related group-generated plans, then it may be necessary to carry out special consultation with this group.

The plans formulated by the various groups would be compared for common elements or concepts and classified into categories. The concepts and notions behind the plans would be studied to determine the existence of any patterns which would be compiled for each category. Plans would then be generated by the architects, planners and anthropologists responsible for directing the user participation process, synthesizing the plans within each category. These "typical" plans would contain the major concepts and patterns in each category.

The various "typical" plans would then be presented and explained in detail to the community in a general meeting. The "typical" plans, by integrating the common aspects of all plans within a category, would remove personal identification from the plans with its attendant problems of partisan voting for personalities. The plans produced by the 18-29 age group, if this group is set up, would be one of the "typical" plans presented for vote without being identified as such. The voting members of the community (age 18 and over) would then be asked to vote by secret ballot for the plan of their choice.

The plan receiving the most votes would then be verified to ensure that it included the more important patterns and concepts contained in the other categories of plans. This plan generated by cultural factors (Cu.), would then be synthesized with the synthesis of the G./H.; T.S.I./S.S.I.; and the Cl. plans. See Fig. 161 for the synthesis procedure at this level.

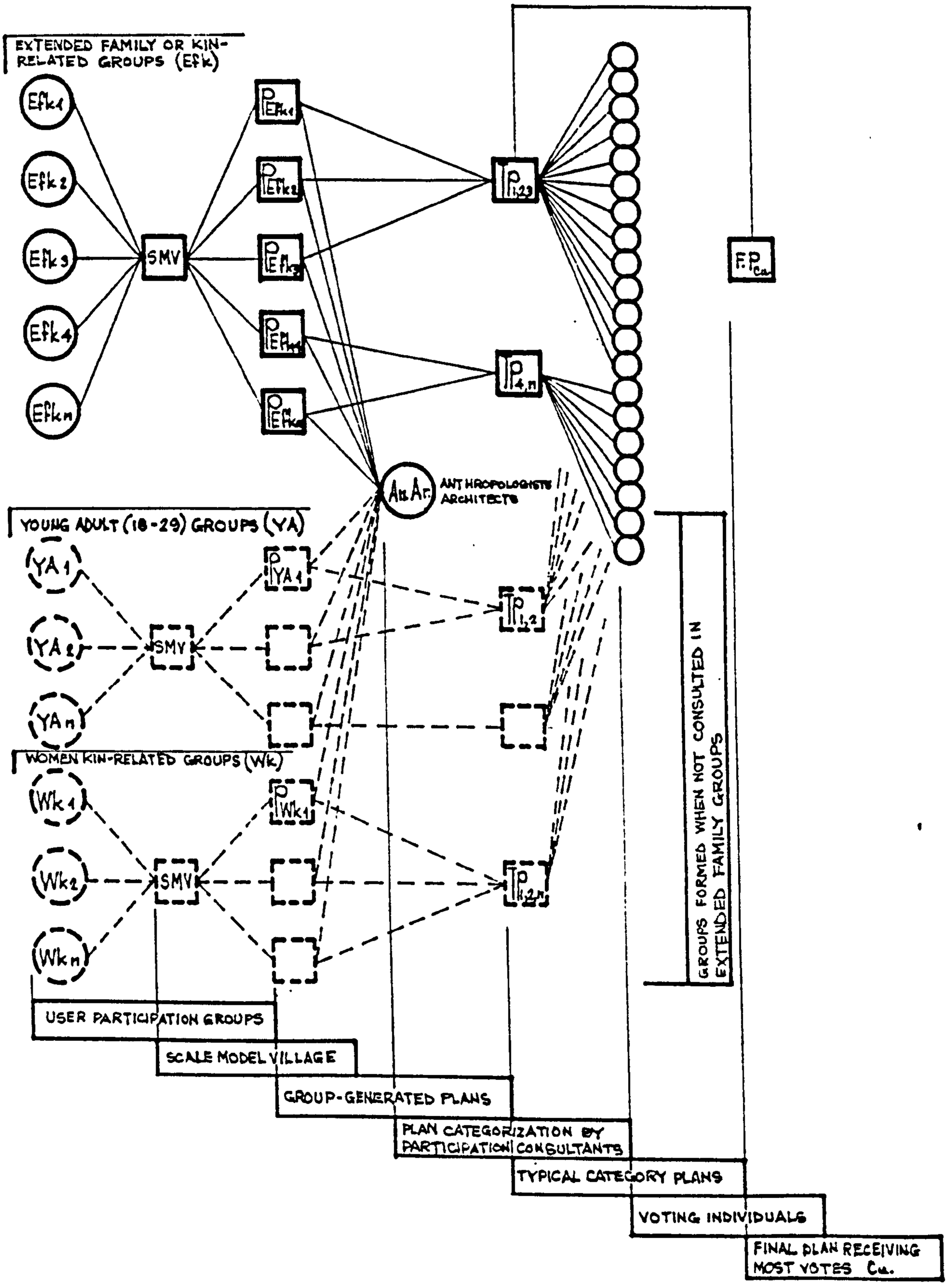


Fig. 161. Synthesis Process - Cultural Factors.

2.2.5 Final Synthesis

This procedure progresses through the various levels of technical complexities, terminating with the cultural factors which are the most difficult to obtain and the most difficult to integrate in the plan. During the procedure, specialists will have become familiar with each other's requirements and after several consultation sessions, involving various compromises, will have arrived at a plan that incorporates the majority of the more important elements contained in the plans produced for the various level's requirements. The evaluation during the consultation would not be made entirely on economic considerations. For example, when the climatic factors are being assessed, the comfort-protection requirements cannot be evaluated directly in economic terms, whereas the snow accumulation factors can. The first two levels of requirements (geological-hydrological (G./H.) and technical-social service infrastructure (T.S.I./S.S.I.)) can be judged on economic values, so it is appropriate that they be combined in the first synthesis. The cultural requirements, which involve the user in the planning process, has to be assessed more subjectively because a scale of positive and negative values is difficult to assign to such factors. The population has to decide which cultural patterns they believe must be kept at all costs; which ones can be modified slightly; and which ones can be modified greatly. This gradation would permit dialogue and discussion which would eventually lead to agreement on an acceptable compromise in a plan retaining the most important factors, while modifying portions of the plan controlled by factors of lesser importance. It is also important not to keep bringing the population back for a prolonged series of plan dialogues because they might become disenchanted with the process and regard it as an academic or theoretical exercise involving the white man's propensity for prolonged abstract discussions. This is why the cultural requirements are integrated in the last phase of the synthesis process although a group designated by the community would follow all phases of the synthesis procedure. This group of Inuit would be made up, ideally, of the leaders of the various clan groups.

The final phase would involve the synthesis of the cultural requirements generated plan with the synthesis of the plans at the three other levels (Cu. - G./H. - T.S.I./S.S.I. - Cl.). Any conflicts resulting from the

synthesis would be discussed with the specialists and elected representatives of the village who would defend the cultural plan in the negotiation process. After explanations by the Inuit representatives and the specialists, concerning the advantages and disadvantages of the two plans (the Cu. plan and the synthesis of the G./H.; T.S.I./S.S.I.; and Cl. plans) in relation to the areas of conflict, negotiations would take place with compromise and trade-offs until a plan acceptable to both groups was arrived at. The process of compromise could take some time if certain aspects of the cultural plan, which are in conflict with the synthesis plan of the three other levels, are essential to cultural traditions. A trade-off might involve, for example, the acceptance by the Inuit of higher installation or maintence costs if a cultural pattern which is in conflict is deemed crucial to their needs.

When the final plan is agreed upon, it would then be resubmitted to the people in the village for their comments on the compromises made. If a compromise was made that was not acceptable to the majority of the people, negotiations would be reopened with the specialists to produce another plan which would resolve the objections raised by the community. Once the plan resolved all objections, it would then proceed to the contract plan stage and finally to the implementation phase. See Fig. 162 for the total synthesis procedure for the Four-Level Model.

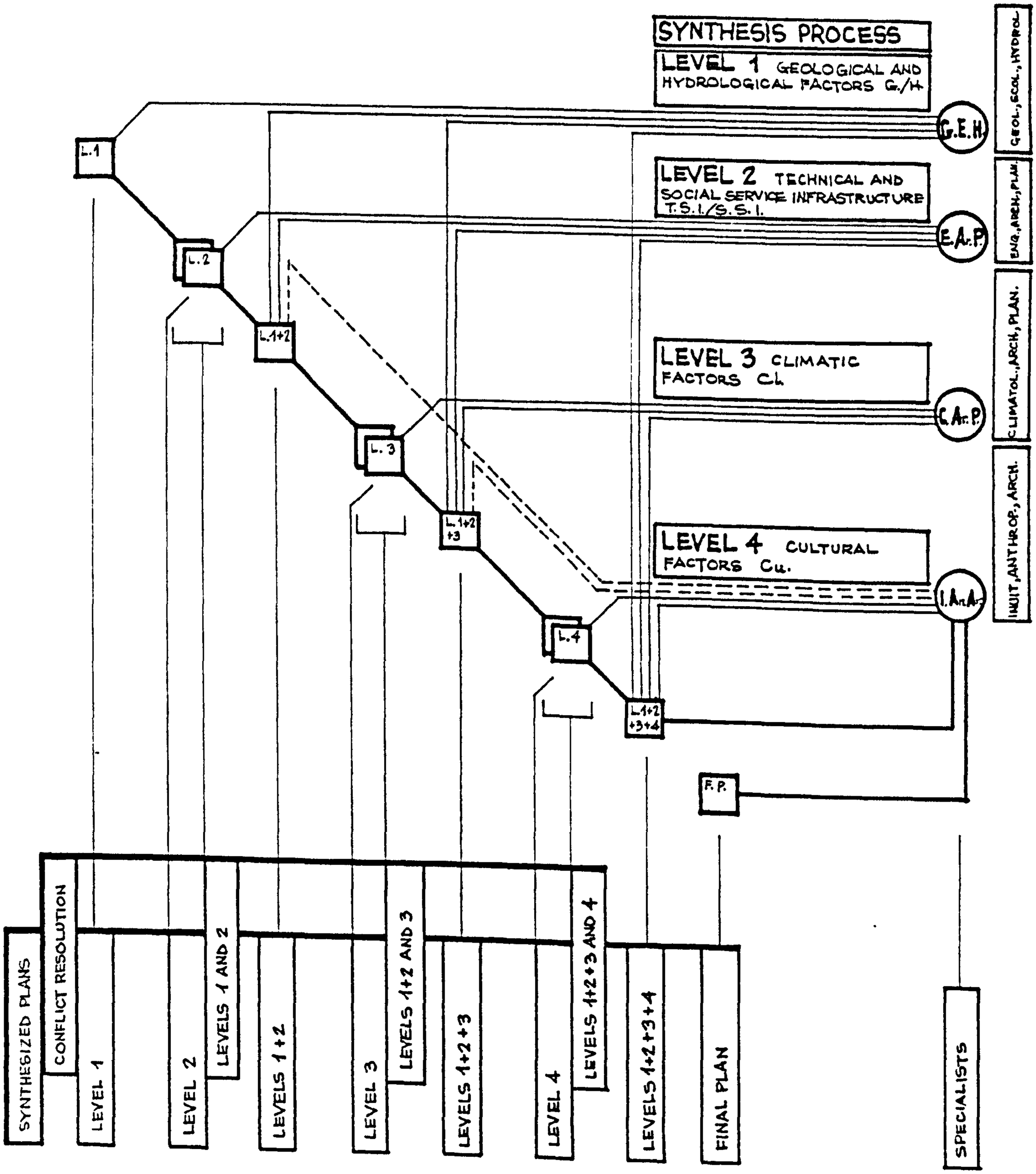


Fig. 162. Total Synthesis Process.

CHAPTER THREE

3. HYPOTHETICAL CASE STUDY

In order to illustrate and test the model proposed, it was felt that a hypothetical case study should be carried out. In lieu of taking an existing village and using its site, or taking a completely hypothetical site, it was decided to use a site for which a village has been proposed but not yet built. The site for the new village at Richmond Gulf in Arctic Québec was chosen because information was available for use at the four levels of planning. Particularly important is the existence of 2 plans for the village generated by the Inuit. The site is shown in Fig. 163.

The number of houses in the plan proposed by the planners for Richmond Gulf is 94, consisting of 51 detached houses, 16 duplexes, and 27 triplexes, making a total of 164 housing units (Pluram, 1979, p. 153). For the purposes of this paper the houses will be considered to be all detached and the plans will include a minimum of 100 houses.

3.1 Level 1 Requirements - Plan Generated by Geological and Hydrological Conditions

Analysing the site contours indicates that the land rises gently to the east from the sea at a slope of less than 15% in the area between the streams to the south and the river to the north (Pluram, 1979, p. 8). Therefore, the site would permit the placement of detached houses without any difficulties.

The soil composition is mainly sand and silty sand (pp. 80,102) which is suitable for the support of most small and medium size buildings. Thus buildings such as the school as well as detached houses could be built on the site.

Because the slope of the land is less than 15%; the soil is sand and silty sand; and a stream drains most of the surface water; the site would not be subject to serious soil erosion (idem). Wind erosion, however, seems to be a problem, having caused the hollow in the northeast corner of the site (pp. 102, 104). It would seem wise, therefore, to avoid construction in the area of the hollow. There are also problems of earth stability near the river to the north, requiring a safe distance between the buildings and

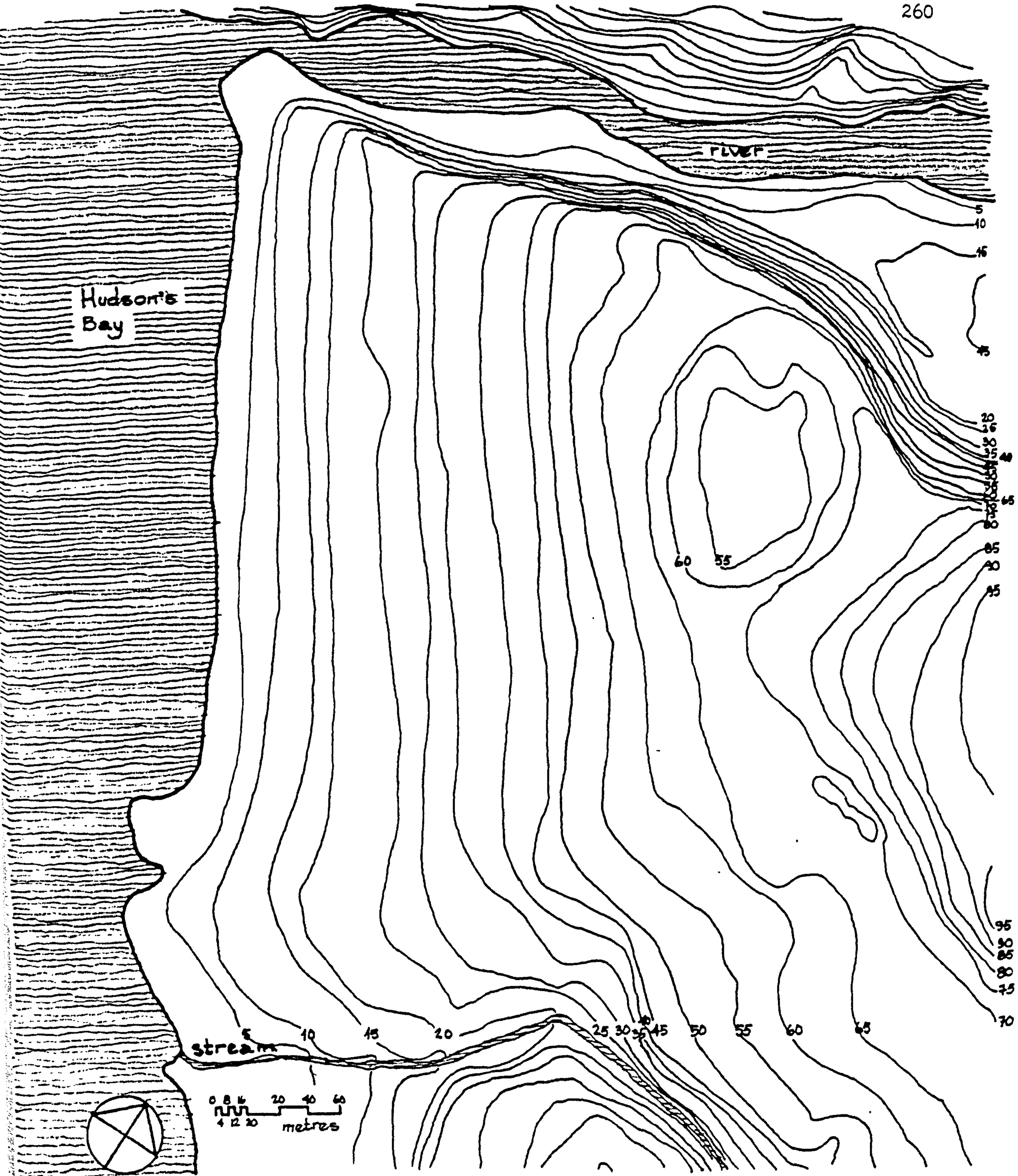


Fig. 163. Site of the new village of Richmond Gulf, Arctic Québec (from Pluram, 1979).

the edge of the steeply sloping land near the river (p. 104). Building too close (40-60m) to the sea's edge is also to be avoided because of the buildup of ice on the beach during high tides (p. 102).

Potable water is available from the river at a distance sufficiently upstream so as not to be affected by the salt water of the sea at periods of high tides and strong westerly winds (pp. 164-172). Thus the pumping station should be placed to the eastern limit of the site and generally not too distant from the river.

The plan in Fig. 164 shows the plan generated by Level 1 requirements. It can be seen that the houses are all laid out parallel to the land contours with the larger buildings placed in the zones where the slope is more gentle. The houses are set back from the sea's edge at a distance of between 60 to 90m and are a minimum of 25m from the unstable land that slopes down to the river. No buildings are built in the wind-eroded hollow, nor is the hollow filled in to allow the construction of a large building, because of the danger of the wind erosion. The water-pumping station is placed at the eastern extremity of the site and approximately midway between the stream and the river. No consideration was given to the centrality of services such as the school, store, infirmary and the electricity generation-pumping station, as the slope dictated the location of the buildings according to size. The roads run perpendicular to the sea in the direction of the slope of the land in order to avoid the damming of water run-off which would cause flooding, destroying the roadbed and disrupting building foundations uphill from the roads (Environment Canada, 1979, p. 2-21). The plan presented is the author's version of a plan generated by level 1 requirements.

3.2 Level 2 Requirements - Plan Generated by Technical and Social Service Infrastructure Factors

The technical services infrastructure can influence the layout of a village greatly because of the requirements imposed by the water and sewage network if piped systems are used and also by the electricity supply lines. The social services, if they are planned to be as close as possible to the greatest number of people, would also have an important influence on the plan of a settlement. Thus the technical and social services infrastructures are treated at this level in two separate stages.

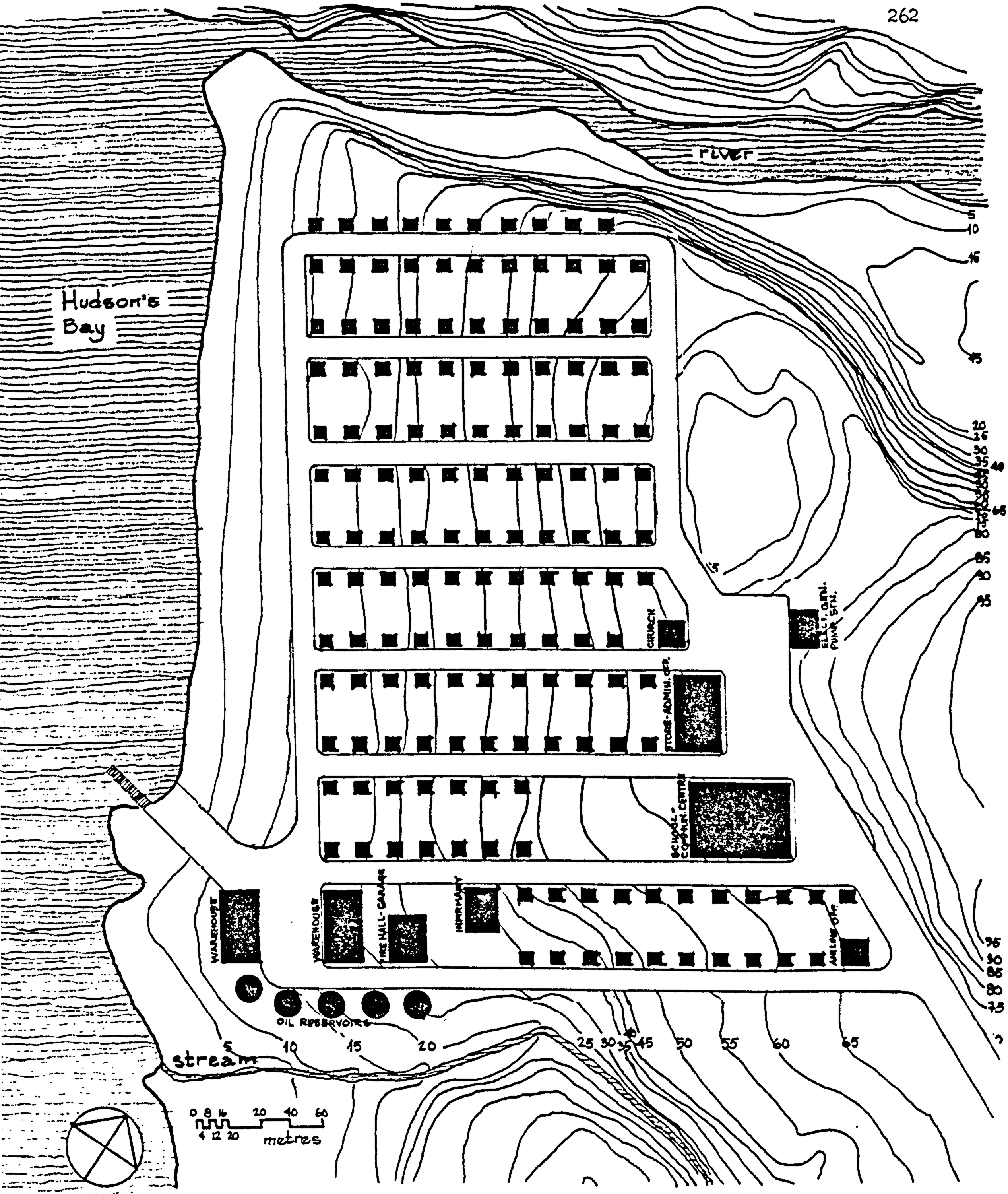


Fig. 164. Plan generated by Level 1 requirements - geological and hydrological considerations. (154 houses)

3.2.1 Level 2A - Plan Generated by the Technical Service Infrastructure

One of the major influences on the layout of a settlement is the delivery of water and the collection of sewage. Of the piped systems, a single pipe recirculation type, installed below grade at the back of the houses, is strongly recommended for the Arctic (Environment Canada, 1979, pp. 2-22 to 2-26; 2-46 to 2-47; 6-18 to 6-21; and section 9). The plan shown in Fig. 165 is based on an ideal town layout for a single-pipe recirculation system (Environment Canada, 1979, p. 6-29). The circulation of water is facilitated through two loops, one north and the other south of the water pumping station centrally situated in the village.

The electricity lines are laid out in straight lines branching out from the electricity generation - water pumping station. Two transformers, placed centrally in the northern and southern sectors of the settlement, assure that the maximum 400' (122m) distance from the transformer is respected (Lynch, 1970, pp. 184, 185).

The sewage lines are the gravity type and run from the north and south extremities of each block towards the centre of the settlement joining with the main line running east to west, terminating in the sewage disposal near the dock. An Imhoff tank would be the primary treatment of the wastewater before disposal into the sea (Pluram, 1979, 196-198).

It was decided to use an underground piped water and sewage system because it is more hygienic than the delivery of water by truck and the collection of sewage in plastic bags. The piped system has a higher capital cost than the delivery and collection by trucks, but has a lower maintenance and operating cost (Pluram, 1979, pp. 284, 288, 334 and 340). The piped system could be installed in phases with the truck delivery and collection system being used until the entire piped system was phased in. The residential streets all branch off the central service spine making the delivery of services and the collection of waste relatively easy. The fuel tank depot is close to the dock and to the water for direct provisionment.

This plan represents the author's interpretation of a plan generated by the technical service infrastructure requirements at level 2A.

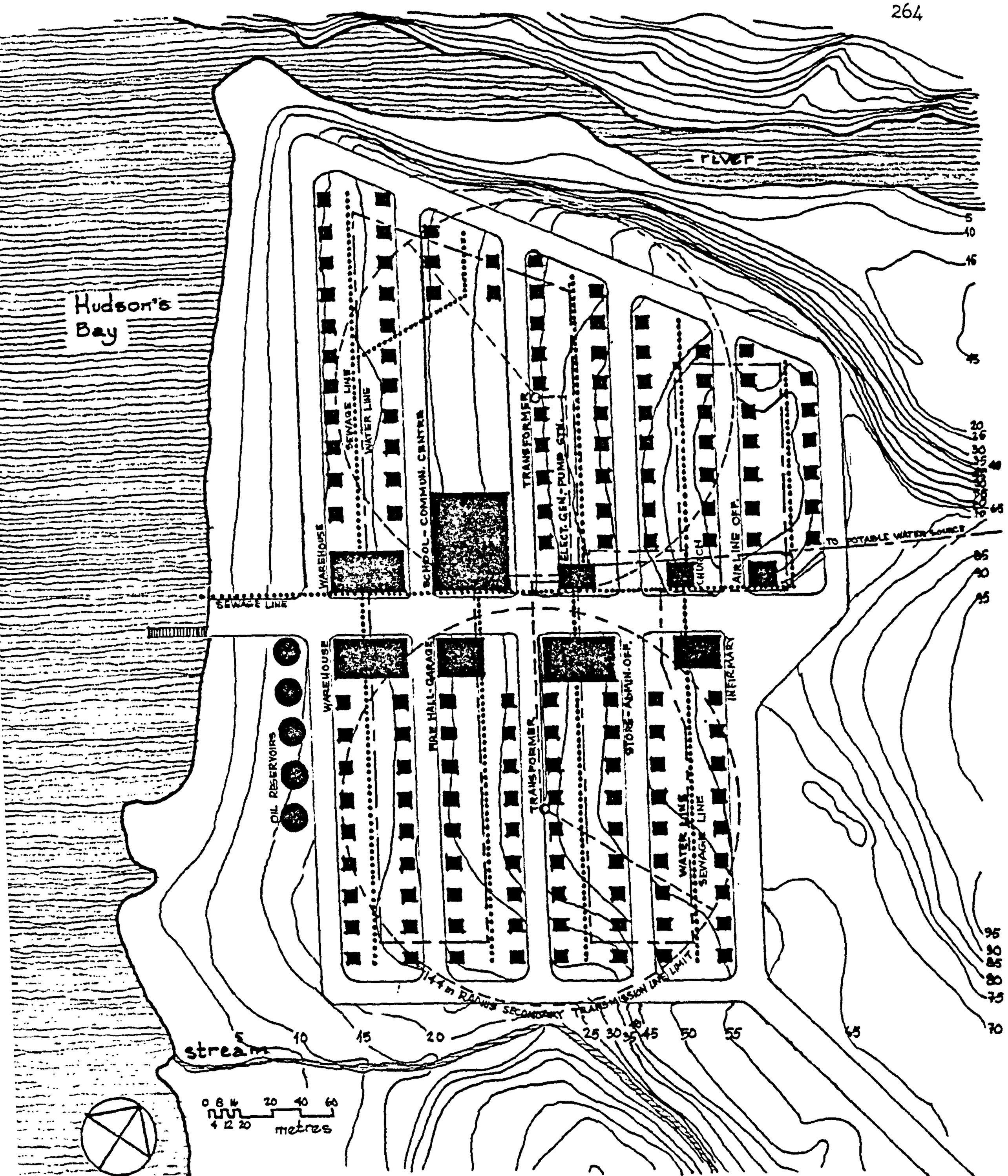


Fig. 165. Plan generated by Level 2A requirements - technical infrastructure considerations. (146 houses)

3.2.2 Level 2B - Plan Generated by the Social Service Infrastructure

For the social services, the entry and the movement of goods and people is of prime concern. The plan in Fig. 166 groups all the social services in the centre of the settlement with direct road connections from the dock and the airport. The houses are laid out on circles radiating out from the central service core formed by the first circle. Because the houses radiate out from the centre, distances to the service core centre are minimized and all houses in the same circle are the same distance from the centre. Another feature of the plan is that many of the houses that are the furthest from the centre are the closest to the water, thereby compensating these households for their greater distance from the centre by a closer distance to the sea. Older people could be housed closer to the central core with young families and hunters further out. The paths which lead to the centre divide the ring of houses into groups of 4 to 14 houses which could become the basis of kin-related groups.

The school, store - community centre - administrative centre, church, and the infirmary are all situated immediately adjacent to the geometric centre of the settlement. Other services, such as the warehouses and garage-firehouse are located behind the infirmary, while the electricity generation-pumping station and the airline office are located on the periphery of the first circle because people tend to use them less frequently. One warehouse is located directly on the access road from the dock and the other near the airline office which is on the road to the airport. The airline office marks the entrance of the airport road into the service centre core, making departures and arrivals readily accessible to the infirmary and store without congesting the central area.

The school is central and has two playgrounds, a smaller area for younger children on the north side of the school, and a larger area for older children to the east. The houses near the school could be allocated to the teachers giving close access to the school.

The water pumping station is located at the eastern extremity of the central core where the water line would enter the village from the river. The garage-firehouse is also on the southeastern extremity of the central core

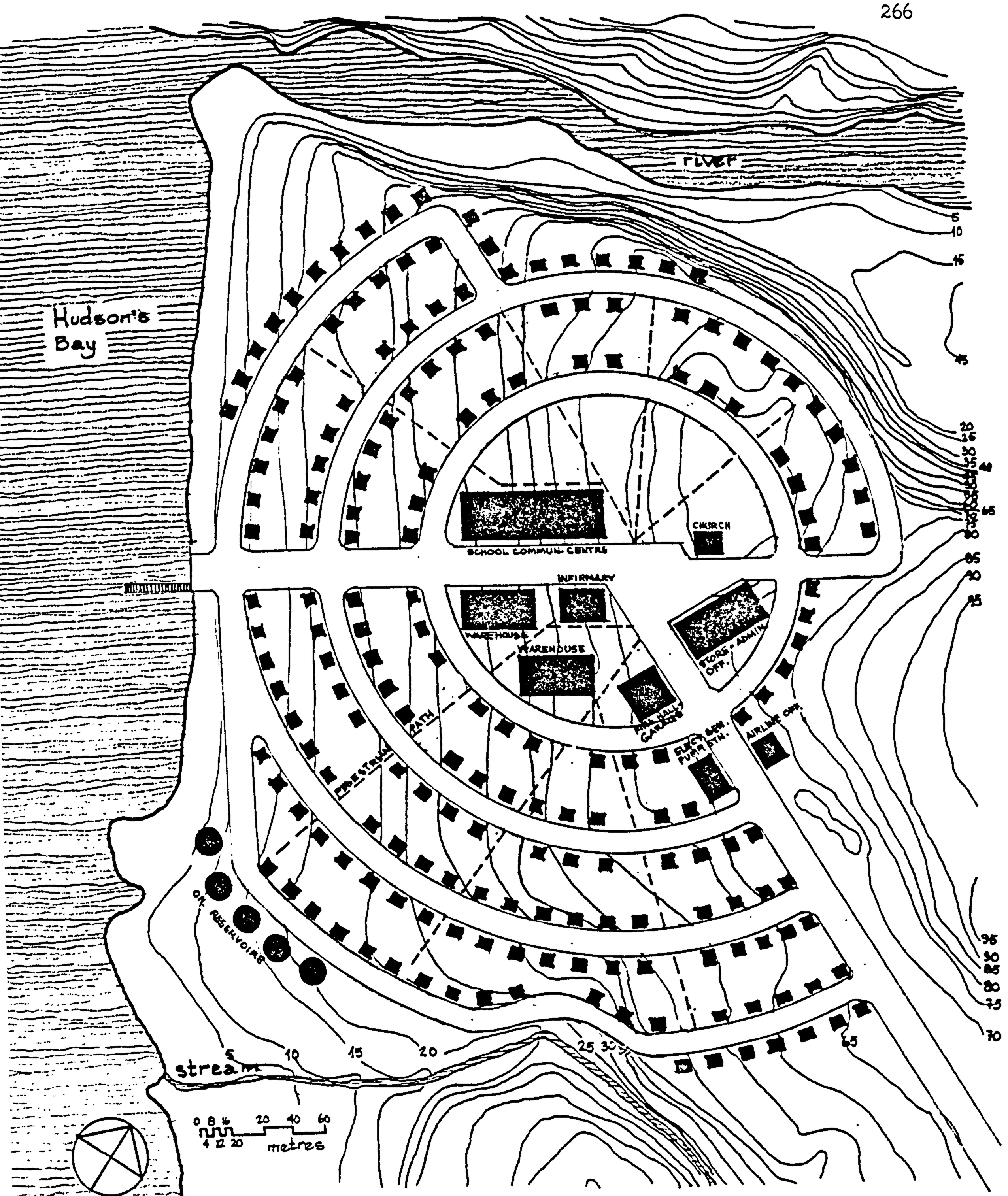


Fig. 166. Plan generated by Level 2B requirements - socio-institutional infrastructure considerations. (187 houses)

allowing the fire truck quick access to any of the circular roads and thereby to the houses, and to the airport, and dock via the central roads. This plan represents a plan generated by the social service infrastructure requirements at level 2B.

The process of synthesizing the plans at levels 2A and 2B into a single plan for level 2, as well as the synthesis of plans for levels 1 and 2 into a single plan fulfilling the requirements of levels 1 and 2 will not be carried out, because the author feels that to attempt to simulate the result of a complex process of consultation, negotiation and trade-offs between the specialists who would be involved, would bring too many personal biases to the final plan, and would probably not be indicative of a synthesis generated by these specialists. Therefore, the author will only carry out the synthesis process for the plans at levels 3A, B and C (the climatic level) in order to illustrate the result of the process.

The synthesis of the resultant plan of levels 1 and 2 and the synthesis of level 3 will also not be attempted for the above mentioned reas. Level 4 will also be illustrated by the examples of plans generated by user participation, without any attempt at synthesis. The method will therefore be illustrated in its synthesized parts, or sub-levels, but not in its synthetic whole. The model will therefore remain 'static' until it is rendered 'dynamic' in a real world situation, the design of a settlement.

3.3 Level 3 Requirements - Plans Generated by Climatic Factors

The climatic factors to be considered as mention in the description of the four-level model (Section 2.1.3), are solar shading, wind and snow. These factors are treated separately so that a plan can be generated for each factor that would satisfy the requirements of that particular factor alone. The author believes that in this way no compromises will have to be made when fulfilling the requirements of one climatic factor alone, and that each factor's requirements can be satisfied completely.

3.3.1 Level 3A Requirements - Plan Generated by Solar Shading Considerations

The solar shading requirements, which state that for the period of May 6 to August 4, at least 30% of the space between buildings facing each other which form a major pedestrian path or public gathering place must be in

sunlight from 9:00 to 16:00; it would seem that the best way in which to avoid shading of spaces between buildings would be to place the buildings far enough apart that their shadows do not completely cover the space. At 9:00 for one-storey buildings, this would mean placing the structures at least 7.3m apart, and allowing a distance of 13.1m for two-storey structures. Since the minimum road width is 15.2m, there is no problem meeting this requirement for the May 6 to August 4 period, but if the same requirement was demanded for the period from February 5 to May 5, there would be some difficulties because the one-storey shadow on February 5 is 40m long. At the equinox the shadow would be 12.5m for a one-storey building and 22.9m for a two-storey structure. See solar altitude, azimuth and shadow lengths in Appendix II-D.

Since the school, infirmary, and store are often 1½ to 2 storeys high, it would be logical to place these buildings to the north of the settlement so that no shadows are cast by these buildings on the houses or public spaces. Thus in the plan shown in Fig. 167, all the service buildings are located at the north and northeast sector of the village. The shadows drawn on the plan are for February 5 and November 6, and show that no shade occurs on the areas directly in front of the infirmary, school, and store, - the buildings that people use most frequently. The fuel storage tanks, garage-firehouse and warehouses are situated behind the most frequented buildings and are in shade throughout the whole day on February 5, as the shadow at 12:00 noon is 30.8m long and the space between the buildings is 25m. The public spaces in front of the store, school, infirmary, and church are always in full sunlight and therefore completely fulfill the solar shading requirements (the dotted lines on the airline offices (A.0) shows shadow limits at 9:00 for 21 March, 6 May and 21 June). However, the roads between the houses is in shade during the whole day because even at 12:00 noon the shadow is 17.1m long, and the spaces between houses is 15.2m. Therefore, pedestrian paths are laid out not in the streets but in the space between the houses inside each block which gives more sunlight on the pedestrian path than if it was in the street (see dotted line behind houses showing the limit of the 12:00 shadow). This also fulfills the requirement that there must be an average of 50% of the area between building groups in sunlight between 9:00 and 15:00 on November 6 and February 5.

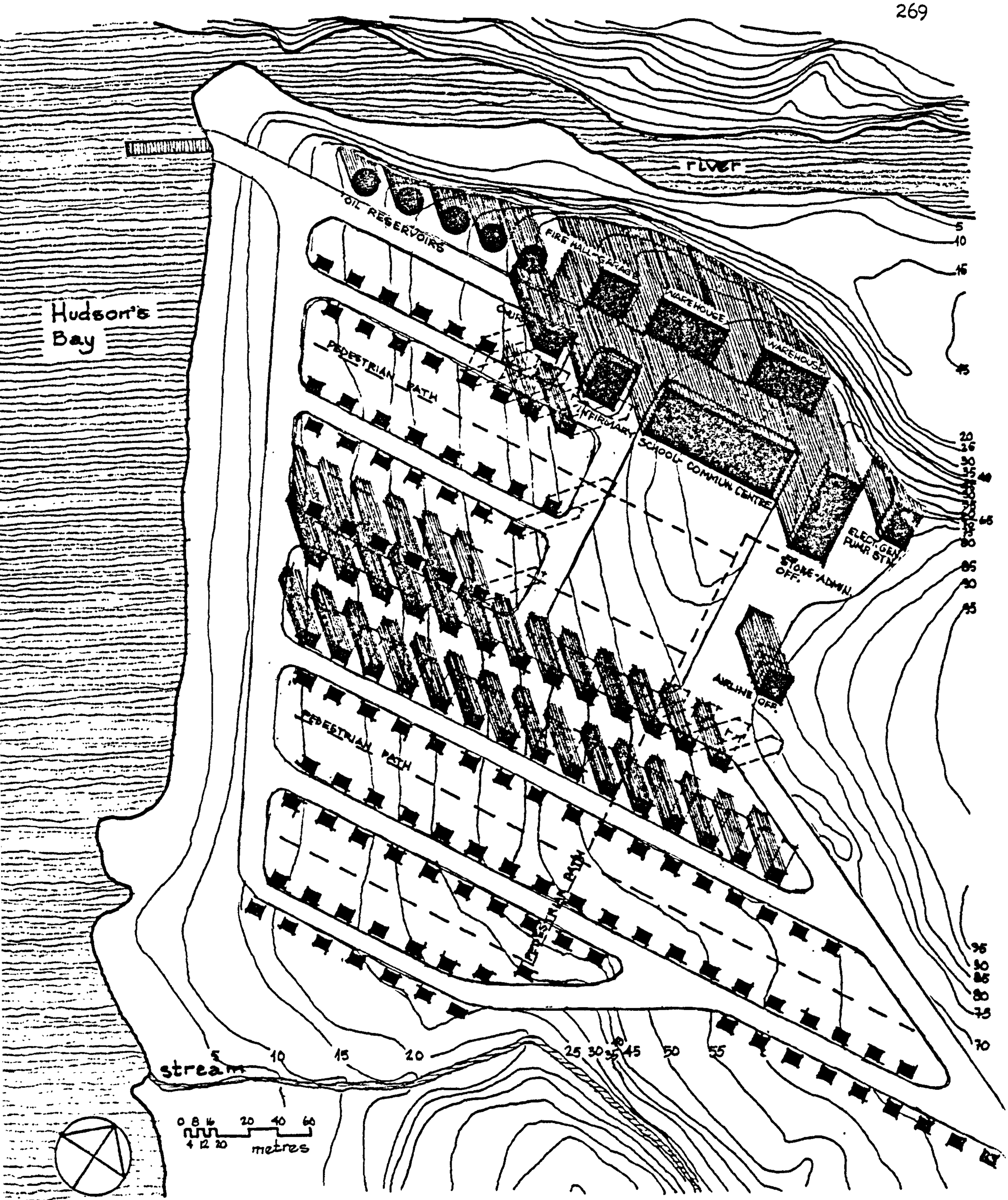


Fig. 167. Plan generated by Level 3A requirements - solar shading conditions. (134 houses)

The shadows of this plan were calculated using mathematical formulae for the solar altitude and azimuth (Lynch, 1979, pp. 69-73). It is a time-consuming method for discovering the solar shading effect of a town layout because of the number of calculations involved for the various hours of the day and the various seasons. Altitude and azimuth data can be taken from solar charts which give this data for various latitudes, month, and hours (see "Sun Angles for Design", R. Bennett, 1978). It's precision depends on the scale of the plan and the precision of drawing and measuring instruments.

Another method simulates the sun's movements through a combination of moving lights and adjustable table called a heliodon. Adjustments are made on the table and/or lamp for the latitude, the season, and the hour of day. This method requires the fabrication of a model which is a time-consuming process, and there may also be scale imprecision in its construction. The adjustment of the lights and the table can create small errors which when added to the other possible sources of error can cause a degree of imprecision. Koenigsberger et al., (1973, pp. 269-271) show examples of several heliodons, while Olgyay (1963, pp. 180-185) describes a more complex thermo-heliodon which includes thermal and air movement simulation in addition to solar shading. The more simple heliodon is the more commonly used simulation device for architectural and town planning, because of its relatively low cost and its visual presentation. It involves a good deal of time in the fabrication of the model and has the danger as Broadbent notes, of designers becoming attached to their models and being unwilling to seek out and test alternatives (1973, p. 94).

Another simulation technique is a computer solar shading program which calculates and draws the shadows automatically once the layout is fed into the computer. Depending on the precision of the mathematical model used and the amount of computer time available, a very accurate solar shading printout can be obtained in a very short time. Shading patterns for many seasons can be superimposed automatically and percentage periods of sunlight can be calculated very quickly. Changes to the layout can be made and tested in less time than by the calculation and heliodon method. The display of shadows can be given in percent figures at node points on a site grid, or can be given in darkness intensity to visually illustrate the percent of time that an area is in the shade. See Figs. 168 and 169 for

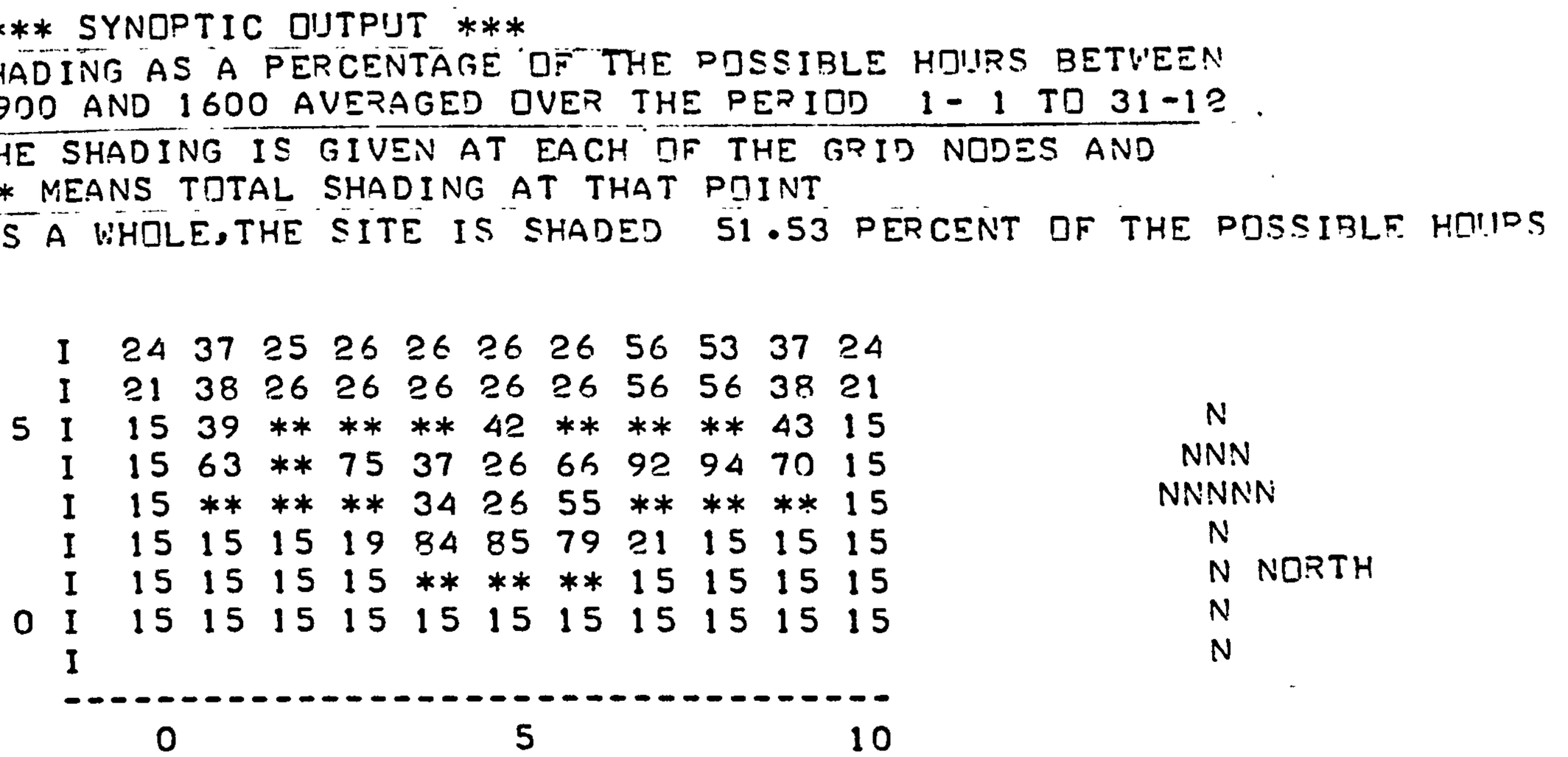


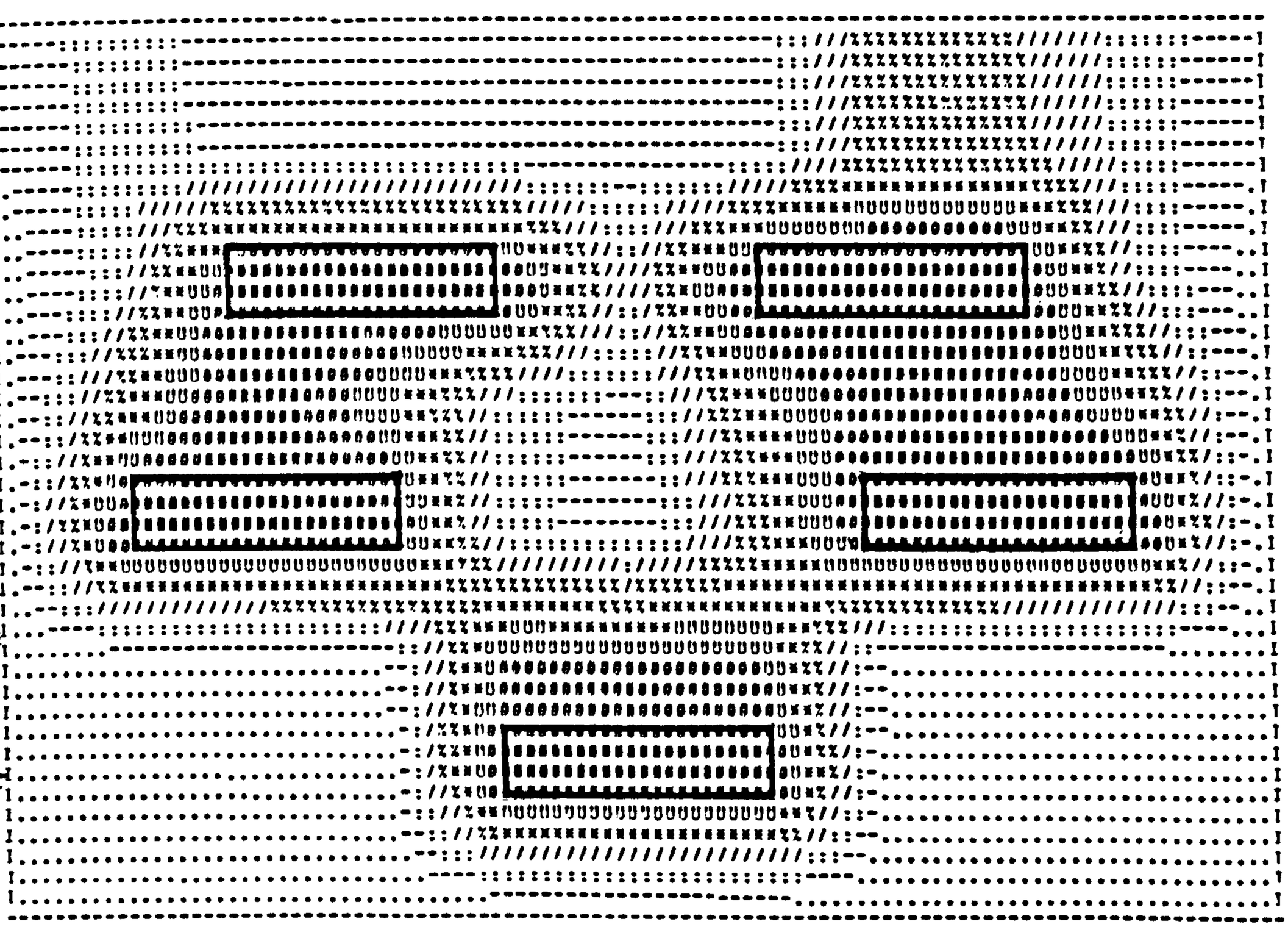
Fig. 168. Computer display generated by program, called SHADE developed by Smith and Wilson (1976).

examples of these two display methods generated by a computer program (SHADE) developed by Prof. C.B. Wilson and Dr. F. Smith of the Department of Architecture, Edinburgh University (for a description of this program see Smith and Wilson, 1976). For other examples see Mitchell (1972, p. 75)and Arumi (1977, p. 154). Arumi also points out the difference in shade values obtained by hand calculation methods and those obtained by his computer program which indicate that the errors in the hand calculation method are unacceptable (Arumi, and Dodge, 1977, pp. 186-189). Another computer display technique is described by Gero (1977, pp. 285-303) which gives a graphic display of the buildings and their shadows at the time intervals chosen. See Fig. 170 for an example of this type of display technique. This technique is visually clearer and more precise than the examples in Figs. 168 and 169, but it is costly when taking samples over longer periods than just one day.

A very sophisticated computer display technique is described by Rogers et al. (1978, pp. 97-109) which consists of computer generated shadows and perspectives of buildings in colour. See Fig. 171 for an example. However, this technique would likely be too costly for most solar shading studies at this time.

The precision of the various solar shading simulation techniques varies greatly, but because the importance of accuracy at the level of predicting

A MAP OF THE AVERAGE SHADING BETWEEN THE HOURS OF 900 AND 1600 OVER THE PERIOD 1 - JAN TO 31 - DEC INCLUSIVE



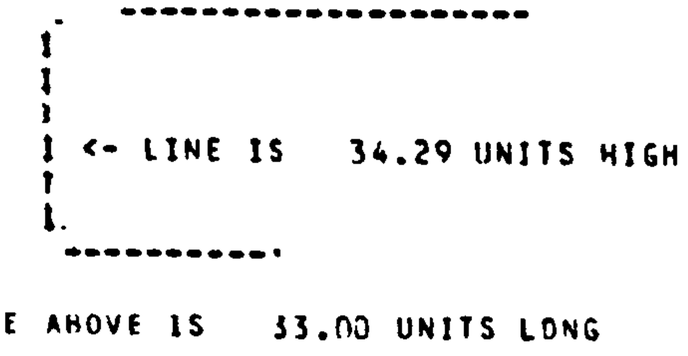
THIS IS A MAP OF THE SHADING DUE TO THE FORMS WITH THE FOLLOWING REFERENCE NUMBERS
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

KEY TO SYMBOLS

blank REPRESENTS 0 TO 10 PERCENT SHADING
. REPRESENTS 11 TO 20 PERCENT SHADING
- REPRESENTS 21 TO 30 PERCENT SHADING
: REPRESENTS 31 TO 40 PERCENT SHADING
/ REPRESENTS 41 TO 50 PERCENT SHADING
% REPRESENTS 51 TO 60 PERCENT SHADING
≥ REPRESENTS 61 TO 70 PERCENT SHADING
U REPRESENTS 71 TO 80 PERCENT SHADING
REPRESENTS 81 TO 90 PERCENT SHADING
@ REPRESENTS 91 TO 100 PERCENT SHADING

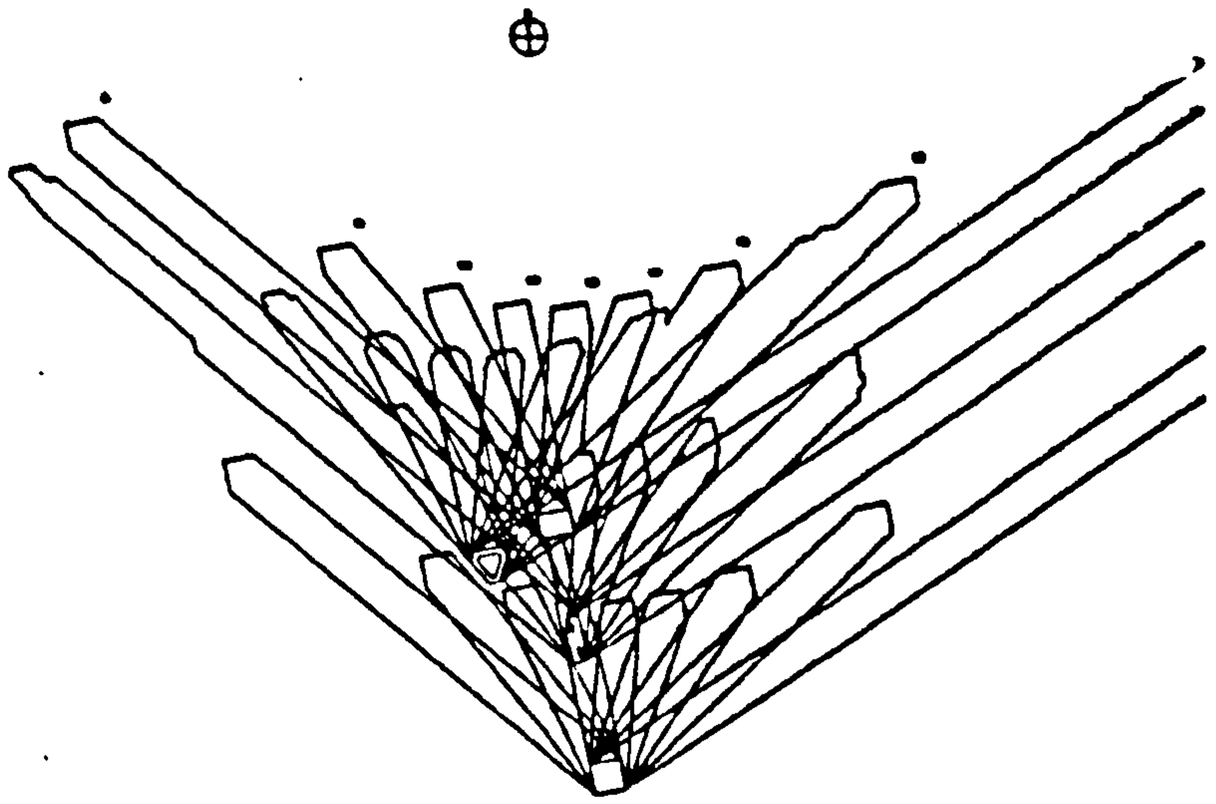
N
NNN
NNNNN
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NORTH

KEY TO LENGTH SCALES



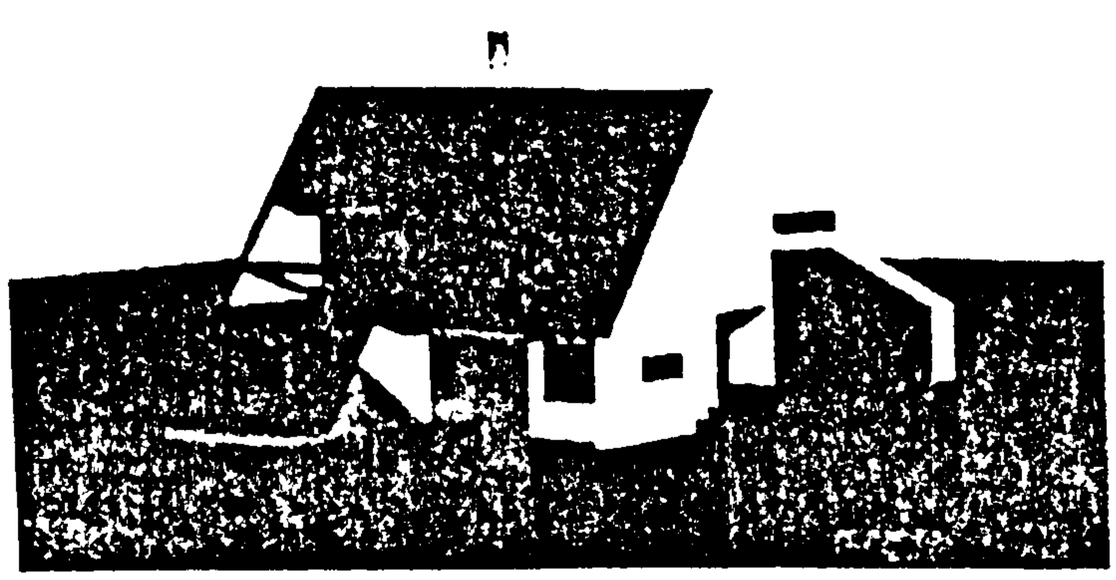
LINE ABOVE IS 33.00 UNITS LONG

Fig. 169. Computer display map generated by Smith and Wilson's SHADE program (1976).

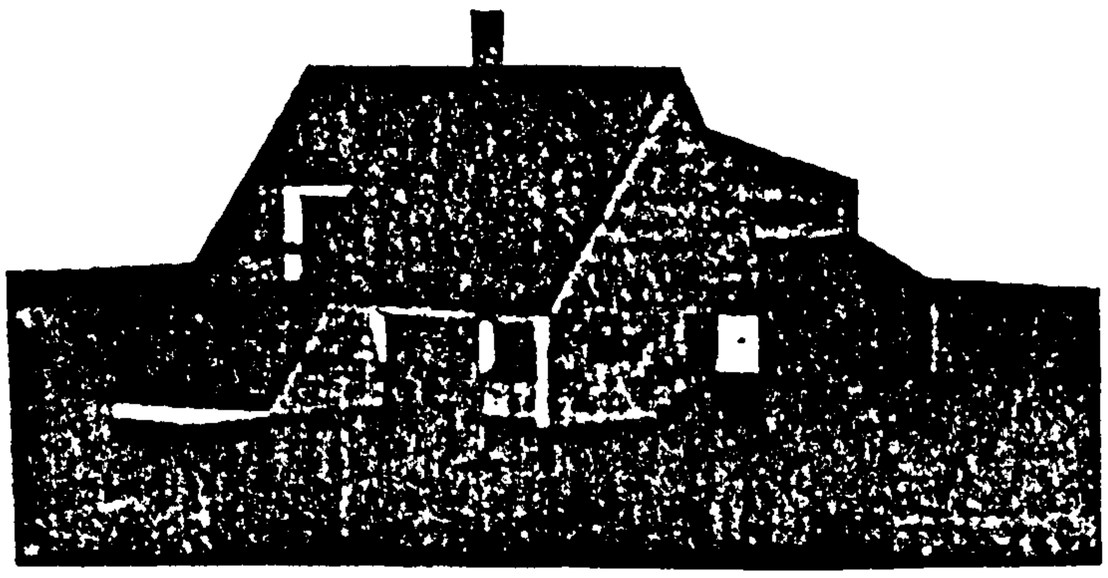


Shadows in a day of high-rise buildings. Shadows plotted at one-hour interval. (Nikken Sekkei Ltd.)

Fig. 170. Shadow graphic generated by computer program (from Gero, 1977).



Visual examination of a simulated shadowed site
Views at 11:00 AM (mid-winter day)



Visual examination of a simulated shadowed site
Views at 2:00 PM (mid-winter day)

Fig. 171. Three dimensional shadow display technique generated by a computer program (Rogers et al. 1978).

sunlit spaces for human comfort is less than that required for the prediction of the amount of sunlight for solar energy systems, most of the above techniques are equally valid. However, certain computer programs can be less costly than the hand calculation method because less man-hours are used and alternatives can be explored in much less time than with the hand calculation and heliodon techniques. The author feels that a computer program similar to the one developed by Prof. Wilson and Dr. Smith could be an appropriate technique if the buildings themselves could be drawn on to

the graphic (Smith and Wilson, 1976, p. 195), and if the number of nodes could be augmented to increase the definition and the precision of the shadow lines.

The plan generated by the solar shading requirements could be produced by the above-mentioned computer shading program either in its entirety or in zones, depending on the computer time budget available. The author proposes the use of a computer solar shading simulation technique or a heliodon if no computer program is available.

3.3.2 Level 3B Requirements - Plan Generated by Wind Protection Needs

The plan is based on the premise that wind protection would be required for the outdoor areas where people are most likely to gather. These spaces are found in front of the store, the school-community day care centre, infirmary, and the church, and are the normal places where people would meet and spend time chatting. It was decided that these services should be grouped into a continuous protective-wall type building so that the spaces immediately in front of the buildings would be protected from the full force of the wind.

In order to create a building sufficiently long to provide the protection required, the school had to be broken up into 4 separate modules. Each module as well as all the other services are separated by a distance of 17m to prevent the spreading of fire from one building to another, which necessitates the addition of a smaller connecting element between buildings so that a continuous protective wall can be achieved. The connecting element could be an unheated corridor which provides a pedestrian link between buildings and also carry utilities. It could be provided with automatic fire doors so that fire spread can be controlled.

The protective wall is wrapped around the settlement on the northeast, northwest and southwest sides in order to protect the settlement from the dominant northwest, north and west winds. The protective wall is prolonged perpendicular to the northeast to prevent side winds around the ends of the northern section of the wall from penetrating into the village.

An extension perpendicular to the southwest is proposed so that the building parallels the shore and does not waste land space as would a wall perpendicular to the westerly winds. This creates a V-shaped junction between the

northwestern and southwestern sections of the protective wall, which would deviate the westerly winds along the southwestern and northwestern faces. With regard to protection from the strongest winds, because the first and second strongest winds blow from the northwest and north respectively, and the third strongest winds come from the west and east, protection is provided by the protective wall for all but the east winds which are deviated by the hill to the east of the village. Thus wind protection is provided from all dominant winds and from the winds with the highest velocities.

The first row of houses is placed at a distance of 45m from the protective-wall building, forming a permeable fourth wall and thereby creating a walled enclosure condition where the average wind speed would be theoretically reduced to 30% of the free wind speed. All the houses are oriented with one face perpendicular to the dominant northwest wind, resulting in the other faces being oriented at 45° to the north and west secondary winds. The distance between houses back to back across the rear yards is approximately 45m creating a protected zone where the wind would be reduced to 30% of the free wind speed, permitting the use of this common space for outdoor activities.

The houses are laid out in rows perpendicular to the northwest, but also in such a manner that any house would provide wind protection not only for the houses directly behind, but also for the houses laid out at 45° in both north and west directions. Thus each row of houses provides a 'wind shadow' behind it in all three dominant wind directions creating protected activity zones behind all houses where the wind would be reduced to approximately 75% of the free wind speed for the distance of 60m between houses 45° to each other (see Fig. 153 - 60m = 15 wind barrier hts. house ht. 4m). Wind shadow planning is often avoided because most wind orientation studies have concentrated on increasing movement, as they were concerned with ventilation in hot humid countries (see examples in Olgyay, 1963, pp. 100, 101; Koenigsberger et al., 1973, pp. 128, 129; and Mair and Maull, 1971, pp. 436, 437). In the north, however, the creation of 'wind shadows' should be a design objective, because they provide zones of reduced wind speeds which can reduce building heating loads by 30% (Arens and Williams, 1977, p. 79) as well as providing a greater degree of comfort in outdoor spaces.

Another recommendation from the wind protection requirements is related to the maximum distance from the farthest house and the closest indoor public space, which was recommended not to exceed 400m (maximum distance suggested by the Russians, N.R.C., 1972, p. 13). This is the distance it would take for flesh to freeze in 5 minutes walking at 1.33 m/s in winter at latitude 65°N with a wind speed of 5.5 m/s and an average temperature of -24 to -29°C. In the plan illustrated in Fig. 172, the nearest indoor public space would be the warehouse (W) on the southwestern side of the village, and the airlines office (A.O) on the northeastern side of the settlement. Both these services are joined by a covered but unheated corridor to the rest of the public buildings, situated more centrally in the protective wall. See Fig. 173 for a drawing of a similar concept for an Antarctic research station.

It is also recommended that 50% of all the houses be within a radius of 270m from the store or school, which is achieved in the plan presented in Fig. 172 (see 270m radii marked on the plan).

The final recommendation that no building be situated farther than 54m from its closest neighbouring building is easily complied with as all houses are placed no further than 45m from each other and the furthest distance from a public building to any house or other public building is a maximum of 48m.

This plan would create a settlement in which pedestrians would always have protection from the wind at sufficiently short distances so that they would not freeze. The maximum distances are also such that people in very severe wind and temperature conditions would never have more than 5 minutes of exposure (at 1.33 m/s) before being able to reach the shelter of a public building with its connecting corridor in the protective wall. In addition, 50% of the population would be able to reach the store or the school in 5 minutes (walking 0.9 m/s) avoiding the danger of frostbite under average winter conditions. Under severe conditions (winds of 29.5 m/s and a temperature of -33°C) exposed flesh would freeze in one minute (assuming buildings reduce windspeed to 30%, this would give a wind speed of 8.9 m/s) and therefore people would never have more than one minute walking distance between their house and the next closest house or building where they could take shelter, a distance of 54m at a walking pace of 0.9 m/s or 79.8m at 1.33 m/s.

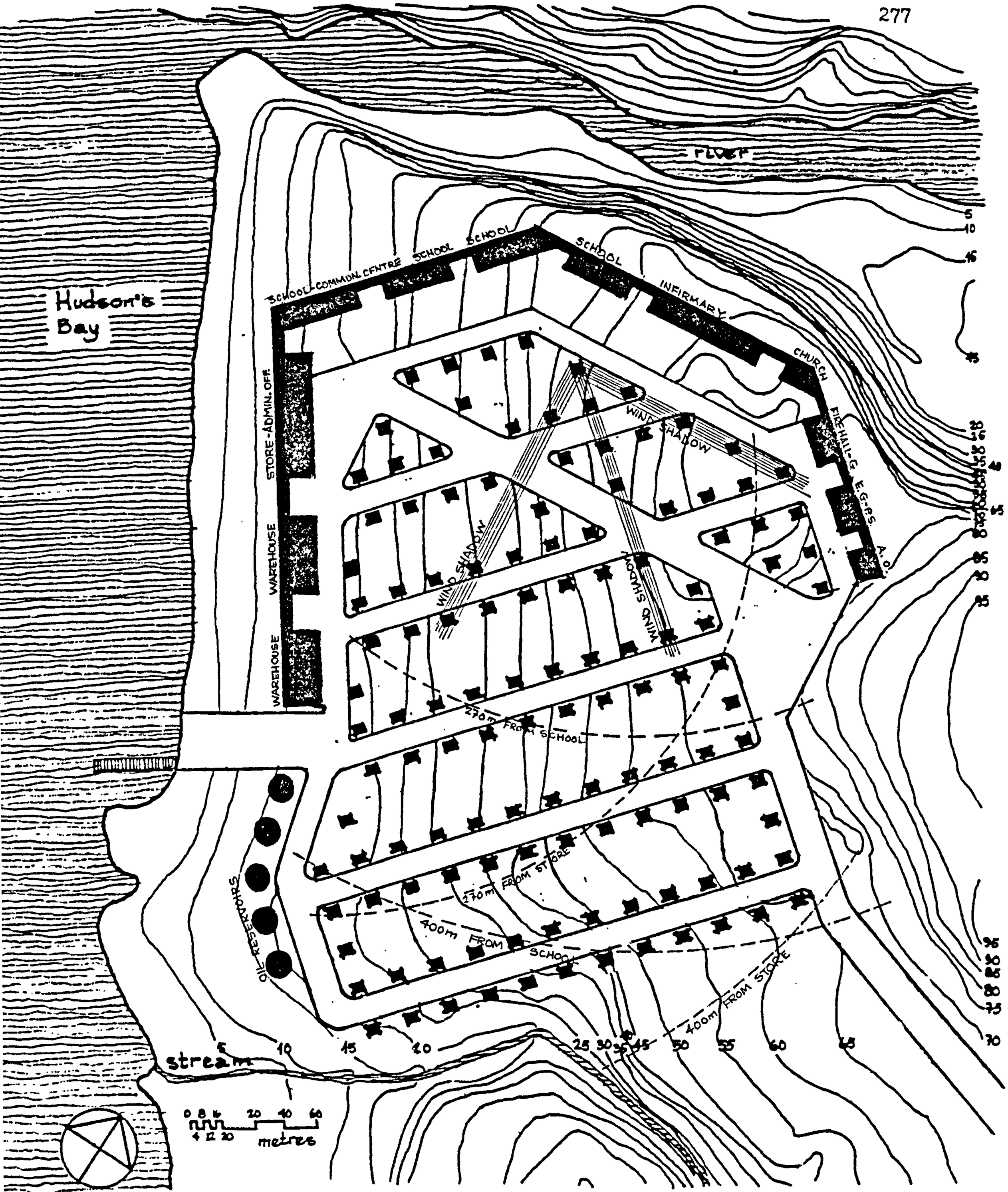


Fig. 172. Plan generated by Level 3B requirements - wind protection factors. (125 houses)

It would seem, therefore, that this plan provides a high level of wind protection for pedestrians. The proposed plan would then be tested in model form in a wind tunnel to determine the degree of correlation between the proposed probable wind-speed reductions, the distances at which they would occur, and the wind-speed reductions and distances as they would be in reality.

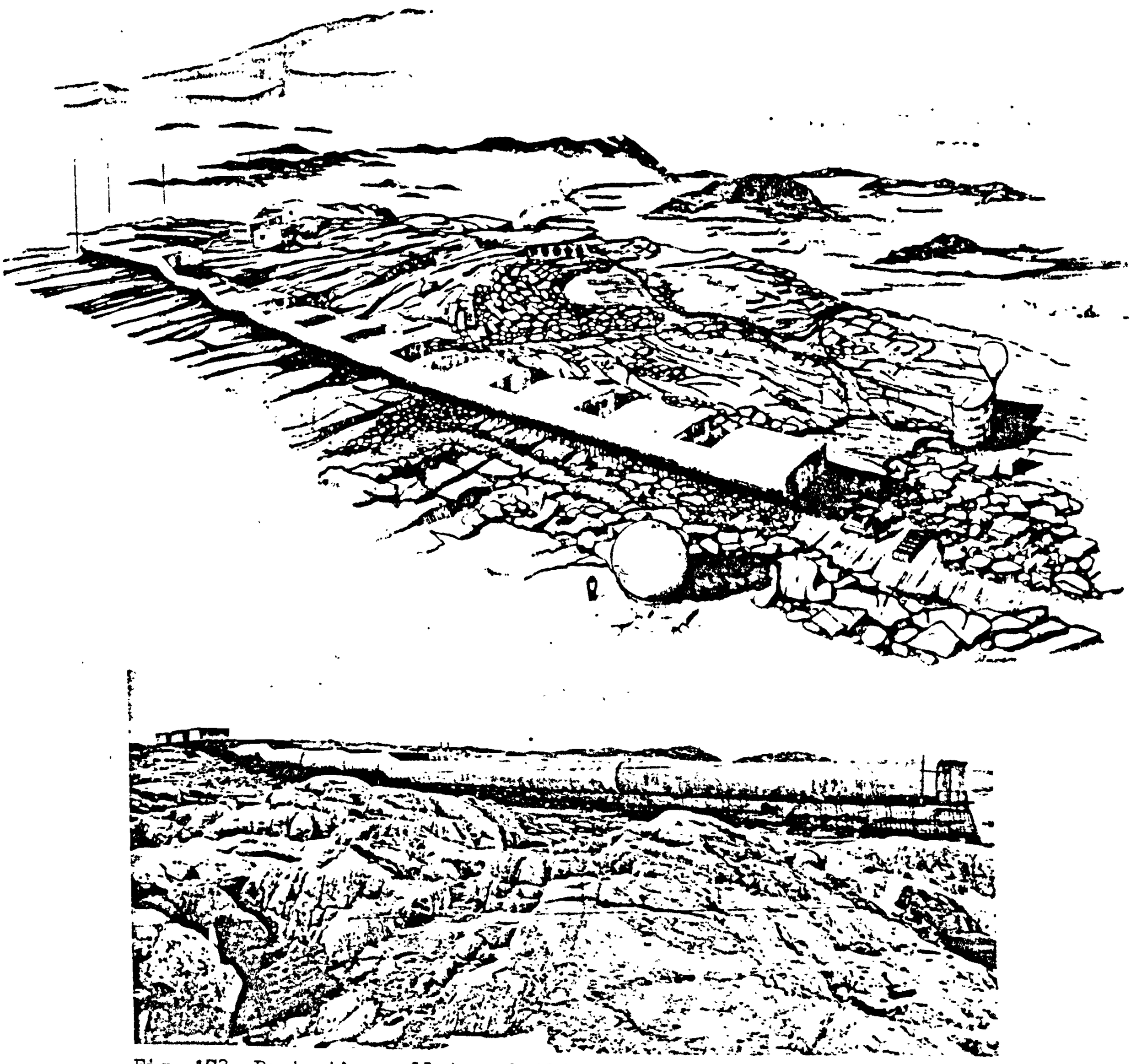


Fig. 173. Protective-wall type building, Australian Antarctic Research Station. Perspective above and ground level photo below (Brown, De Mole and Gamble, 1968).

3.3.2.1 Wind Flow Simulation

Anysley has noted that: "...because of the complex geometry of urban environments it is difficult to accurately predict airflow without a wind tunnel test" (1974, p. 93). However, wind tunnel simulation of wind flow has many similitude problems involving geometric, dynamic and kinematic similarity. In order to reproduce full scale effects in model tests, the ratio of dimensions and forces must be equal and there must be a similarity of particle/trajectory paths (Korbacher, 1969, p. 59; Aynsley, Melbourne and Vickerey, 1977, p. 59).

In wind tunnel simulation, because a scale model is a reduction in dimensions of the real object, for dynamic similarity, an increase in the windspeed equivalent to the dimensional reduction is required (Korbacher, 1969, p. 59). However, it is impossible to scale windspeeds directly proportional to most scale models because the sppeds would have to be supersonic, i.e., if a building was modelled at 1:100 the speed would have to be multiplied by 100 (Schneider, 1962, p. 58). Since it is not feasible to build supersonic wind tunnels for wind flow studies around buildings, the wind is modelled at subsonic speeds and is therefore not proportional to the dimensional scale of the model and becomes one parameter that does not respect the rule of similarity.

The Reynolds number defines the parameters for which geometrically similar bodies will be dynamically similar. The Reynolds number is Re = Inertial Forces / Viscous Forces or = Density X Speed X Length / Viscosity (Shapiro, 1964, p. 72). At low Reynolds numbers (less than 10^5) the boundary layer[1] is laminar and at high Reynolds numbers the boundary layer becomes turbulent (Aynsley et al., 1977, pp. 62, 63). The transition from laminar to turbulent flow in a boundary layer is dependent on pressure distribution, roughness of the body surface, and the intensity of the turbulence (Schlichting, 1962, p. 378).

For most blunt bodies with sharp edges (e.g. a cube), this does not pose

1 The boundary layer is "...a relatively thin layer with a mean velocity profile starting at zero at the solid boundary and increasing to the free-stream velocity at the outer edge" (Aynsley et al., 1977, p. 62).

a great problem because the point of separation of the boundary layer from the body is determined by the edges (Schlichting, 1962, p. 563). However, with a more or less streamlined body (e.g. a cylinder or hemisphere) drag becomes an important factor to consider because boundary layer separation occurs rapidly due to the high buildup of pressure at the shoulder of the smooth edge (Shapiro, 1964, p. 148). Thus, at low wind tunnel speeds separation could occur before it would in reality, thereby creating a larger wake than should occur. By roughening the surface of the streamlined body a turbulent boundary layer is formed which remains attached longer and produces a smaller wake (Shapiro, p. 159; and Houghton and Carruthers, 1976, p. 223).

Because wind tunnels normally produce uniform flow with low turbulence a great deal of error was introduced into early studies because the wind tunnels did not recreate the turbulent boundary layer as it exists in nature. It is necessary, therefore, in wind tunnel studies to correctly model the turbulent properties and velocity profile of the natural wind (Aynsley et al., 1977, pp. 35, 71, 72). Large and long wind tunnels have been used to reproduce wind properties naturally, but shorter tunnels can achieve the same results through the use of such techniques as vorticity generators and roughness elements on the tunnel floor (see Standen, 1972; Gartshore, 1973; and Davenport and Isyumov, 1967 for descriptions of these techniques).

With regard to modelling specific characteristics of the wind such as peak gust and turbulence intensity, Aynsley et al. note that "...areas likely to have unacceptably high wind conditions, such as near corners, in narrow alleys and in arcades, the turbulence intensity is relatively low and ...it would be reasonable to assume that the peak gust windspeeds will be about twice the mean windspeed..." They conclude from this that wind tunnel studies to determine areas of high wind speeds and to test solutions for improving the conditions, could be based "...very simple and inexpensive model measurements of mean wind speed" (Aynsley et al., 1977, p. 160). Aynsley et al. go on to state that "...bearing in mind the subjective nature of the decisions made (whether to use peak gust wind speed and gradients or turbulence intensity), the prediction accuracy required does not really warrant great sophistication. In fact, simplicity and speed are

the main factors required in practice..." (Aynsley et al., 1977, p. 162). Jackson supports this approach when he states that "...it has not been adequately shown that wind tunnel simulations reproduce the flow of wind around buildings right down to the detailed structure of the turbulence, and for this reason it is preferable to work with mean and r.m.s. velocities rather than statistics like probable densities and frequency spectra" (1978, p. 257).

Thus it can be concluded that when wind tunnel studies of airflow conditions around buildings are carried out, there is not a need for a high degree of precision in all the factors modelled. However, it is important that the velocity gradient be correctly modelled in relation to the turbulence characteristics of an open field, a suburban or dense urban situation. A study by Jones and Wilson confirms the reliability of models reproducing full scale measurements if the above factors of velocity gradient and turbulence characteristics are properly modelled (1968, p. 39). Both Aynsley et al. and Jones and Wilson note that the precision of the features of the surrounding site are not too important, especially if they are less than 1m in height (Aynsley et al., 1977, p. 163) or are several building heights away from the building or site under study (Jones and Wilson, 1968, p. 39).

Wind tunnel testing for air flow patterns and speeds has become a relatively common planning tool for architects, developers and urban planning commissions, especially with regard to the effects of tall buildings on pedestrian comfort. Penwarden and Wise (1975), Brisker (1967), and O'Hare (1967) describe several wind tunnel studies which experimented with various means for correcting accelerated wind flow in complexes with tall buildings. The need for wind tunnel tests for buildings was in part stimulated by accidents and a few deaths that were casued by accelerated wind speeds around buildings (Penwarden, 1973, p. 260; Jackson, 1978, pp. 251, 252). This eventually led to several city planning authorities demanding that the wind conditions around any new tall buildings be proven acceptable before building permission would be granted (Hunt, Poulton, and Mumford, 1976, p. 27).

The National Research Council of Canada has carried out many wind tunnel studies of buildings in urban centres across Canada to establish not only

structural wind effects (Lemberg, 1973; Cooper, 1973; Standen, 1974; and Irwin and Standen, 1975), but also the quality of the pedestrian wind environment (same as above and Standen, 1973). Even in studies devoted mainly to structural wind effects, tests were made to determine wind speeds at the pedestrian level, which indicate a concern by engineers, architects and developers for pedestrian comfort.

The study carried out for Teron Construction Company for an Ottawa complex (Standen, 1973) is especially interesting as it was carried out in the preliminary design stage with three different configurations being tested before a final design choice was made. In all the other studies, major design decisions had been made and no alternatives were investigated.

Unfortunately wind studies of building complexes already built and which have serious wind environment problems (see the very detailed study on La Defence in Paris by Baille, 1974, and another for the city of Aou by Dabat, Perrin, Valensi, Howard and Audoly, 1972) seem to be still quite frequent, implying a general lack of interest in the pedestrian wind environment. The fact that wind tests are required by some city planning commissions, but only for tall buildings, illustrates that the pedestrian environment is not a high priority in planning criteria, even though the form of buildings can affect the environment whether buildings are tall or not. This author has been encouraged by a study in which the plan of a sector of the city of Marseille was based on a series of wind tunnel tests to determine the best layout with regard to pedestrian comfort in the wind (Groupe A.B.C., 1975). This study was a rigorous planning exercise carried out in concert with wind tunnel tests on various plan lay-outs, building shapes, and landscaping features. It represents an ideal collaboration between architects, architectural climatologists, aerodynamics specialists and a city planning commission, which provides a glimmer of hope that such collaboration will be more common in the future.

3.3.3 Level 3C Requirements - Plan Generated by Snow Accumulation Considerations

The basic governing principle of this plan is based on the notion that the wind is the major mechanism responsible for the accumulation of snow and that snow accumulates to a greater degree on the leeward side of obstacles.

Although the windward side of an obstacle is clear of snow intially because of the reversed flow caused by the windward face, the windward snowdrift eventually attaches itself to the object and becomes saturated with snow, taking on a streamlined shape (Roots and Swithinbank, 1955, pp. 386, 387; see also drawings of snowdrift formation around solid fences in Jumikis, 1970, pp. 212, 213; Schneider, 1962, pp. 176, 178; Mellor 1965, p. 46; and Hogbin, 1970, Figs. 2-5). Therefore, the location of entrances on the windward face of a building do not assure their freedom from snow drifting and also have the disadvantage of increasing air infiltration, resulting in a higher heat load.

Orienting buildings with the shortest face into the wind does not ensure that entrances placed on sides parallel to the winds would be free of snow because as mentioned in the section on Snow Control Requirements (2.1.3.4), it is rare that the wind blows in absolute dominance from one direction. The frequency of winds at latitude 65°N are first from the northwest, second from the north (which is half as frequent as the northwest wind) and third from the west (which is a little more than a third as frequent as the northwest wind (see Appendix I-G, Table 3)). Thus, orienting streets and buildings with the long axis parallel to the northwest winds would not necessarily keep streets clear of snow. It would assure that an entrance placed on the north side of a building oriented with its long axis northwest would be clear of snow for northwest and north winds at least, until the point of saturation was attained. As the northwest wind is twice as frequent as the north wind and almost three times as frequent as the west wind, six of the streets are oriented northwest, five oriented north, and three oriented west. See Fig. 174. The multiple orientation of streets should ensure that some of the streets would always be clear of snow, therefore offsetting the cost of extra road length by minimizing the cost of snow removal.

The service buildings are laid out in a continuous protective wall oriented north and west providing surfaces at 45° to the northwest winds. Comparing the reduced wind speeds in Figs. 154 to 156, in Section 2.1.3.3 (Wind Protection Requirements), one finds that at wind orientation of 30° and 60°, a W/H of 8 and a L/H of 2 to 4, the wind speeds are above 60% of the free wind speed which Melbourne and Styles (1967, p. 153) proposed as the

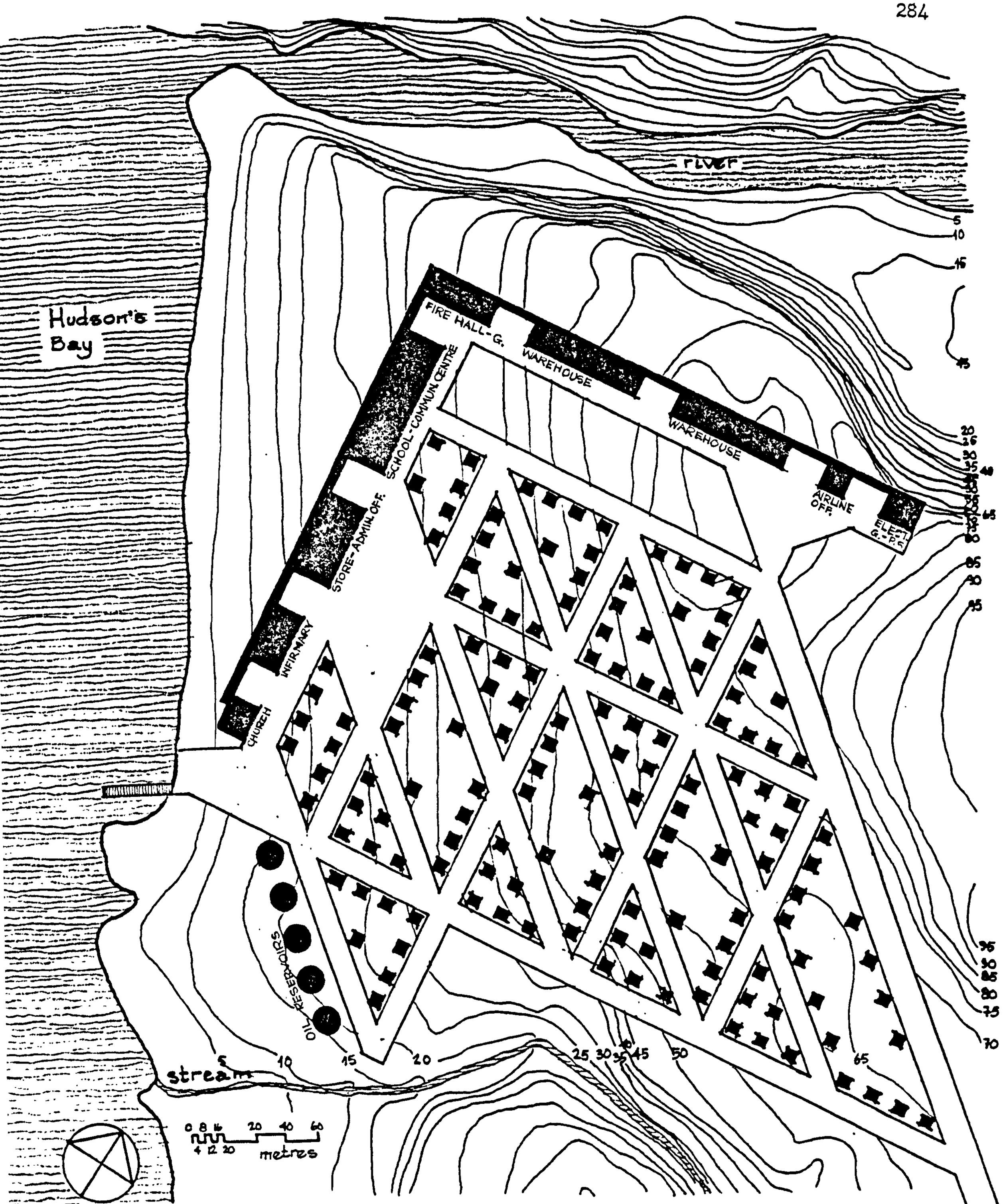


Fig. 174. Plan generated by Level 3C requirements - snow accumulation control factors. (149 houses)

velocity at which "...excessive drift accumulation could be expected." Therefore, at a 45° wind orientation, it would seem reasonable to expect that major snow accumulation would begin immediately leeward of the perimeter-wall buildings and at distances of approximately four times the building height (i.e. 4 X 7 = 28m). In order to eliminate snowdrifts leeward of the infirmary, store, school, and the fire station - garage (buildings in the N.-S. section), these buildings would be raised on pilotis 1.5m above the ground as recommended in section 2.1.3.4. This would put the loading platform of the store at approximately the height of large truck bodies. Vehicular access to the fire station - garage could be made by means of a retractable 'draw-bridge' type platform attached to the entrance which would be raised during a storm and lowered immediately afterwards allowing the wind to blow unobstructed under the building.

The other service buildings (i.e. the 2 warehouses, airline office and the electricity generator - pumping station) located in the E.-W. section of the protective-wall building, do not need to be above the ground because these services are less frequented by the public, and secondary means could be used to eliminate snowdrifting at entrances. The distance between the E.-W. section of the protective-wall buildings and the first row of houses is 74m. There are two roads near this section, one in front of the warehouses, and the other in front of the houses facing them with the school playground in between. As the section on snow control suggests, a leeward zone of 33 to 47m would collect most of the snow, and in this case under north and northwest wind conditions, the majority of the snow would accumulate in the playground. This would leave the road next to the houses and a portion of the playground, adjacent to the road, with minimal snow accumulation.

The single detached houses are all square in shape and oriented at 45° to the dominant northwest winds as recommended in the snow control section to minimize snow accumulation on the north and west faces of the houses. This would occur because all 3 dominant winds being at 45 or 90° to each other would always blow the snow clear of these two faces either by blowing parallel, perpendicular, or at 45° to them. The houses are laid out with the recommended 10 to 20m distances between them across back yards and

streets to avoid the coalescence of snowdrifts between houses.

The service buildings were not laid out according to this same recommendation (i.e. buildings designed as near to square as possible and oriented at 45° to the storm winds) because square detached buildings the size of the store, school or warehouses would create a snow accumulation zone of 33-47m in depth and would also allow snow to blow between the service buildings creating large snowdrifts around the houses. The formation of a continuous protective wall creates a sort of snow collector type of building, causing most of the snow to precipitate out on the leeward side of the protective-wall building.

All entrances to the houses and service buildings would be free of snow due either to the building orientation (45° to the northwest winds), or by being raised up 1.5m above the ground, with the exception of the 2 warehouses, the airlines office,and the electricity generator - pumping station. The latter buildings would have a canopy over the entrances projecting approximately one-quarter of the width of the building. This is based on the eddy dimensions for objects with projecting roofs as established by Evans (1972, p. 12-9).

By responding to all the recommendations in the section on snow control, this town plan should have minimal snow accumulation problems. Nevertheless, snow accumulation simulation studies would be necessary to verify the effects of the layout on snowdrift patterns and the zones of maximum deposition.

3.3.3.1 Snow Accumulation Simulation Techniques

Drifting snow simulation has been generally carried out through the use of wind tunnels and hydraulic flumes. The simulation of drifting snow adds the problems of scaling snow particle size and velocity to the normal similitude problems mentioned in the preceding section 3.3.2.1 (Mellor, 1965, p. 35).

An important factor in establishing similitude for snow accumulation is the duplication of the saltation process in which particles bounce along the surface of the snow dislodging other particles (Mellor, p. 5). Kobayashi has proposed that the great majority of drifting snow is transported by saltation (in Kind, 1974, p. 1) of which the simulation in water is not

recommended due to the difference in lift of particles in air and water which could produce errors (Kind, pp. 27-29). This would seem to rule out the use of hydraulic flumes for the simulation of snow accumulation. But if the saltation process is not the major mechanism in snowdrift formation, and as Mellor proposes, that "...in major polar snowstorms most of the snow is transported by turbulent diffusion...", (1965, p. 6) then simulation could be carried out in hydraulic flumes with a reasonable degree of accuracy. Krasinski and Anson propose that because more than 70% of the sand in the simulation of drifting sand in a water context is displaced by saltation at a height of approximately 30cm. above the surface (taken from Bagnold, 1956); this is similar to the case of drifting snow (1975, pp. 26, 27), and they therefore used water simulation techniques for snow in their study.

Calkins mentions that Isyumov chose a hydraulic flume to simulate snow accumulation in his study on roof snow loads even though he had the use of a large wind tunnel because of problems such as the difficulty of loading the borax/air simulator, the high cost of large wind tunnels capable of simulating atomospheric boundary layers, and the absence of an adequate means for handling particles once introduced into the tunnel. Because 1) good results were achieved with the water/sand analog in relation to snowdrift patterns; 2) the scale relationships between sand/water and snow/air were acceptable;and 3) the hydraulic flume was relatively inexpensive; Isyumov chose to simulate snow accumulation in water (in Calkins, 1975, pp. 1.2).

Calkins, in his simulation studies concentrated on predicting the patterns of snow accumulation in relation to time, measuring only the area of the resulting snowdrift and not its depth. He found that the scale of the model had little effect on the 'areal distribution pattern' which was also true of the flow velocity[1] if it exceeded the sand particle threshold velocity, giving support to the notion of Reynolds number independence for modelling (Calkins, 1975, p. 9). Calkins defined the assumptions under

1 Schneider also makes a similar suggestion in a comment on natural snow drifting in relation to wind speed and snow density distribution. He states that "...probably the deposit has the same form regardless of the wind speed" (1962, p. 38).

which hydraulic flume simulation is acceptable, namely: "...a) cohesive forces between snow particles are neglected, b) the snow particle is "dry" and can be transported, and c) the model snow particle is not scaled in the same geometric ratio as the model structure" (Calkins, 1974b. p, 1). He also points out that to determine the final shape of the snowdrift, field correlation studies are needed to discover the "...vertical to horizontal scale ratio distortion..." (ibid).

This author attempted to overcome some of the problems of particle simulation in wind tunnels by verifying the possibility that snow particles may be deposited around obstacles in comformity with the streamlines around them. A hint of this hypothesis could be taken from Odar who set out a series of equations to deal with the "...similitude of streamlines and the duplication of snow concentration along them" (in Mellor, 1975, p. 38). If it could be possible to determine snow deposition from the streamlines, then it would be a relatively simple matter of measuring the flow speeds around obstacles to generate velocity contours which would be the equivalent of snowdrift patterns. This procedure has some resemblance to that used by Melbourne and Styles, who in their Antarctic study, measured the velocity profiles under and downwind of elevated buildings. From the correlation of snowdrift occurrence under an existing building at the site and the velocity at the same point on a model of the same building in a wind tunnel, they concluded that at any point where the local speed is diminished to 0.6 of the free-stream velocity, excessive snow accumulation would occur (Melbourne and Styles, 1967). They therefore measured the velocity profile along various wind directions and adjusted the model's leading edge-shape and the height of the building above the ground until the profiles under and behind the buildings were above 0.6 of the free-flow speed. They then simply determined the zones where lower speeds occurred and changed the height under the building until the speeds were accelerated to, or above the threshold value. Since in more complex town layouts it is not always possible nor desirable to achieve accelerated speeds, this procedure would not be useful in determining snow deposition contours unless the threshold velocity contour could be established for the three-dimensional zone influenced by the objects.

The tests carried out by this author consisted of measuring the velocity at a significant number of positions on three models (a cube, cylinder, and hemisphere of the same volume) in two different states, (with and without snowdrifts around them) at four different speeds. Originally the tests, carried out in consultation with Professor C.B. Wilson, Dr. F. Smith, and Dr. J. Morgan of Edinburgh University, had as their objective the verification of the Reynolds number dependency of snowdrifts. Upon re-testing the models for reproducibility, it was noticed that several curves produced by plotting the ratio of measured velocity/reference velocity against the reference velocity at four different wind tunnel speeds for a cube (with and without the snowdrift contours), bore strong similarities. It was then decided with Professor Wilson and Dr. Smith, to run a series of tests with and without snow contours, to discover whether snow accumulating around an obstacle does so by filling up the streamlines around it - a theory this author has dubbed the 'streamline hypothesis'.

After many problems of reproducibility from one series of tests to another, the shapes of some of the curves (representing the ratio of measured vel./ref. vel. to ref. vel) suggested that the positions at which they were measured were situated in the transition zone from laminar to turbulent flow. This could explain the problem of reproducibility, because the transition zone is very unstable and the measuring position could be deeper in the transition zone in one test than in another, thereby creating a distorted beginning or termination to the velocity curve. The velocity curves were finally averaged to produce straight lines and then compared, giving more positions with good reproducibility. The results gave partial support for the streamline hypothesis, however they failed to provide the hard evidence required by fundamental research such as this hypothesis implies (data in unpublished thesis progress report, Zrudlo, 1977).

Another interesting document came into the author's possession after the above tests were carried out which points to another aspect of the 'streamline' theory. Krasinski and Anson note that at later stages of snow accumulation "...an interaction occurs between the air around the new shape emerging from the snowdrift-building combination. Snow simulation is therefore essential..." (1975, p. 26). A problem with the streamline theory is brought to light in a study by Kungurtsev which demonstrated that snow

particles do not follow the flow of the wind, but rather fall directly to the surface in a fairly uniform parabolic path (in Schneider, 1962, pp. 38,178). The work by Kungurtsev needs careful verification, but it does not discount the possibility of adapting Melbourne and Style's snow deposition threshold velocity method to the determination of snow-drift limits. However, their method cannot predict the dynamic action of the drift in formation which may modify the wind flow in a manner different from the streamlines.

Therefore, it would seem that hydraulic flumes are the most practical snow simulation technique at the present time, if one keeps in mind that this technique produces snow patterns which represent an average condition (Krasinski and Anson, 1975, p. 8) which "...at present are qualitative only, and can be used only as an indicator of the applicability of proposed solutions of snowdrifting problems" (Adam and Piotrowski, and emphasized by Calkins, 1975). Despite the limitations of thc technique, many studies have been carried out to rectify snowdrifting problems on existing buildings (Malinowski and Theakston, 1968; Darby, 1969; Theakston, 1970; Calkins, 1974b; Morrison, Hershfield, Theakston and Rowan, 1977); on buildings designed but not built (Morrison et al. 1974; Culjat, 1975; Krasinski and Anson, 1975; Morrison et al., 1977; Frenette, 1979); and as a part of the design process in formulating the design of a building (Melbourne and Styles, 1967). It would therefore seem that the hydraulic flume is sufficiently accepted as a technique for the simulation of snow accumulation patterns about buildings and groups of buildings. It is therefore proposed as the simulation technique for the verification of snowdrift patterns that would be produced by the plans generated by the Four-Level Model.

3.3.4 Synthesis of Levels 3A, 3B and 3C Requirements - Plan Generated by the Synthesis Process

3.3.4.1 Identification of Requirement Conflicts

The conflicts that appeared between Levels 3A, B and C are:

1) Level A (Solar Shading) - The houses are oriented with one side facing directly south. There is a conflict with Level B because windward houses do not protect leeward houses for the 3 dominant winds. There is no conflict with Level C.

Level B (Wind Protection) - The houses are oriented with one face perpendicular to the dominant northwest winds. A conflict therefore exists at level A, but not with Level C because the 45° orientation also provides snow control.

Level C (Snow Control) - The houses are oriented with the corner facing the dominant winds, i.e. 45° to the northwest or with one face oriented directly south. Thus no conflict with Level A occurs and there is no real conflict with Level B because the same wind protection would be achieved with a north - south house orientation.

2) Level A - Taller structures (institutional buildings, oil tanks, etc.) are situated at the north and northeast limits of the village so that their long winter shadows will be cast on service areas and buildings, and not on the houses. This Level is in conflict with Level B because there is no wind protection for the village from these buildings. There is little conflict if any with Level C, as the buildings are grouped in a zone where their snowdrift patterns would not affect or coalesce with drifts around the houses.

Level B - The service and socio-institutional buildings are situated in a continuous protective-wall building oriented perpendicular to the southwest, northwest, north and northeast directions. A conflict with Level A exists because the southwest portion of the protective perimeter-wall building and the oil storage tanks would cast long shadows on the houses nearby at 3:00 pm., and possibly at noon in winter. See Fig. 175. There is also a conflict with Level C caused by the position of the school modules which would create snowdrifts at its entrances and those of the store and infirmary due to the northwest, north and west winds.

Level C - The service and socio-institutional buildings are contained, as in Level B, in a continuous protective-wall building oriented only in two directions, north - south and east - west, i.e. perpendicular to the north and west winds, and 45° to the northwest winds. A conflict with Level A is produced by the north - south segment of the perimeter wall, because a shadow would be on the nearby houses and the public gathering places in front of the infirmary, store, and school. See Fig. 176. This level is also in conflict with Level B because the north - south perimeter wall is raised 1.5m above the surface which would accelerate the winds,

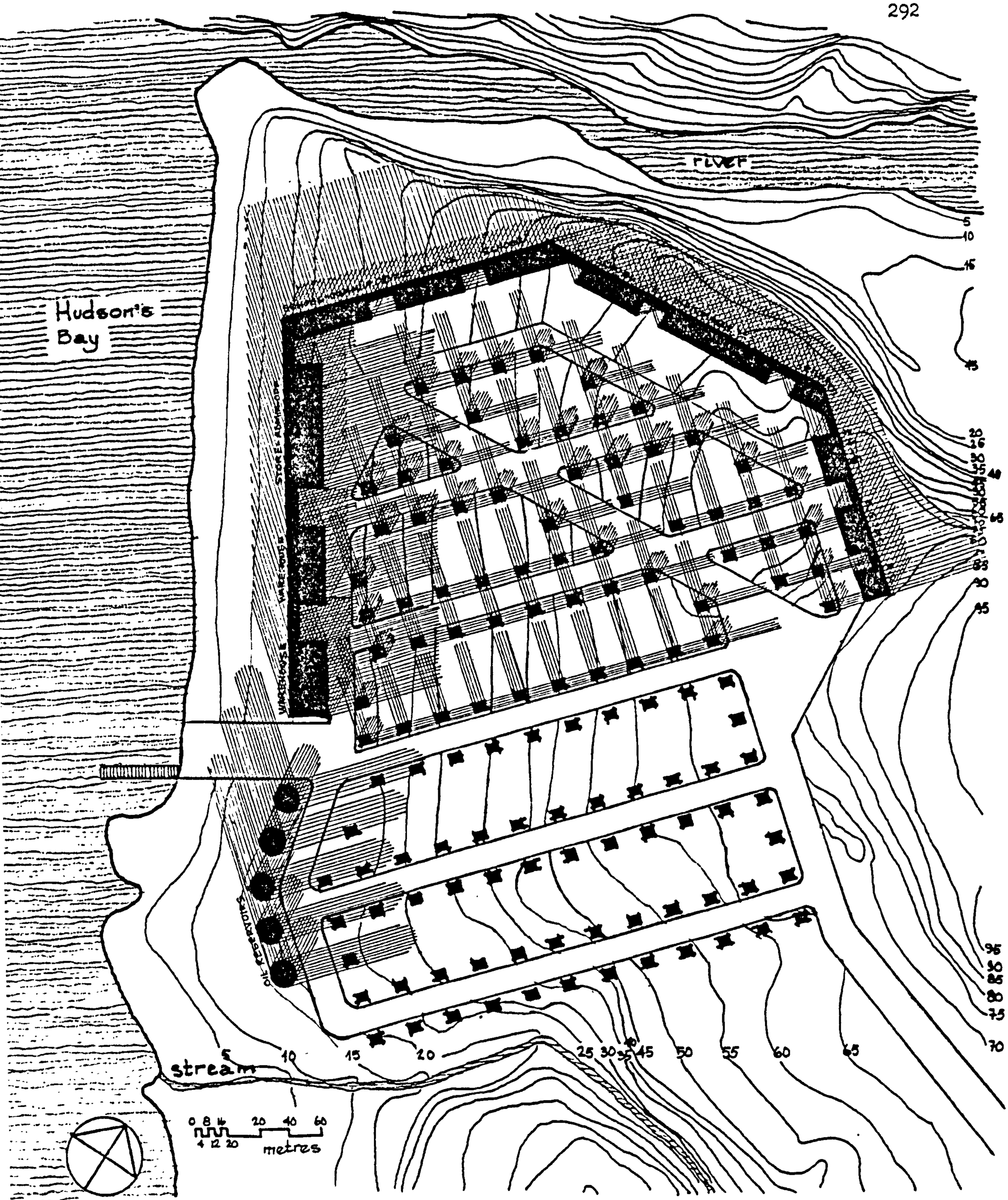


Fig. 175. Solar shading on plan generated by wind protection factors.

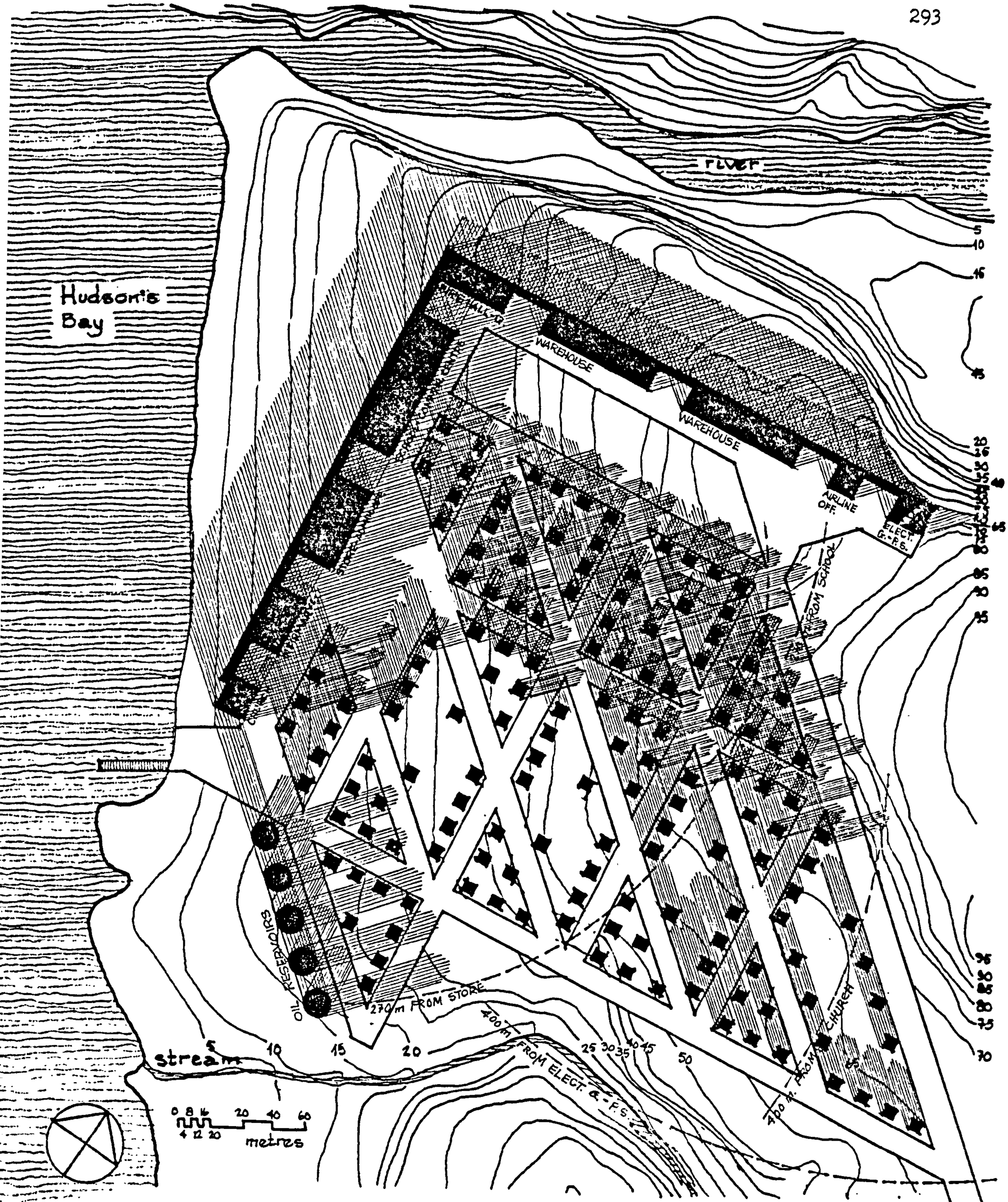


Fig. 176. Solar shading on plan generated by snow accumulation control factors.

making it uncomfortable for people approaching these buildings.

3) Level A - The public gathering places in front of the infirmary, school, and store are sufficiently distant from the houses and other buildings so that no shadows are cast on them. A conflict exists with Level B because the public gathering places are not protected from the west winds and only partially from the northwest winds (this is especially true of the school playground). There is a conflict with Level C because the entrances to the infirmary, school, and store would be blocked by snow from the northwest and north winds.

Level B - The public gathering places are located leeward of the north, northwest and southwest segments of the protective perimeter-wall building for wind protection from the 3 dominant winds. There is a partial conflict with Level A because the public space in front of the store and the southwest end of the school playground would be in shade from noon onwards. See Fig. 175. A conflict also exists with Level C because the north, northwest and west winds would all produce large snowdrifts at one time or another, in front of the school, store, or infirmary.

Level C - The public spaces in front of the infirmary and store are located leeward of the north - south segment of the protective wall, and the school yard is leeward of the east - west segment. Only a minor conflict exists with Level A because the public places would be in shade only well past noon. A greater conflict exists with Level B because even though the school yard is protected from the north winds, the public place in front of the infirmary and store is not. None of the public spaces are protected from the northwest and west winds, because the north - south segment is elevated 1.5m above the ground accelerating the winds in the portion of the school yard closest to the school and in the store - infirmary public space.

4) Level A - The streets are oriented east - west so that all houses will have the optimum orientation for the sun. The street widths and house to house dimensions across the back yards are such that at noon no shadows are cast on the houses across back yards, across the streets, or on the pedestrian paths. A conflict exists with Level B for west winds which would blow unobstructed along the streets and pedestrian paths. There is also a conflict with Level C because the streets would be blown clear of

snow only for the third dominant wind from the west.

Level B - The streets are oriented northeast - southeast so that the houses can be turned with one facade oriented northwest against the dominant wind. This is in conflict with Level A, because the houses cast shadows on their neighbours next to them in the morning and on the houses across the street in the afternoon. See Fig. 175. There is a conflict with Level C as well, because with the exception of two short streets which are oriented west, none are laid out in the dominant wind directions to be blown clear of snow.

Level C - The streets are oriented in the direction of the three dominant winds - six to the northwest, five to the north, and three to the west, so that they will be blown clear of snow. A conflict with Level A exists because the houses are placed close to each other in order to have a sufficient number of houses in the whole layout. Thus, the shadows in the morning and afternoon shade most of the houses, and the majority of the streets are in shade in the afternoon. At noon, all houses on the north - south axis are in shade as well. A conflict occurs with Level B as well, because the streets leading to the school, store, and infirmary are oriented northwest into the dominant wind, and therefore provide wind protection only when people are walking on the east - west streets.

3.3.4.2 Synthesis Plan for Level 3 Resolving Requirement Conflicts

3.3.4.2.1 Houses

The synthesis began by choosing the house orientation (north - south and east - west) which satisfies all three sub-levels, because the 45^{o} orientation to the dominant northwest winds still provides good wind protection as well as optimum sun orientation and the recommended orientation for snow-drift control. The houses would also be square or as near to square in plan as is feasible to fulfill the snow control recommendation. The spacing of the houses adjacent to each other was set at 12m, so that the shadows across a street (houses are 20m face to face across a 15.3m street) at noon, would not reach the house opposite, and from 9:00 to 15:00 there would be an average of 50% sunlight between the houses. At 9:00, 42 out of 131 houses are in sunlight (32% of total houses); at 12:00, 96 of 131 houses are in full sun (73%); and at 15:00, 67 houses are sunlight (51%). Because

9:00 and 15:00 hours are the beginning and end of the period of the year midway between the equinox and the winter solstice, the number of houses receiving sunlight would be greatly increased as the hour approaches noon. Therefore, more than 50% of the houses would be in sunlight during the winter at February 5 and November 6. See Fig. 177.

With regard to wind protection requirements, the houses vary in spacing from a maximum of 15m (northwest - southeast spacing) which is reasonably close to the recommended 14m spacing where wind speeds would be reduced to 30% of free wind velocity. Thus, no house exceeds the maximum distance of 54m from its closest neighbouring house, nor does the distance between the nearest house and a public building in the continuous protective wall exceed 54m. The houses are so situated that no house is further than 400m from an indoor public space, and only 53 houses or 41% of the total housing is outside the 270m distance from the school or store. This fulfills the recommendation that 50% of the houses be no further than 270m from the store or school.

The snow control requirements are largely fulfilled by the house spacing of 12 and 15m which is sufficiently near the 14m recommended to minimize the coalescence of snowdrifts between houses. Across street house spacing is 20m, while back yard spacing varies from 12 to 50m with the average spacing being 14m. This meets the range proposed of 10 to 20m spacing for one-storey buildings for the avoidance of drift attachment, while the houses with 50m spacing could be two-storey units and not cause any drift attachment. This would give the possibility of a variety of house types while respecting the snow control requirements. Entrances on leeward sides of buildings can be kept clear of snow by the use of canopies projecting approximately one-quarter of building width (see Evans, 1972, p. 12-9).

2.2.4.2.2 Socio-Institutional and Service Buildings

The socio-institutional and service buildings were grouped into a perimeter protective wall building, which like the houses is oriented with a corner at 45° to the dominant northwest winds to minimize snowdrifting conditions. Thus the protective wall has two main orientations, namely east - west and north - south, with two shorter walls oriented northwest - southeast channelling the northwest winds past the main body of houses. The church,

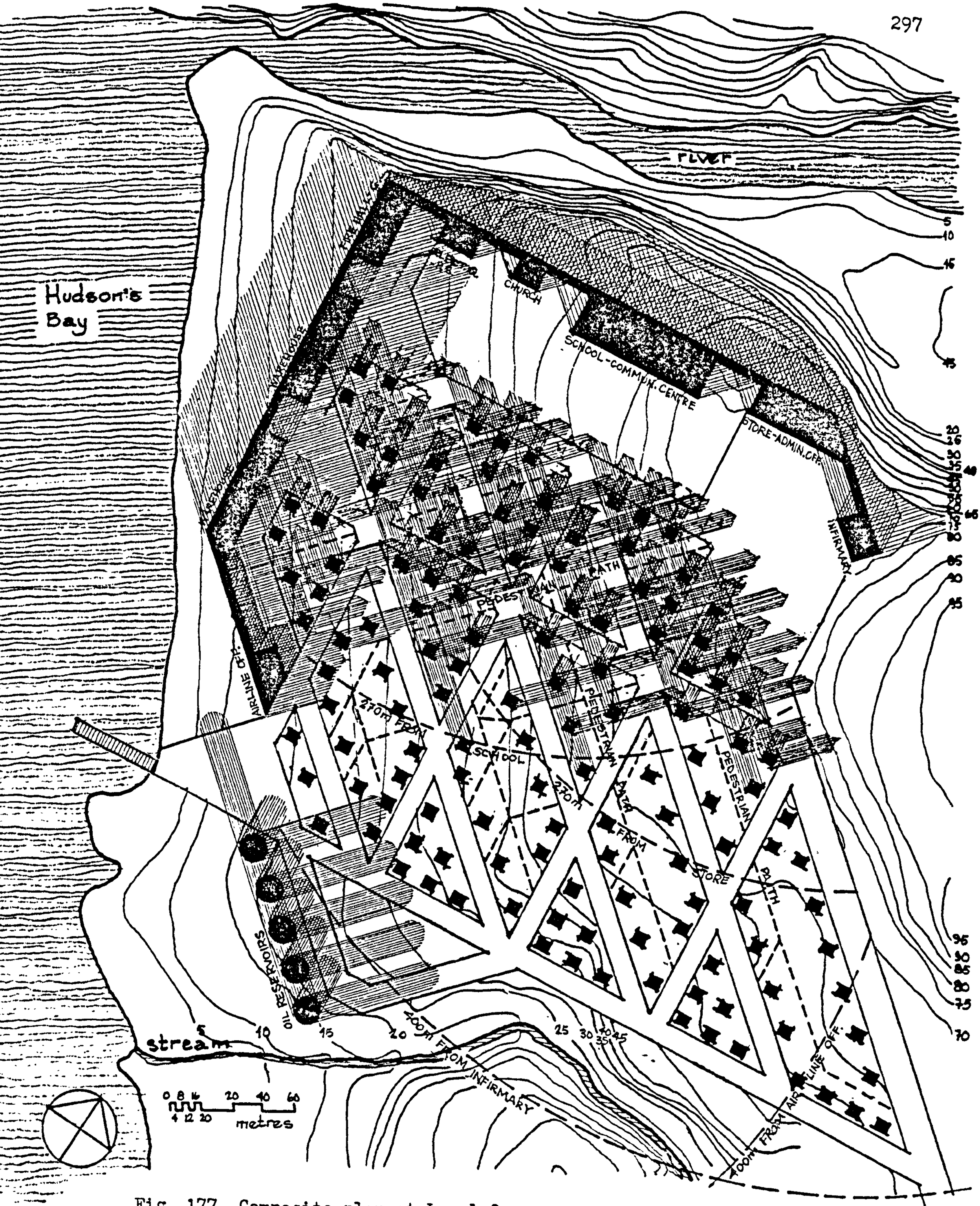


Fig. 177. Composite plan at Level 3 - synthesis of climatic requirements. (131 houses)

school, store, and infirmary are contained in the east - west segment of the protective wall, and are situated at the eastern portion of the wall for maximum sun exposure. The buildings are joined by unheated covered walkways which protect the space between buildings from the wind and are equipped with automatic fire doors and fireproof building materials to prevent the spread of fire (see Brown, De Mole and Gamble for an example in the Antarctic, 1968, pp. 4-6). The corridor would also serve as a buffer zone against the winds to minimize heat loss by infiltration.

To meet the wind protection requirement that no house be farther than 400m from an indoor public space (i.e. any building or corridor which is part of the perimeter protective wall), the protective walls were extended south-easterly from the north - south and east - west segments of the walls so that no house is farther than 400m away. The nearest houses at the south-west and western edges of the village are within the 54m distance specified between them and the protective wall. However, the northern and northeastern sections are beyond the 54m limit. It was decided to compromise on this requirement, even though it could be achieved by placing houses on the northern side of the street paralleling the playground space, because placing houses in this position would put the playground in shade over a large portion of its surface through the whole day.

The snow control requirements for variable wind directions were met in part by orienting the perimeter protective wall's corner at 45° to the dominant northwest wind, orienting the east - west portion of the wall perpendicular to the north wind, and the north - south portion perpendicular to the west wind. The northwest corner (the fire-hall, garage) of the north - south segment of the protective wall is raised 1.5m above the ground so that the entrance would always be blown clear of snow. A draw-bridge type of door-access ramp would be raised during snowstorms and lowered when vehicles entered or left the garage. Because there is a conflict between elevating buildings to accelerate the wind to blow the snow clear of entrances and providing wind protection for pedestrians, only the fire-hall - garage is elevated 1.5m (houses have a minimum 0.61m air space under them to prevent the heat from the floor thawing the permafrost). The school and store are 78m from the closest houses so that any snow blowing from the north would not create an attached drift with the houses, as the drift would not exceed

47m in length. The houses near the north - south segment of the protective wall may become attached to the drift generated by the wall, but it was felt important that people be protected by these houses from north winds so that they could reach the perimeter wall without freezing. However, if hydraulic flume snow simulation proved that these houses were a definite problem, then by removing 5 houses, the problem would be eliminated. The entrances to the socio-institutional and service buildings could be protected by canopies as proposed for the houses, thereby ensuring freedom of entry and exit to these buildings.

3.3.4.2.3 Public Places and Pedestrian Paths

The public places in front of the infirmary, store, and church are situated on the south side of the east - west segment of the perimeter protective-wall building giving them continuous sunlight throughout the day, thereby fulfilling the requirements that public gathering places and playgrounds be 100% in sunlight from 9:00 to 15:00 on November 6 and February 5. The pedestrian paths, which are oriented northeast - southwest, give direct access to the school, store, and infirmary for housing in the western and southwestern sections of the settlement, while the northwest - southeast paths give access to the socio-institutional buildings from the south-eastern section. The inhabitants of the southern section can either use the north - south streets for direct access to services, or join onto the pedestrian paths leading northwest or northeast. The pedestrian paths in all cases have at least 30% of their area in sunlight, even though the northeast - southwest paths at 9:00 in the morning have less than 30% sunlight. As 12:00 approaches they are more than 50% sunlit, and at 15:00 are 100% sunlit. Therefore, they more than meet adequately the 30% sunlight exposure requirement. The northwest - southeast paths do not quite have the reverse performance, because a few houses cast shadows on the beginning points of the paths at 9:00 in the morning so that slightly less than 100% of the paths are in sunlight. However, at noon and 15:00, the paths are more than 15% in sunlight due to the spacing of the houses, therefore the 30% minimum is fulfilled without difficulty.

With regard to the wind protection requirements, all the paths oriented northeast - southwest are protected by the houses from the northwest, north

and west winds. The paths running northwest - southeast are protected by the houses from the north and west winds, but open to the northwest winds. Therefore, in order to be protected from the wind, people in the south-eastern sector of the village could take the north - south streets as far as possible, travelling westward on the east - west streets until reaching another north - south street leading to the building to which they are going. The people living in the southern sector, during periods when the north winds are dominant, could walk northward only until they reached the first northwest - southeast, northeast - southwest paths or east - west street which would give them protection until reaching the protection provided by the perimeter protective wall. Inhabitants in the western and southwestern sectors have the northeast - southwest paths which are continually protected. This would suggest that older people or people with very young children should be located in the western, southwestern or northern sector of the settlement so that they would have access to the best protected paths. The public gathering places and playground are situated in front of the church, school, and store. The distance from the southern face of the school and the first houses on the south side of the playground is 78m, the street width is 15.3m, making the distance across the playground 62.7m, of which the first 10m are shaded by the houses at 9:00 and 15:00 hours. Thus, the 52.7m depth that could be in the sunlight is near the 45m depth which would reduce the free wind speed to 30%, and therefore the playground is well protected. The public gathering places in front of the church, school, store and infirmary would be small and tight to the buildings, because people tend to gather at entranceways. They would be well within the 45m protected zone for north winds, and at the limit of the 3.5m for the northwest wind (see Fig. 155, Section 2.1.3.3. A W/H = 4 with a 0.5 L/H ratio gives a V_{av}/V_{rcf} of 30%, 0.5 of 7m (the height of service buildings) is 3.5m). Therefore, people in the public places would be protected from the north and northwest winds, and open to the west winds. In order to improve the protection from the northwest and west winds, a wind barrier would be placed perpendicular to the northwest wind (this would minimize the shadow especially at 15:00 hours) at a distance of 6.6 or 8.8m from the entranceway to be protected (see Fig. 153, Section 2.1.3.3 which shows that 30% wind velocity would be achieved behind a dense windbreak 2.2m. in height at a distance of 3 or 4 barrier heights).

Wind barriers could also be placed at areas along the pedestrian paths which were found to be unprotected for a particular wind direction.

In relation to the snow control requirements, the accumulation of snow does not create a problem, unless as described in Section 2.1.3.4, the snowdrifts create a pattern of ridges and valleys so close together that pedestrian movement would involve a great effort. Snow accumulation in the public gathering places and playground would not be problematic either unless it made entry and exit to the buildings difficult, and this can be resolved by a canopy as described in Section 3.3.4.2.2.

3.3.4.2.4 Streets

The streets are oriented parallel to the three dominant wind directions, i.e. they run northwest - southeast, north - south and west - east. Because the streets are oriented in three directions, the total length of streets are increased. For instance, the plan for Level A has 3,500m of road; Level B has 2,875m of road; Level C has 4,238m of road; while the synthesis plan has 4,363m of road. The plan at Level 1 has 3,125m of road; Level 2A has 3,363m; and Level 2B has 3,668m of road. If we take the average road length for Level 1, Levels 2A and B, and Levels 3A and B (Level C has a strong resemblance to the synthesis plan and is not included), we arrive at 3,325m of road length, which gives the synthesis plan 1,038m of additional streets. The multiplication of intersections creates triangular and trapezoidal housing blocks, which has the advantage of forming groups of 3, 4, 6, 7, 8, 10, 12, and 16 houses which is closer than the plan for Level 2B to the recommendation in Section 2.1.2 which suggested the formation of small kin-related groups of 6, 7, or 8 houses.

In regard to solar shading, the east - west streets are in shade more often and to a greater degree than the north - south and northwest - southeast oriented streets. As most of the streets are oriented northwest - southeast and north - south, most of the streets would be in sunlight.

The streets are designed to furnish wind protection and the multiplicity of their number and orientations provide the pedestrian with alternative routes depending on the direction of the wind. They also provide paths of quick access to the major socio-institutional buildings, and a means of direct approach to all sectors of the village for the fire truck. The

road from the airport leads directly to the store and infirmary, and the east - west streets give direct access to the warehouses. The dock has close access to the warehouses via the first north - south street, and has a direct link to the oil storage tanks by a special loop road.

The streets are oriented in three dominant wind directions to fulfill the first recommendation of Section 2.1.3.4. This should keep some of the streets clear of snow, thereby ensuring that service vehicles would always be able to reach the houses. This would effectively reduce the probability of the roads being filled up with snow to the same level as the roof tops, making delivery of services dangerous, as vehicles could pass over buried roofs, as has occurred in some Arctic villages (Baker Lake, in Adam and Piotrowski). The roads roads would have side slopes of 1:4 or 1:6 as space permitted to minimize snowdrifting.

Thus, the synthesized plan for Level 3 does in fact meet the majority of the requirements of the three climatic sub-levels. The plan represents the author's simulation of the synthesis process involving the identification of conflicts and their resolution by consultation, negotiation and compromise. This plan illustrates the synthesis process that would be carried out for Levels 2A and 2B, Levels 1 and 2, Levels 1 + 2 and 3, and finally Levels 1 + 2 + 3 and 4.

3.4 Level 4 Requirements - Plans Generated by User Participation

The plans generated at this level are based on the plans generated by the Inuit (see Appendix III-A and B, from Pluram). Since the original plans only contained 22 and 24 houses, and a minimum of 100 are required, this author expanded the number and length of the rows of houses until approximately 100 houses were included without deforming the original concept.

The first plan shown in Fig. 178 situates all the houses in four and a half rows parallel to the sea shore, locating all the socio-institutional and service buildings behind the fourth row, forming part of the fifth and sixth rows. The stores (there are two for competitive prices), infirmary, and school are located closest to the houses,with the church, day-care centre, recreation centre and warehouse in the fifth row. The community workshop (snowmobile repair show) is located at the northeast corner,

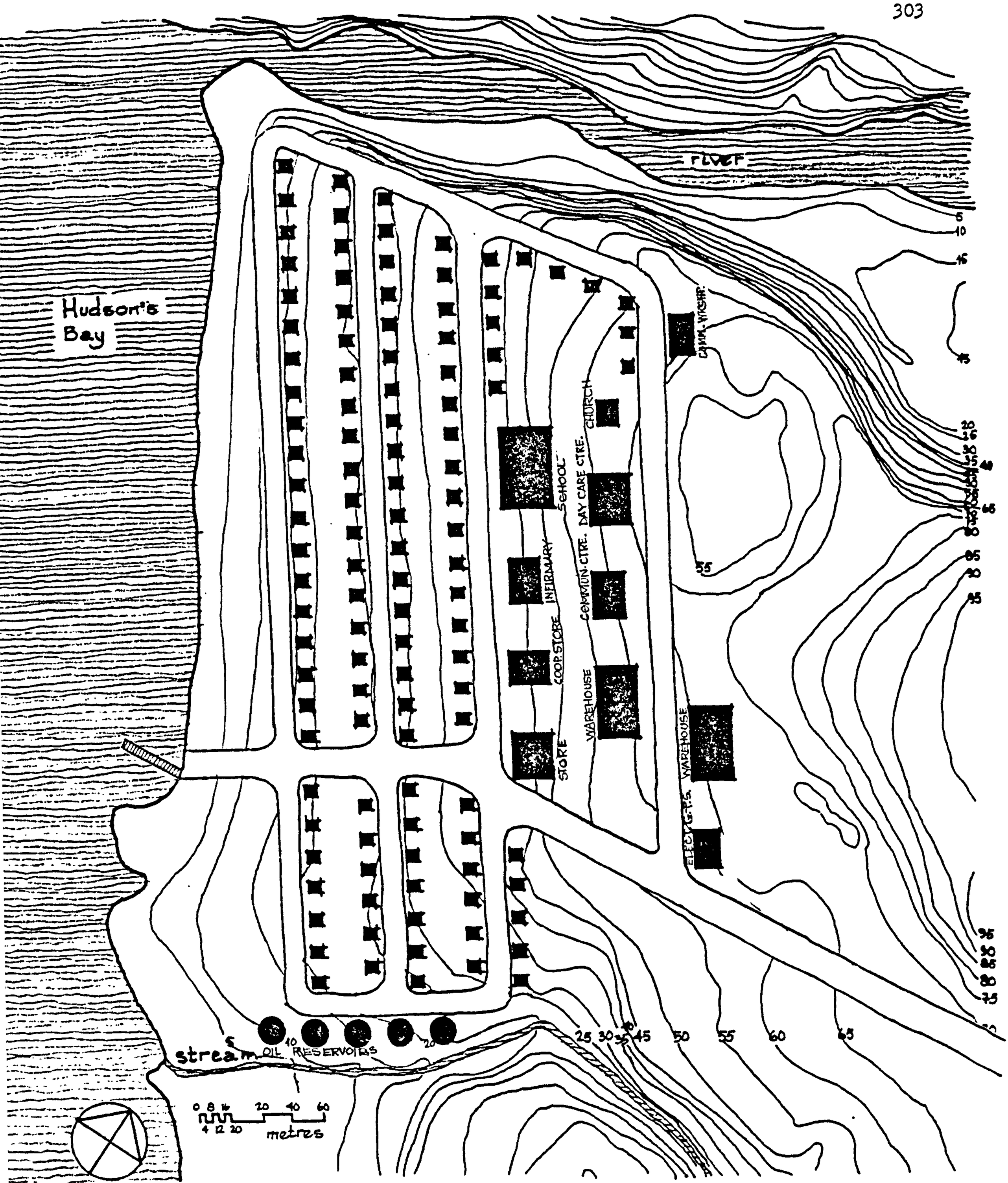
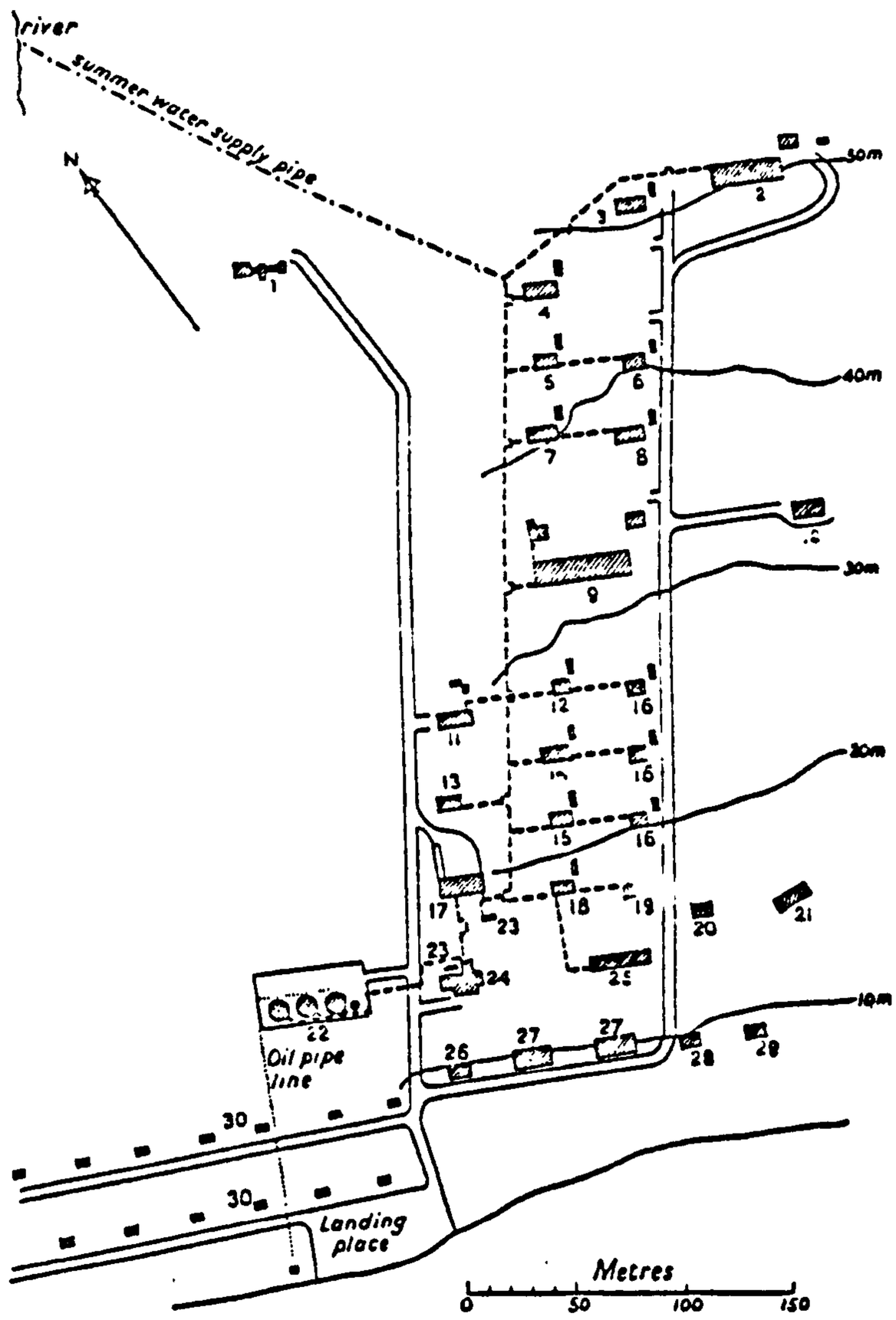


Fig. 178. Plan generated at Level 4 by user participation. (113 houses)

while the other warehouse and electricity generator - pumping station are located in the southeast corner of the village.

The proximity of the school, infirmary, and stores to the main mass of housing indicates the importance of these institutions, while the remote location of the community workshop, warehouse and electricity generator - pumping station either indicate that they are not directly important to the daily activities of the people, or they are sources of unwarranted noise and are situated as far away as possible. The relative directness of the dock to the stores indicates the importance of this link for the yearly stocking-up of provisions.

The location of the houses also indicates the importance of the proximity of the beach and direct access to the water. The houses are also off-set from one row to another so that the view of the sea is not blocked by the house in front and as the land rises, the houses further back would be able to look over the houses in front. Another important feature is that no socio-institutional or service building blocks the view to the sea. It is interesting to note in Maxwell's Study that the "mid-passage" variant of Dorset housing was usually oriented perpendicular to the closest body of water (1980, p. 506), a contemporary cultural trait that is expressed by the orientation of the houses in this plan. In the Pluram report, some Inuit remarked that they were too far from the beach in their present village (Great Whale River), and during the user-participation exercise with the village model, most people placed the first row of houses no further than 130' to 200' (40-60m) from the shore to avoid ice break-up problems (1979, pp. 496, 512). In one case all larger houses were placed closest to the shore "...because the large families need the best access to the hunting and fishing areas" (Pluram, 1979, p. 512). The importance of proximity to the shore was also noted in the Nunaturliq research report (1974, pp. 222, 223). Gerein also notes that proximity of houses to the water is an important design consideration in the settlement extension plan for Holman Island (1980, p. 114). A plan of the village of New Thule in Greenland shows the importance of the houses to the sea, where all the houses are laid out in two rows parallel to the shore and all the service buildings are laid out perpendicular to the sea. See Fig. 179.



Settlement at new Thule.

═══road	10. Church	20. Workers' barrack
····supply mains (above ground)	11. Garage	21. Canteen
1. Magnetic observatory	12. Catechist's house	22. Oil storage tanks
2. Hospital	13. Launderette	23. Oil tanks
3. Doctor's house	14. Electricity works engineer's house	24. Electricity works
4. Administrator's house	15. Trading company assistant's house	25. Office and shop building
5. Observatory director's house	16. Shop assistants' houses	26. Coal shed and warehouse for skins
6. Observatory assistant's house	17. Heating plant and water works	27. Warehouses
7. Teacher's house	18. Electricity works assistant's house	28. Factor's house
8. Priest's house		29. Catechist's house (temporary)
9. Boarding School	19. Workshop	30. Hunters' houses

Fig. 179. Plan of relocated Inuit settlement, new Thule, Greenland (Christensen, Rosendahl and Rosendahl, 1957).

The second plan shown in Fig. 180, locates the houses in four rows, two rows next to the beach and two rows behind the row of socio-institutional buildings. The houses are lined up one directly behind the other and

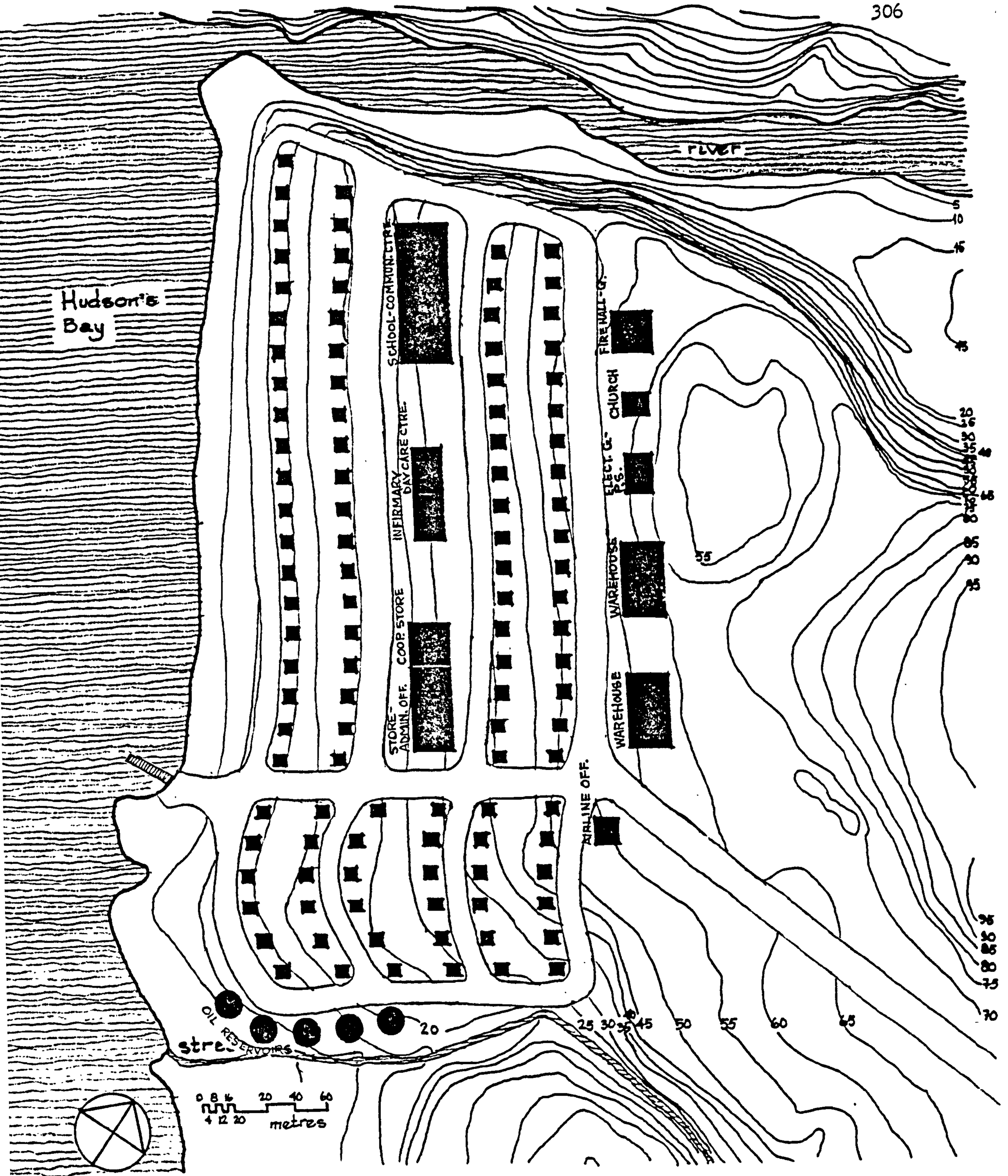


Fig. 180. Plan generated at Level 4 by user participation. (109 houses)

generally follow site contours. The socio-institutional buildings are separated into two groups, the first which includes the school - recreation centre - day-care centre - infirmary, and the two stores - all of which are situated between the second and third row of houses. The second group is made up of the fire-hall - garage, church, electricity generator - pumping station, and the two warehouses located behind the fourth row of houses. The school and the recreation centre, the day-care centre and the infirmary, the two stores, and the local administration offices are grouped together in three buildings, which might either be the expression of concern to conserve energy, or the desire to minimize the amount of land occupied by these services. All the other services are housed in separate buildings either indicating an incompatibility of function, or their relative unimportance to the population. The services incorporated in the three buildings are centrally located in the midst of the housing layout, as they are used on a daily basis.

The road leading from the dock to the airport passes near the stores and warehouses, suggesting that their direct access to the docking area was considered important for the reception of supplies.

The two plans generated by user participation have some similarities that warrant mention. The first common feature is the layout of the houses which are all oriented parallel to the sea shore and are situated as close as is feasible to the water's edge. A second common feature is the importance accorded to the school, infirmary, and the stores by their placement close to the majority of the housing in contrast to the location of the other services which were situated at the extreme eastern edge of the village. Another similarity in the two plans is the placing of a road leading from the dock to the airport in that it passes next to the stores and the warehouses. It should also be noted that both plans have the two competing stores either adjacent to each other or actually sharing a common building.

It is worth mentioning that the stores were situated closer to the road giving direct access to the dock, than to the actual centre of gravity of the village. This could either signify a concern for the easy transfer of yearly supplies to the stores from the dock, or the lack of importance of their centrality with regard to pedestrian access. In the Pluram Report, some Inuit placed the two stores close together so as to have a greater

selection of goods at one location (1979, p. 514), but it was not explained why the stores were located close to the southern extremity of the housing group.

These plans (Figs. 178, 180) represent an example of the synthesis of the different categories of plans that could be generated by the Inuit. The process is similar to that described by Zrudlo for the categorisation of house plans generated by user participation (1979, p. 289; 1980, p. 273). The variety of plans generated would be reduced by grouping them into categories of plan types which would then be presented to the community for the final selection by a community-wide vote. The final plan selected by the community is not simulated here, because it would require too much speculation on the part of the author, and would not illustrate any pertinent information.

The plans presented for the Four Levels therefore terminate the illustration of the Four-Level Model, because any further simulations, as discussed earlier in this section would be overly biased by the author's personal experience, and not representative of the results of the process of negotiation and compromise carried out by a group of specialists and the Inuit.

3.5 Actual Plan of Richmond Gulf Proposed by the Planners

The author decided to apply this document's requirements to the plan actually proposed for the Richmond Gulf site (used by the author for the case study) in order to evaluate a planner's (the Pluram group) town layout, and to test the Four-Level Model's applicability to more specific situations. The plan is assessed using the climatic data from the actual site at 56° 30'N rather than the general climatic data compiled in this document for latitude 65°N.

3.5.1 Evaluation of Richmond Gulf Plan Using Four-Level Requirements

Level 1 - The Pluram Plan in Fig. 181 shows that most of the houses follow the contour lines with the exception of four triplex houses immediately to the west of the school on the road leading to the dock. All the houses bordering the beach are located at least 40m from the water's edge, and the houses at the north end of the village are sufficiently distant from the unstable land that slopes down to the river. The socio-institutional

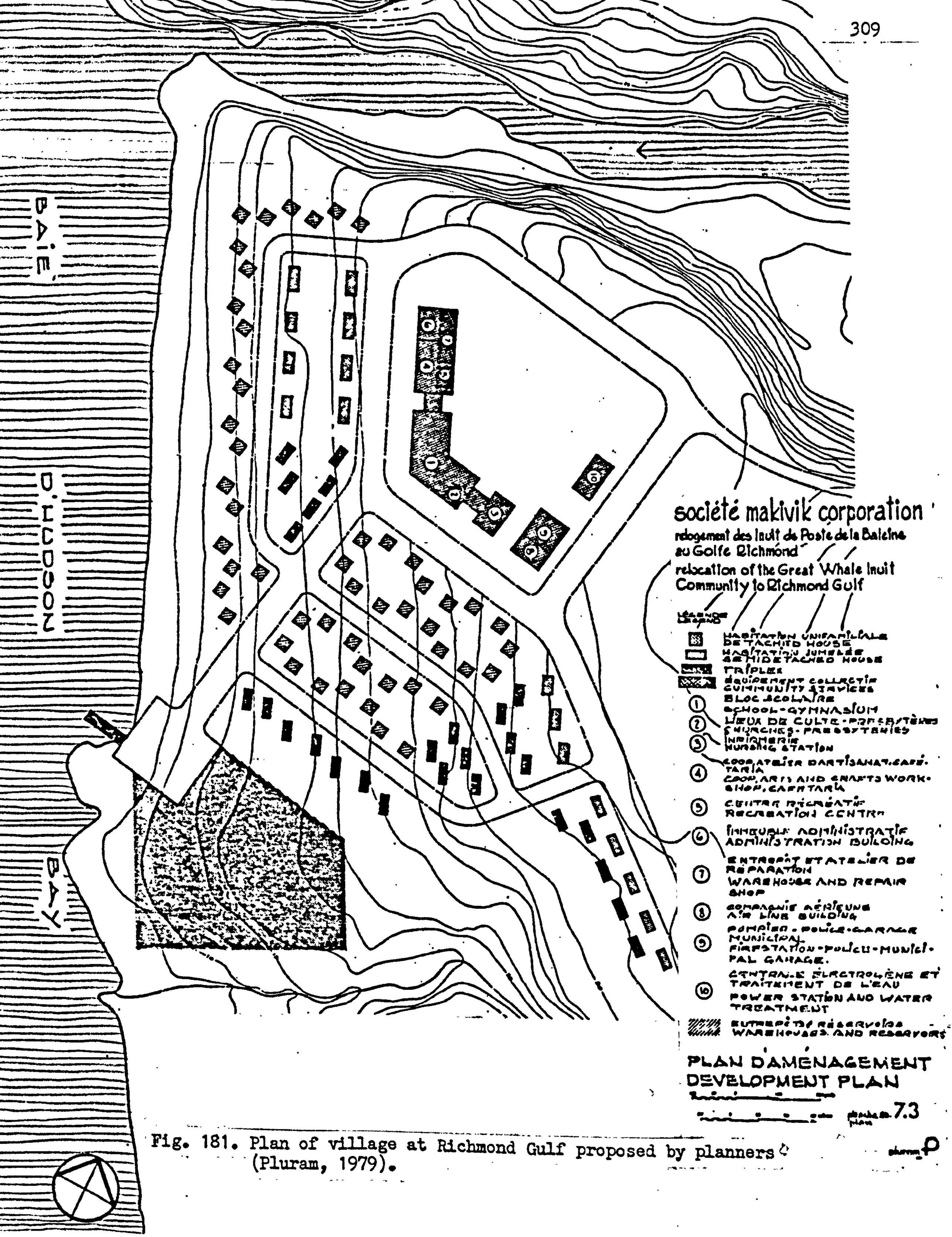


Fig. 181. Plan of village at Richmond Gulf proposed by planners (Pluram, 1979).

and service buildings are situated on the filled-in, wind-eroded hollow, creating the potential future danger of unstable foundations due to wind erosion. The filled-in hollow, however, creates the only flat section of land capable of accommodating the school, church, infirmary, store-cafeteria, recreation centre, administration offices, and repair shop all located in one building.

The water-pumping station is positioned at the eastern limit of the socio-institutional and service building group close to the upstream source of potable water.

The streets run at approximately 0°, 30°, and 60° to the site contour lines, thereby running the risk of damming water run-off which would cause flooding, resulting in the wash-out of road beds and house foundation pads.

The conflicts at this level are: 1) Four triplex houses that do not follow the contour lines, which by their length could present foundation complications; 2) the location of the socio-institutional and service buildings in the zone where wind erosion occurs which could cause foundation instability; and 3) the orientation of the streets at 0°, 30°, and 60° to the contour lines which could cause the damming of water run-off, resulting in road-bed damage and foundation pad erosion.

Level 2 - With regard to the technical service infrastructure, Level 2A, the water supply line has a relatively complicated circuit to follow, although with the exception of the line running parallel to the beach, the sewer runs are simple and follow the slope of the land so that a gravity system could be used. See Fig. 182 (Pluram, 1979, p. 191).

The electricity service lines are not indicated, but it should be feasible to install only two transformers, one near the centre of the group of houses to the north of the village, and the other near the centre of the houses to the southeast. The 122m distance for the secondary lines could easily be respected.

For Level 2B, the socio-institutional and service buildings are all grouped together in three separate buildings facing onto the streets which lead directly to the dock and the airport from which goods and people enter the village.

The furthest houses are 386m from the school and 440m from the store, and

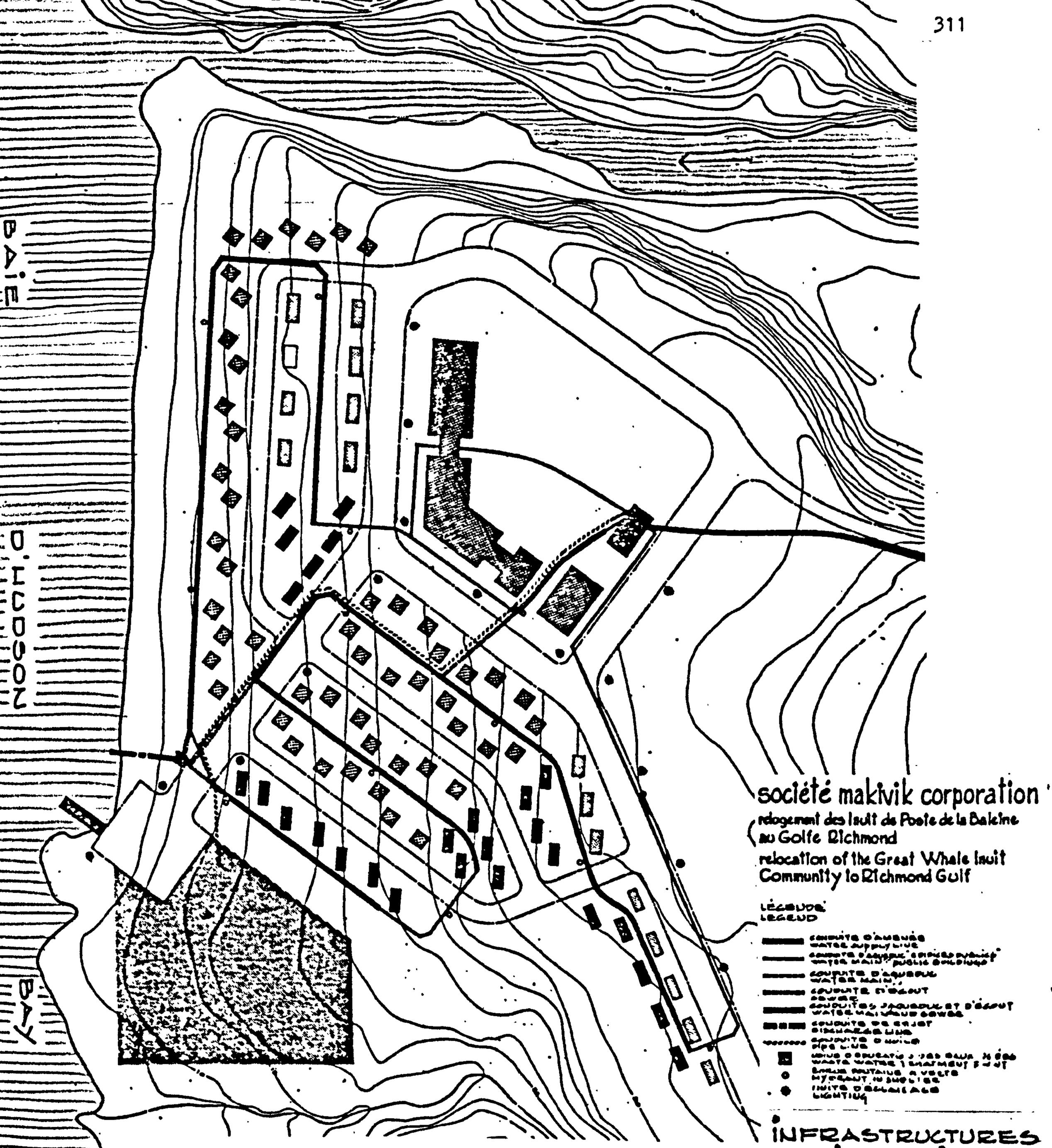


Fig. 182. Plan indicating technical service infrastructure (Pluram, 1979).

are situated at the southeast extremity of the village, which gives the people closest to the beach the additional advantage of being closest to the store and school. It would seem that a more equidistant location of the services in relation to the houses would have been preferable. The four clusters of 8 single detached houses, and the grouping of semi-detached houses and triplexes seems to be an attempt at creating kin-related group clusters, but this is not systematic.

The warehouses and oil reservoirs occupy a privileged position next to the dock and the water's edge which could have been given to the houses. The water pumping station is located at the eastern extremity of the village from where the water line runs out to the river. The fire hall-garage is located near the socio-institutional and service centre which is advisable in the case of fire, but unfortunately the road system would not allow fire-trucks easy access to all the houses.

The disadvantages at Level 2 seem to be minor, such as: 1) a complicated water supply line; 2) the socio-institutional and service buildings are not equidistant from the extremities of the village; and 3) roads do not give the fire truck easy access to all houses.

Level 3 - At Level 3A, the Pluram plan displays a concern for solar exposure by the orientation of all the detached single houses on the north-south axis. The semi-detached and triplex houses are oriented N.NW-S.SE, N.NE-S.SW and NW-SE. The Pluram group set "...maximum exposure to the sun..." as an important objective in house siting (1979, p. 238), but did not respect their objective when it came to multiple-family housing.

The relatively close grouping of the houses results in a good deal of mutual shading. In Fig. 183, the author has added to the Pluram plan the shadows which would occur at February 5 and November 6 at 9:00, 12:00 and 15:00 hours for latitude 56°N. The alternate rows of triplexes and semi-detached houses in the southeast sector are especially disadvantaged. The school playground is also in shade from noon to 15:00 hours, while the entrance to the school and store are in shade from 9:00 to ncon.

The pedestrian paths are assumed to be the streets, and for the most part they are in sun except for the street in the southwest sector near the warehouse area directly in front of the triplex houses. The single detached

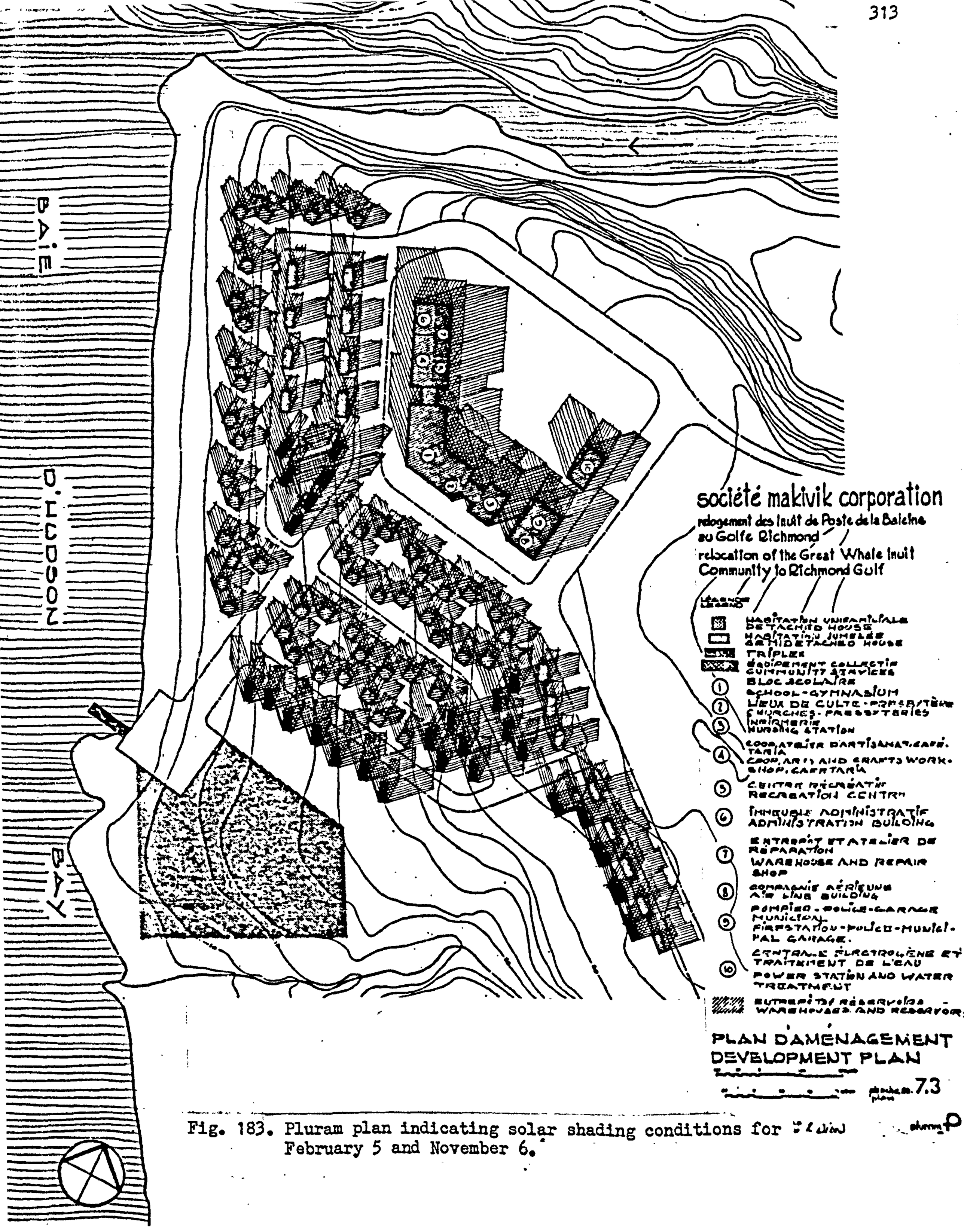


Fig. 183. Pluram plan indicating solar shading conditions for [illegible] February 5 and November 6.

and semi-detached houses are assumed to be one storey in height, while the triplexes are considered to be two-storeys high, which accounts for the variation in shadow length.

Level 3B requirements do not seem to have received as much consideration as the solar shading aspects. It was stated that the grouping of the houses was "...designed to adapt to and to make the best possible use of the specific physical environment and climate of the new village in order to protect the houses from the prevailing winds, and thus create a more favourable micro-climate" (Pluram, 1979, p. 238). The planners also proposed that the socio-institutional buildings be used to protect the village from the east winds by acting as a protective screen (pp. 148, 152). The Pluram group observes that there is a constant exposure of the site to strong winds from the west and east. As was pointed out earlier in Section 1.5.2.14, the wind data was interpolated from Inukjuak and Kuujjuaraapik (p. 114), personal observations by Inuit, and site observations based on geomorphological and erosion indicators (pp. 508, 104, 112). However, the author's analysis of the climatic data from the two villages previously mentioned, which are north and south of the site, and the channelling effect due to the presence of off-shore islands with an open passage leading directly from the site to the expanse of Hudson's Bay (see map in Appendix III-C), - indicates some apparent contradictions in the choice of dominant wind directions made by the planners. As was mentioned in Section 1.5.2.14, Inukjuak (also known as Inoucdjouac) seems to have more geographic similarities to the site than Kuujjuaraapik (also known as Poste-de-la Baleine), leading the author to use the data from Inukjuak. The most frequent winds at Inukjuak are from the northeast, followed closely by the north wind, with a less frequent third dominant wind blowing from the west. With regard to the velocity, Inukjuak's strongest winds come from the northwest followed by the east and southwest winds which are equally strong (Canadian Normals, Wind 1955-1972, 1975, p. 132).

Using Inukjuak's figures for the strongest winds (which are the most favourable for this plan), then the strongest winds would sweep through the village without any protection. Only when the winds blow from the east (7th most frequent wind) would the socio-institutional buildings and the hillside provide some protection for the houses. However, the other wind equal in strength to the east wind blows from the southwest, for which the

plan provides no protection. The difference in velocity between the most frequent northeast and north winds and the 7th most frequent but second strongest wind (east), is only 1.5 and 2.6mph. Therefore, the northeast and north winds are as important as the east wind.

The socio-institutional buildings and the hill would protect approximately 50% of the houses from the northeast wind, and a little less than 50% from the north wind. The third most frequent wind (west) has a velocity only 0.8mph. less than the east wind (which has a velocity of 13.8mph.), and sweeps unprotected across the village.

The houses are not placed in any pattern that would suggest that they were positioned to create "wind shadows" or protected zones behind them for the dominant wind directions. However, there does seem to be an attempt to create a protected microclimate in the interior courtyard formed by the four clusters of 8 single-detached houses in the central southern sector of the village. The validity of this protected courtyard should be verified by wind tunnel tests, and if found effective should be used elsewhere in the village.

The Level 2 requirement that no house be farther than 400m from the closest indoor public space is easily fulfilled, as the greatest distance is 320m between the infirmary and the farthest house in the southeast sector on the road to the airport. Another requirement is met with this housing layout as only 9% of the houses are farther than 270m from the school, and 18% are beyond the 270m limit from the store, which is well below the 50% maximum suggested. There are also no houses more than 54m from their furthest neighbour.

Level 3C requirements seem to have received even less consideration than Level 3B. The Pluram report states quite tersely and with little conviction that: "...the roads should be oriented in the direction of the prevailing winds (natural sweeping of the snow)..." (1979, p. 72). This objective has been proposed by most planners, but no real effort has been made to consider the plurality of prevailing winds. In the Pluram plan the streets are oriented N.NW.-S.SE. and W.NW.-E.SE., and as has been mentioned above, the most frequent winds are from the northeast, north and west, while the strongest winds blow from the northwest, east and southwest. The west and east winds can be said to be considered in the streets oriented W.NW-E.SE.,

of which there are three. The north and northeast winds, however, would blow through the village creating large snowdrifta behind the socio-institutional complex, because the distance between these buildings and the road does not exceed the 33 to 47m limit suggested to avoid drifting. The northwest and southwest winds would also probably create snowdrifts in the streets leeward of the houses. The west and east winds would also produce large snow accumulations in the streets oriented N.NW.-S.SE. In the northwest sector of the village, because the W.NW.--E.SE. streets do not continue through to allow the winds an uninterrupted flow, drifting snow is likely to occur at the point of discontinuity.

Most of the houses do not have the minimum 14m clearance all around them that is recommended to avoid the coalescence of snowdrifts between buildings. The spacing between the two-storey triplexes is even more serious, as none of them approach the 33m minimum distance suggested to prevent drift coalescence. Since the most dominant winds are northeast and north, and the strongest winds are from the northwest, the north - south orientation of the single detached houses (for solar exposure) meets the requirement that the houses be turned 45° to the storm winds. The semi-detached and triplexes do not have this ideal orientation, and would most probably create large drifts in their leeward zone. In any case, the plan requires snowdrifting simulation studies to verify to what degree snow accumulation would be problematic.

The major conflicts at Level 3 are: 1) the lack of maximum solar exposure for the semi-detached and triplex housing; 2) the high incidence of mutual solar shading in the housing groups; 3) the shading of the playground from noon to 15:00 hours on November 6 and February 5; 4) the houses are not protected from the west winds (third most frequent), the northwest (strongest wind at 14mph.) and the southwest wind (second strongest wind equal to the east wind at 13.8mph.); 5) the street layout does not provide the diversity of orientation so that the most frequent northeast and north winds, as well as the strongest northwest winds can blow the streets clear of snow;
6) the distance between the socio-institutional building complex is not large enough to prevent snowdrifting in the streets; 7) the spacing between the triplex housing is insufficient to avoid the coalescence of drifts;

8) the semi-detached and triplex housing are not turned at 45° to the most frequent and strongest winds (northeast and northwest) and would not minimize snow accumulation around their leeward faces.

Level 4 - The plan respects, to a certain degree, the major requirement brought out in the plans generated through user participation, namely: the proximity of most of the houses to the beach and an unobstructed view of the sea. There is, however, some housing in the southeast sector which does seem a little distant from the shore, especially the semi-detached and triplex houses on the road to the airport. The houses in the user participation plans were all parallel to the shore, which emphasizes the importance the Inuit give to the view. In the Pluram plan the single detached houses in the four clusters and those in the extreme southeast sector do not have an unobstructed view of the sea.

The location of the store, school and infirmary central to the majority of the houses achieves a need expressed by the Inuit in their plans. The electricity generator - pumping station, fire-hall - garage and airline office are located in the northeast sector so as to isolate any annoying noise from the rest of the village. The store and infirmary are on streets that give relatively direct access to the dock and the airport which was another planning pattern that emerged from the user participation generated plans.

A housing pattern which did not emerge from the user participation generated plans, and might have emerged under a differently structured participation procedure, is the grouping of houses into clusters or neighbourhood units based on kin-related groups such as those found in the 1964 plan of Salluit (see Fig. 130). This may be due to the absence of an educative phase in the user participation procedure, which results in the users simply reproducing variations of the environment they presently inhabit (see Taylor, 1973, p. 728; Martin, 1974, p. 629; Zrudlo, 1979,p.282). Therefore a participation procedure needs to be developed that exposes the participant to alternatives that do not exist in his environment, allowing the user to explore and produce solutions that could only be brought forward through this kind of stimulation (Zrudlo, 1980, pp. 267-269). The presentation of a cluster alternative may have proven a desirable pattern, but one that the people may not have thought possible. Thus the four clusters of 8 houses presented in the Pluram plan does not seem to satisfy a cultural need, but requires

verification in a more rigourous and educative user participation procedure. In Section 2.1.2 the author presents archeological data that suggests that kin-related housing groups of 6 to 8 houses were frequent, and could be valid for present day Inuit.

The only major conflict at this level seems to be the somewhat arbitrary decision to locate a large portion of the village away from the beach. Normally a major design decision such as this would be supported by evidence based on solid design criteria.

From the eveluation it is evident that the proposed village plan functions best at the technical (Levels 1 and 2), moderately well at the cultural level, and very weakly at the climatic levels. The plan has the most conflicts at the solar shading and snow control levels, but the lack of protection for the houses from the dominant and strongest winds is a rather major flaw, affecting as it does the comfort of pedestrians and the heating load of the houses.

The degree of involvement of the population in the design process is commendable (although the procedure used lacks the rigour the technique demands), but what is surprising is that the plans generated by the Inuit, which consistently positioned the houses parallel to and in immediate proximity to the beach, did not have a greater influence on the final plan which situates a significant number of houses away from the beach. As was mentioned previously, the warehouses occupy prime waterfront land which is questionable, as is the limiting of the housing parallel to the beach to only three rows of houses when they could have been easily increased to four or five rows by moving the socio-institutional complex slightly to the northeast.

In general, it can be said that the planner's settlement plan resolves most of the normal technical problems, a few of the climatic problems, and is more sensitive to cultural needs than most plans produced to date. It is a small step in the right direction of giving more consideration to the very important factors of climate and culture.

4. CONCLUSION

The case study has shown that the integrated design approach to settlement planning as demonstrated by the Four-Level Model is in fact an integrative process which depends on the synthesis within and between each level.

As noted in the description of the theoretical basis for the model (Section 2.), the synthesis process, which requires consultation, negotiation and compromise with all the members of the design process (specialists and future inhabitants), would bring about a greater awareness, understanding and appreciation of the fellow participant's requirements. This is especially true for the Inuit today who are becoming more alienated from the government decision-makers who are seen as opponents rather than as partners.

Popper describes the attitude needed when involved in free discussion between people who do not share common basic assumptions. He states that what: "...is needed is a readiness to learn from one's partner in the discussion, which includes a genuine wish to understand what he intends to say. If this readiness is there, the discussion will be more fruitful the more the partners' backgrounds differ. Thus the value of a discussion depends largely upon the variety of the competing views" (Popper, 1963, p. 352). It is important that an attitude of mutual respect exists, and that there is a realization of the need for differing points of view, so that a "true" synthesis can be achieved. A synthesis on any other basis could result in one group dominating another group, producing reasons of a highly technical nature to support their unwillingness to listen carefully with respect to the ideas and opinions of the other participants. The result could be a synthesis that has in fact been forced upon the other participants. This latter fact, in the case of the Inuit, is at present being echoed with more and more bitterness, and a definite breach is starting to take place between them and the government. An attitude of partnership is necessary so that specialists will look for alternatives when their technical requirements come into conflict with the requirements of other members of the partnership.

The synthesis procedure in the Four-Level Model provides the framework within which this attitude of partnership could develop. From the beginning

of the synthesis of Levels 1 and 2, all participants should be present and actively involved, whether the particular level of requirements they are concerned with is in the process of being integrated or not. It has been observed that: "...insufficient knowledge is always a serious limitation in a dialogue between users, architects and authorities" (Egelius, 1980, pp. 3-4). This is important because "...one party (the specialists) has a set of constructs that are more complex (which) requires an expository or educative process in which the complexities are made fully intelligible to the public" (Stringer, 1972, p. 29). The involvement of the users at all phases of the synthesis would ensure that this educative process would in fact occur. Through this involvement, the user would know the reasons for decisions, and could make informed choices between alternatives.

Ideally the synthesis of all Four Levels should be carried out in a relatively short, single time period, so that a final solution could be achieved without the partnership changing its members or the decisions taken during the various phases of synthesis.

The Four-Level Model, as has been pointed out previously, needs testing in a real situation to assess the workability of the synthesis procedure between levels. It may prove, for example, that Levels 1 and 2 should be combined into a single level which is typical of the actual planning process. This may shorten the time involved for the whole synthesis procedure, but could eliminate valuable alternative plans if the synthesis is made in a single stage rather than three separate stages (Levels 1, 2A, and 2B).

The final phase of the synthesis process (Levels 1, 2, 3, and Level 4), requires testing with the users in order to reveal any difficulties in working with user representatives in the "synthesis partnership", who would explain the synthesis plan of Levels 1, 2, and 3 to the users in order to facilitate the negotiation and compromise process necessary to the integration of Level 4. It should be assured that a cross-section representative of the age, sex, clan, and family structures is achieved when the user representatives are chosen for the synthesis partnership.

The author considers user participation an underlying principle in all design solutions, and it has been called: "...one of the most fundamental

civil rights" (Maver, 1972, p. 83). The author believes that for this fundamental right to be exercised with justice to all concerned, governments and organizations must understand that: "...it is through people-involvement and commitment that problems can be solved and goals reached" (Feo, 1972, p. 41).

The author's model provides not only a framework for user participation, but also furnishes design guidelines for the uninitiated as well as the experienced arctic designer. Detailed guidelines are given for the climatic factors and a strategy for their use is elaborated in the case study. These factors which have received so little serious attention in the past can now become a natural phase of the planning process.

The model is sufficiently open-ended in its structure that it can include and encourage the changing needs that will occur in a culture that is in transition, as is that of the Inuit. It may happen, for example, that the Inuit in the future will require more protection from the hostile aspects of the climate, and will begin to be more concerned with comfort and energy costs. In this thesis, great emphasis has been put on climatic considerations for which there is an urgent need of solutions as villages become more responsive to energy constraints.

The Four-Level Model furnishes a "...solution-generating system rather than solutions" (Maver, 1972, p. 83), which is a break with past planning traditions. It is hoped that the Four-Level Model, even if it is proven to have shortcomings, will "...suggest some more or less radical modifications. .." which will furnish "...important stepping stones towards the truth, (providing an) instrument for further discoveries" (Popper, 1963, pp. 141, 245).

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APPENDIX I-A

SETTLEMENTS IN THE CANADIAN ARCTIC ABOVE THE TREE LINE - LATITUDES

Aklavik	68°	Eskimo Point	61°
Alert	83°	Eepikitajuk	72°
Arctic Bay	73°	Frobisher Bay	64°
Aupaluk (Qué.)	59°	Ferguson Lake	62°
Apex	64°	Fort Ross	72°
Agu	70°	Fort Collinson	72°
Amadjuak	64°	Fort Conger	82°
Angukalee	74°	Fort Chimo (Qué.)	58°
Arnaguakjuk	72°	George River (Qué.)	59°
Avataktoo	66°	Gjoa Haven	68°
Aquiatulavik Point	64°	Grise Fjord	76°
Anderson River	70°	Holman Island	71°
Baker Lake	64°	Herchel Island	69°
Broughton Island	68°	Inoucdjouac (Qué.)	58°
Belcher Islands	56°	Inuvik	68°
Bathurst Inlet	67°	Isachsen	79°
Bernard	69°	Ivujivik (Qué.)	62°
Bache Peninsula	79°	Igloolik	69°
Cape Hope's Advance (Qué.)	61°	Ikaluit	64°
Churchill (Man.)	59°	Iglungo	66°
Cambridge Bay	69°	Kingmiksok	65°
Cape Dyer	67°	Koluktoo	72°
Cape Parry	70°	Kivitoo	68°
Chesterfield	63°	Kittigazuit	69°
Clyde	70°	Kekertuk	68°
Coppermine	68°	Kangmakjuk	74°
Coral Harbour	64°	Karman	67°
Cape Dorset	64°	Kekerten	66°
Cape Smith (Qué.)	61°	Koartak (Qué.)	61°
Craig Harbour	76°	Lake Harbour	63°
Cape Bathurst	70°	Leaf Bay (Qué.)	59°
Dundas Harbour	75°	Letty Harbour	70°
Ennadai Lake	61°	Mould Bay	76°
Eureka	80°	Maguse River	61°

Latitudes (cont.)

Martin House	67°
Nottingham Island	63°
Nuwata	65°
Nunalla	60°
Nunatak	66°
Nedlung	67°
Napakot	69°
Opingivik	65°
Ooyarasukjooeet	73°
Padloping Island	67°
Pelly Bay	68°
Pond Inlet	73°
Poste de la Baleine (Qué.)	55°
Padle	67°
Padlei	62°
Pangnirtung	66°
Povungnituk (Qué.)	60°
Port Burwell	60°
Payne Bay (Qué)	60°
Perry River	68°
Paulatuk	70°
Resolute	75°
Resolution Island	61°
Rankin Inlet	63°
Repulse Bay	67°
Read Island	69°
Reindeer Depot	69°
Saunik	66°
Starvation Cove	69°
Sachs Harbour	72°
Sagluk (Qué.)	62°
Spence Bay	70°
Stanton	69°
Sanikiluaq	57°
Tesseralik	66°
Tikeetawkut	73°
Tununuk	69°
Tavani	62°
Tuktoyaktuk	69°
Tom Cod	70°
Thom Bay	70°
Usualuk	66°
Utusivik	65°
Wager Bay	66°
Whitefish	69°
Wakeham Bay (Qué)	62°
Whale Cove	62°

LATITUDE TOTAL 7,774

Total number of settlements 115

Therefore the average latitude of the 115 settlements is 67.6° - thus latitude 65° was adopted.

The settlements and latitudes were taken from the following sources:

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APPENDIX I-B

CALCULATION OF AVERAGE TEMPERATURES (°F) OF 36 ARCTIC SETTLEMENTS RANGING IN LATITUDE FROM 60°N to 70°N, TO BE USED AS TYPICAL CONDITIONS FOR THE LAT. 65°N.

N.B. SPRING IS TAKEN AS MAY
SUMMER IS TAKEN AS LASTING FROM JUNE TO SEPTEMBER
AUTUMN IS OCTOBER
WINTER IS TAKEN AS RANGING FROM NOVEMBER TO APRIL

	SPRING		SUMMER			AUT.	WINTER						
VILLAGE	M	J	J	A	S	O	N	D	J	F	M	A	
AKLAVIK	31	49	57	52	39	19	-3	-17	-20	-17	-8	9	Av. Daily
(68°14'N)	40	58	65	59	44	24	3	-11	-12	-10	1	19	Av. Max. Daily
	23	41	49	44	33	15	-9	-24	-27	-25	-17	-1	Av. Min. Daily
BAKER LAKE	19	38	51	50	36	19	-4	-18	-29	-27	-17	0	
(64° 18'N)	26	44	60	57	42	25	3	-11	-22	-22	-9	9	
	12	31	42	42	31	13	-11	-24	-35	-33	-24	-8	
BREVOORT ISLAND	23	33	40	39	32	23	13	2	-8	-6	-2	7	
(63° 21'N)	28	37	44	44	35	26	17	7	-3	0	3	15	
	18	29	35	35	28	19	8	-4	-13	-12	-8	-3	
BROUGHTON ISLAND	19	31	41	39	29	18	5	-6	-12	-13	-10	2	
(67° 33'N)	24	36	47	43	32	22	9	-1	-6	-7	-5	7	
	14	26	35	34	25	14	0	-11	-17	-19	-16	-3	
BYRON BAY	16	36	48	45	31	14	-9	-19	-27	-28	-20	-6	
(68° 45'N)	23	42	55	51	36	19	-3	-13	-21	-22	-18	2	
	9	31	41	39	27	8	-16	-26	-33	-34	-27	-13	
CAMBRIDGE BAY	15	35	47	44	31	12	-11	-21	-29	-30	-22	-8	
(69° 06'N)	21	40	54	50	35	18	-4	-15	-22	-24	-15	0	
	8	30	40	39	27	6	-17	-28	-35	-36	-29	-16	
CAPE DYER	22	33	42	40	30	19	5	-5	-8	-9	-8	6	
(66° 35'N)	28	39	48	46	36	25	13	3	0	-1	0	14	
	16	27	36	35	25	12	-2	-13	-16	-18	-17	-3	
CAPE HOOPER	19	31	41	37	29	19	4	-8	-13	-14	-11	2	
(68° 26'N)	24	36	46	42	32	22	8	-3	-9	-9	-7	7	
	14	26	35	33	26	15	-1	-12	-18	-19	-16	-3	
CAPE HOPES AD-	26	35	42	42	37	29	19	5	-7	-7	0	12	
VANCE (61° 05'N)	31	40	49	48	41	32	24	11	-1	-1	6	18	
	21	30	36	37	33	25	14	0	-12	-13	-6	6	
CAPE PARRY	21	35	42	42	34	20	-1	-12	-19	-23	-15	1	
(70° 10'N)	26	40	48	46	37	24	5	-7	-14	-17	-9	7	
	16	31	37	37	30	17	-6	-18	-25	-29	-21	-6	
CAPE YOUNG	19	36	44	44	34	20	-3	-15	-21	-23	-17	-2	
(68° 56'N)	27	42	51	50	38	25	4	-7	-13	-16	-8	7	
	12	30	37	38	31	15	-10	-22	-29	-31	-25	-11	
CHESTERFIELD	20	36	48	47	37	23	2	-14	-25	-26	-14	2	
(63° 20'N)	26	42	55	54	41	28	9	-7	-19	-17	-6	10	
	13	31	40	41	32	18	-6	-21	-32	-32	-22	-7	

APPENDIX I-B (cont.)

	M	J	J	A	S	O	N	D	J	F	M	A	
CLINTON POINT	23	38	45	44	33	19	0	-10	-17	-20	-12	3	Av. Daily
(69° 35'N)	29	44	52	50	38	24	6	-4	-11	-13	-5	9	Av. Max. Daily
	17	32	39	38	29	15	-6	-16	-23	-27	-19	-4	Av. Min. Daily
CLYDE	20	34	40	39	32	20	2	-12	-16	-17	-15	-2	
(70° 27'N)	27	39	47	45	36	25	8	-5	-9	-10	-7	8	
	12	28	33	34	27	15	-5	-18	-24	-25	-24	-11	
CONTWOYTO LAKE	20	39	48	48	36	19	-5	-18	-24	-24	-16	1	
(65° 29'N)	28	47	57	55	40	24	2	-11	-17	-17	-7	10	
	12	31	39	41	31	14	-12	-25	-31	-31	-24	-10	
COPPERMINE	22	38	49	48	36	21	-3	-14	-21	-24	-15	0	
(67° 50'N)	29	45	56	54	41	26	4	-7	-14	-16	-7	9	
	15	32	41	41	31	15	-10	-21	-28	-31	-23	-9	
CORAL HARBOUR	20	36	47	46	34	18	1	-12	-23	-21	-12	3	
(64° 12'N)	28	41	55	53	39	25	9	-5	-15	-13	-3	12	
	13	30	40	38	29	12	-6	-20	-30	-29	-21	-7	
DEWAR LAKES	17	31	43	40	27	13	-2	-12	-17	-18	-16	-2	
(68° 39'N)	22	36	49	45	30	18	4	-7	-12	-12	-10	4	
	12	26	37	35	23	8	-8	-17	-22	-25	-21	-8	
FROBISHER BAY	26	38	46	45	36	24	10	-5	-15	-13	-8	7	
(63° 45'N)	32	44	53	51	41	29	16	3	-8	-5	0	15	
	20	33	40	38	32	18	3	-12	-22	-21	-17	-2	
GLADMAN POINT	15	33	46	43	30	12	-11	-22	-30	-32	-24	-8	
(68° 40'N)	21	38	53	49	34	18	-4	-15	-24	-25	-17	1	
	8	28	38	37	26	7	-18	-28	-36	-38	-31	-17	
HALL BEACH	16	33	42	41	31	14	-6	-16	-25	-25	-19	-4	
(68° 47'N)	24	37	47	46	34	20	2	-9	-18	-17	-11	5	
	8	28	36	36	28	7	-13	-24	-32	-32	-27	-13	
INUVIK	31	50	56	51	37	19	-5	-17	-21	-21	-11	6	
(68° 18'N)	39	61	67	60	44	25	2	-8	-11	-11	0	18	
	22	39	45	41	30	13	-12	-26	-30	-31	-22	-6	
JENNY LIND IS-	15	33	43	41	30	14	-9	-21	-29	-31	-22	-8	
LAND (68° 39'N)	21	37	49	46	34	19	-2	-15	-23	-24	-16	0	
	8	28	37	36	26	8	-16	-28	-36	-37	-29	-16	
LADY FRANKLIN	19	36	43	43	34	20	-3	-16	-22	-24	-17	-3	
POINT (68° 30'N)	26	41	49	49	38	24	3	-10	-15	-17	-10	6	
	12	30	37	38	30	15	-10	-22	-29	-31	-25	-11	
LONGSTAFF BLUFF	19	34	45	44	31	15	-1	-13	-19	-19	-15	0	
(68° 57'N)	24	38	50	49	34	20	5	-6	-13	-12	-10	5	
	14	30	39	38	27	11	-7	-19	-26	-25	-20	-6	
MACKAR INLET	15	31	43	41	26	10	-7	-17	-27	-26	-17	-3	
(68° 18'N)	20	35	50	46	29	15	-1	-10	-21	-20	-11	2	
	10	26	37	35	22	5	-12	-23	-32	-32	-23	-9	
NICHOLSON PENIN-	22	39	46	44	34	19	-3	-14	-18	-21	-13	0	
SULA (69° 54'N)	28	47	54	50	38	23	2	-8	-11	-14	-7	7	
	16	31	38	38	29	15	-8	-20	-24	-28	-20	-7	

APPENDIX I-B (cont.)

	M	J	J	A	S	O	N	D	J	F	M	A	
NOTTINGHAM IS-	24	35	43	42	35	26	14	-1	-12	-12	-4	9	Av. Daily
LAND (63° 07'N)	30	40	50	49	39	30	19	5	-6	-5	3	17	Av. Max. Daily
	19	30	36	36	30	22	8	-6	-18	-18	-12	1	Av. Min. Daily
PADLOPING IS-	22	35	42	40	34	24	10	-6	-8	-13	-12	1	
LAND (67° 06'N)	28	40	48	46	38	28	14	0	-8	-8	-6	8	
	16	30	35	35	30	20	6	-11	-20	-18	-17	-6	
PELLY BAY	15	31	45	41	27	10	-9	-19	-28	-28	-20	-4	
(68° 26'N)	19	35	51	47	30	15	-3	-13	-22	-22	-15	2	
	10	27	38	36	23	5	-14	-24	-33	-34	-25	-10	
RESOLUTION IS-	27	34	38	38	35	23	22	11	0	1	6	15	
LAND (61° 18'N)	30	37	42	42	38	32	25	15	5	6	11	19	
	24	30	34	34	32	26	18	6	-5	-4	1	10	
RESOLUTION IS-	23	32	40	40	32	25	17	6	-4	-3	0	11	
LAND C. WARWICK	27	36	46	44	36	28	21	11	2	3	5	16	
(61° 35'N)	19	28	35	35	28	21	13	1	-9	-9	-5	6	
ROWLEY ISLAND	17	32	42	41	30	15	-2	-14	-22	-20	-16	-2	
(69° 05'N)	22	36	48	47	33	20	3	-8	-16	-14	-9	6	
	11	28	36	35	27	11	-8	-20	-28	-27	-22	-8	
SHEPHERD BAY	14	33	47	44	30	11	-11	-24	-32	-34	-25	-9	
(68° 49'N)	21	38	54	50	34	17	-3	-16	-23	-26	-16	1	
	7	27	39	38	26	5	-19	-31	040	-41	-33	-19	
SPENCE BAY	14	33	45	44	30	11	-11	-22	-30	-30	-25	-8	
(69° 32'N)	21	38	52	49	34	16	-4	-16	-23	-24	-18	1	
	7	29	38	38	26	5	-17	-28	-37	-38	-32	-16	
TUKTOYAKTUK	24	40	51	48	36	20	-3	-13	-17	-21	-13	2	
(69° 27'N)	30	48	59	54	40	24	3	-7	-11	-14	-7	9	
	17	32	42	41	32	15	-8	-19	-23	-27	-19	-6	

APPENDIX I-B (cont.)

	M	J	J	A	S	O	N	D	J	F	M	A	
TOTALS	730	1276	1618	1557	1175	663	2	-429	-641	-719	-485	30	Av. Daily
	950	1474	1860	1766	1321	835	219	-200	-466	-476	-235	305	Av. Max. Daily
	505	1076	1372	1346	1022	485	-217	.654	-930	-960	-738	-252	Av. Min. Daily
AVERAGE (divided by 36)	20.3	35.4	44.9	43.3	32.6	18.4	0.06	-11.9	-17.8	-20.0	-13.5	0.83	
	26.4	40.9	51.7	49.1	36.7	23.2	6.1	-5.6	-12.9	-13.2	-6.5	8.5	
	14	29.9	38.1	37.4	28.4	13.5	-6.0	-18.2	-25.8	-26.7	-20.5	-7	
TEMPERATURE °C	-7	2	7	6	0	-8	-18	-24	-28	-29	-25	-17	
	-3	5	11	10	3	-5	-14	-21	-25	-25	-21	-13	
	-10	-1	3	3	-2	-10	-21	-28	-32	-33	-29	-22	

SOURCES:

Temperatures and Precipitation - The North - Y.T. and N.W.T. -1941-1970

- Québec - 1941-1970

Atmospheric Environment Service, Department of the Environment,
Downsview, Ontario.

APPENDIX I-C

CALCULATION OF AVERAGE ANNUAL MEAN RAINFALL AND SNOWFALL (IN INCHES) FOR 36 ARCTIC SETTLEMENTS RANGING IN LATITUDE FROM 60°N TO 70°N TO BE USED AS TYPICAL CONDITIONS FOR LATITUDE 65°N

VILLAGE	SPRING		SUMMER			AUT.		WINTER						
	M	J	J	A	S	O	N	D	J	F	M	A	YEAR	
AKLAVIK	0.06	0.68	1.33	1.68	0.42	0.04	0.00	0.00	0.00	0.00	0.00	T	3.90	mean rainfall
	2.6	0.4	T	0.4	3.8	12.3	8.3	9.6	4.7	4.2	4.4	3.2	53.9	mean snowfall
BAKER LAKE	0.11	0.55	1.40	1.35	1.14	0.31	T	0.00	0.00	0.00	0.00	0.01	4.87	
	2.6	0.8	0.0	0.1	1.9	7.0	6.4	2.4	2.8	2.2	3.8	5.0	35.0	
BREVOORT ISLAND	0.04	0.40	2.90	3.68	1.88	0.68	0.05	0.01	0.00	T	0.00	0.01	9.65	
	10.9	8.9	3.2	1.7	9.1	20.2	19.4	15.2	14.5	12.6	7.0	10.1	132.8	
BROUGHTON ISLAND	T	0.19	0.37	0.57	0.20	0.01	0.00	0.00	0.00	0.00	0.00	0.00	1.34	
	12.0	10.1	0.9	3.1	15.2	23.3	16.5	6.9	5.1	4.8	2.4	6.5	106.8	
BYRON BAY	0.05	0.12	0.76	0.94	0.45	0.02	T	0.00	0.00	0.00	0.00	0.00	2.34	
	1.2	0.4	T	0.1	3.3	4.7	1.7	0.9	0.4	0.6	1.0	1.4	15.7	
CAMBRIDGE BAY	0.02	0.37	0.86	1.02	0.35	0.04	T	0.00	0.00	0.00	0.00	0.00	2.66	
	3.0	1.6	0.1	0.1	3.0	6.1	3.7	2.4	2.1	1.7	2.3	2.5	28.6	
CAPE DYER	0.02	0.29	1.08	2.05	0.70	0.14	0.06	0.01	0.01	0.02	0.00	T	4.38	
	19.3	14.3	1.9	4.3	22.8	39.1	30.3	28.1	28.3	30.3	10.6	14.8	244.1	
CAPE HOOPER	0.00	0.21	0.55	0.63	0.45	0.03	0.00	0.00	0.00	0.00	0.00	0.00	1.87	
	12.9	8.8	2.0	4.1	11.4	13.6	14.2	5.7	3.9	6.3	3.1	8.5	94.5	
CAPE HOPES ADVANCE	0.16	0.92	1.61	1.79	1.50	0.45	0.05	0.01	0.01	T	T	0.01	6.51	
	4.8	2.3	0.2	0.1	2.0	8.5	9.1	9.0	7.1	4.7	5.3	4.9	58.0	
CAPE PARRY	0.03	0.46	0.68	1.17	0.47	0.04	T	T	T	T	T	T	2.85	
	4.8	1.3	0.4	0.7	6.7	11.0	5.3	3.9	2.8	3.1	4.5	5.0	49.5	
CAPE YOUNG	0.06	0.63	1.23	1.37	0.79	0.01	0.00	0.00	0.00	0.00	0.00	0.00	4.09	
	1.8	0.3	0.1	0.5	2.0	7.7	4.9	2.0	2.3	2.3	2.5	2.0	28.4	
CHESTERFIELD	0.15	0.88	1.63	1.46	1.31	0.40	0.02	T	0.00	0.00	0.00	0.01	5.86	
	4.6	1.4	0.0	0.1	2.8	8.3	7.7	5.6	3.1	1.9	4.0	4.9	44.4	

Note: T equals trace

APPENDIX I-C (cont.)

	M	J	J	A	S	O	N	D	J	F	M	A	YEAR	
CLINTON POINT	0.08	0.53	1.11	1.38	0.80	0.03	0.00	0.00	0.00	0.00	0.00	0.00	3.93	mean rainfall
	3.0	1.5	T	0.3	5.7	8.2	3.8	3.0	1.9	1.0	1.5	4.1	34.0	mean snowfall
CLYDE	0.01	0.09	0.64	0.97	0.43	0.01	T	0.00	T	T	0.00	0.00	2.15	
	5.5	3.3	2.8	2.2	11.0	12.9	7.3	3.0	4.3	2.6	2.0	3.3	60.2	
CONTWOYTO LAKE	0.16	1.32	1.73	1.59	0.83	0.07	T	T	0.00	0.00	0.00	T	5.70	
	3.6	2.4	0.1	0.2	6.2	11.1	7.3	4.0	3.8	4.1	4.4	4.0	51.2	
COPPERMINE	0.08	0.55	1.30	1.56	0.81	0.17	T	0.00	0.00	0.00	0.00	0.01	4.48	
	3.5	1.0	0.2	T	2.6	8.3	5.8	4.1	4.1	2,3	4.4	3.8	40.1	
CORAL HARBOUR	0.09	0.76	1.57	1.73	0.99	0.20	0.01	T	T	T	0.01	0.05	5.41	
	6.0	2.8	0.2	0.1	3.8	9.9	6.8	4.7	3.4	4.1	4.5	5.7	52.0	
DEWAR LAKES	0.01	0.22	1.29	1.65	0.67	T	0.00	0.00	0.00	0.00	0.00	0.00	3.84	
	8.3	5.0	1.8	1.7	8.1	9.7	6.1	2.2	1.8	1.3	1.8	5.6	53.4	
FROBISHER BAY	0.07	1.15	2.08	2.28	1.16	0.28	0.04	T	0.01	T	T	0.01	7.08	
	8.5	3.3	0.1	0.1	5.7	14.2	14.9	11.1	10.1	11.4	8.5	9.3	97.2	
GLADMAN POINT	0.01	0.08	0.93	1.16	0.33	0.07	0.00	0.00	0.00	0.00	0.00	T	2.68	
	3.4	0.6	T	0.1	2.9	5.2	1.5	1.1	1.5	1.0	1.0	1.3	19.6	
HALL BEACH	0.01	0.24	1.12	1.22	0.40	0.02	T	0.00	T	0.00	0.00	T	3.01	
	6.2	2.4	0.1	0.3	3.1	8.7	6.2	3.9	3.6	3.9	3.5	3.8	45.7	
INUVIK	0.20	0.42	1.34	1.51	0.43	0.08	T	0.00	0.01	0.00	0.00	T	3.99	
	5.5	0.9	0.1	1.7	4.5	13.6	7.3	8.5	8.5	4.7	7.3	5.9	68.5	
JENNY LIND ISLAND	T	0.22	0.67	1.22	0.36	0.06	0.00	0.00	0.00	0.00	0.00	0.00	2.53	
	1.8	0.5	0.1	T	1.6	3.2	1.2	0.5	0.7	0.8	0.6	1.3	12.3	
LADY FRANKLIN POINT	0.02	0.45	1.03	1.14	0.48	0.18	0.00	0.00	0.00	0.00	0.00	0.00	3.30	
	0.7	0.1	0.0	0.1	1.1	7.4	4.2	1.2	2.7	1.9	1.3	1.7	22.4	
LONGSTAFF BLUFF	T	0.30	1.15	0.86	0.58	0.02	T	0.00	0.00	0.00	0.00	0.00	2.91	
	5.3	3.0	0.1	0.5	6.2	8.9	4.2	2.7	1.6	3.2	0.9	3.0	39.6	
MACKAR INLET	T	0.13	1.24	1.49	0.29	0.06	0.00	0.00	0.00	0.00	0.00	0.00	3.21	
	5.2	2.0	0.4	1.2	8.0	9.0	2.4	1.2	0.8	1.7	0.6	3.0	35.5	

APPENDIX I-C (cont.)

	M	J	J	A	S	O	N	D	J	F	M	A	YEAR	
NICHOLSON PENINSULA	0.07	0.32	0.81	1.22	0.42	0.03	0.00	0.00	0.00	0.00	0.00	0.00	2.67	mean rainfall
	0.8	0.8	T	0.3	1.7	4.0	1.6	1.2	0.9	0.9	1.3	1.4	14.9	mean snowfall
NOTTINGHAM ISLAND	0.14	0.56	1.21	1.40	1.03	0.26	0.01	0.00	0.00	0.00	0.00	T	4.61	
	5.1	2.9	0.2	0.1	4.3	10.6	11.7	6.5	4.9	4.7	3.9	5.7	60.6	
PADLOPING ISLAND	T	0.24	0.76	0.35	0.40	0.02	T	0.00	T	0.03	0.00	0.00	1.80	
	5.6	3.6	1.0	1.9	6.6	15.3	13.6	5.3	6.3	6.0	2.6	2.1	69.9	
PELLY BAY	0.00	0.20	1.31	1.95	0.61	0.05	0.00	0.00	0.00	0.00	0.00	0.00	4.12	
	5.0	2.4	0.2	1.3	6.2	7.3	3.5	1.3	1.0	0.7	1.1	4.4	34.4	
RESOLUTION ISLAND	0.20	0.84	1.39	1.66	1.43	0.48	0.06	T	0.01	T	0.01	0.04	6.12	
	4.1	2.1	T	0.1	2.2	7.2	10.1	11.0	6.7	5.4	6.8	5.4	61.1	
RESOLUTION ISLAND C. WARWICK	0.04	0.50	2.90	3.41	2.23	0.86	0.08	0.01	T	0.01	T	T	10.04	
	3.9	2.4	1.1	0.2	2.4	8.6	8.0	8.5	5.1	4.0	3.9	3.7	51.8	
ROWLEY ISLAND	0.00	0.09	1.33	1.52	0.45	0.01	0.00	0.00	0.00	0.00	0.00	0.00	3.40	
	7.0	1.8	T	0.7	4.7	7.0	2.4	1.9	1.7	2.7	0.8	2.2	32.9	
SHEPHERD BAY	T	0.29	0.88	1.55	0.50	0.04	0.00	0.00	0.00	0.00	0.00	0.00	3.26	
	1.9	0.7	0.1	0.5	2.8	5.1	2.5	2.2	1.3	2.1	0.8	2.4	22.4	
SPENCE BAY	T	0.27	0.98	1.14	0.47	0.01	0.00	0.00	0.00	0.00	0.00	T	2.87	
	3.2	3.3	0.1	T	4.0	7.6	3.0	2.0	1.8	2.2	2.4	2.2	31.8	
TUKTOYAKTUK	0.12	0.40	0.85	1.11	0.39	0.02	T	0.00	0.00	0.00	0.00	0.00	2.89	
	1.6	1.3	0.1	0.2	1.6	4.7	2.0	3.0	2.0	2.1	1.4	1.9	21.9	
RAINFALL TOTALS	2.03	15.97	44.02	52.48	26.14	5.2	0.38	0.04	0.05	0.06	0.02	0.15	146.52	
RAINFALL AVERAGES	0.06	0.44	1.22	1.46	0.73	0.14	0.01	0.00	0.00	0.00	0.00	0.00	4.07	
SNOWFALL TOTALS	185.2	98.7	17.6	29.1	191.0	369.5	264.9	185.8	157.6	149.5	118.2	156.0	1925.1	
SNOWFALL AVERAGES	5.1	2.7	0.5	0.8	5.3	10.3	7.4	5.2	4.4	4.2	3.3	4.3	53.5	

AVERAGE MONTHLY SUMMER RAINFALL - 0.96 inches; TOTAL SUMMER RAINFALL - 3.85 inches; AVERAGE MONTHLY WINTER SNOWFALL - 4.8 inches.

SOURCES: Temperature and Precipitation - The North - Y.T and N.W.T. 1941-70; Québec - 1941-70, Atmospheric Environment Service, Department of the Environment, Downsview, Ontario.

APPENDIX I-D

MEAN HUMIDITY VALUES OF RELATIVE HUMIDITY AT 01:00, 07:00, 13:00 and 19:00 HOURS FOR 20 SETTLEMENTS FROM LATITUDE 60°N TO LATITUDE 70°N.

	SPRING		SUMMER			AUT.		WINTER					MIXING
VILLAGE	M	J	J	A	S	O	N	D	J	F	M	A	RATIO
BAKER LAKE	80	78	72	76	83	85	74	69	-	-	74	73	86
CAMBRIDGE BAY	87	85	79	83	89	84	-	-	-	-	-	77	72
CAPE DYER	84	83	75	80	85	85	82	78	79	78	73	76	69
CAPE HOOPER	91	88	77	87	92	90	81	76	71	70	70	77	60
CAPE HOPES ADVANCE	90	90	86	89	87	90	88	84	76	78	82	88	75
CAPE PARRY	93	90	89	89	91	90	82	78	76	75	75	82	77
CHESTERFIELD	87	85	79	81	86	87	83	78	73	75	78	80	96
CLINTON POINT	89	87	84	87	90	86	78	75	73	75	71	78	93
CLYDE	83	85	8;	88	87	83	73	66	62	64	61	71	60
CONTWOYTO LAKE	84	73	66	69	81	85	73	-	-	-	65	77	75
COPPERMINE	82	85	80	83	83	86	79	78	-	-	71	77	114
CORAL HARBOUR	85	84	79	82	87	85	81	77	74	79	77	79	110
FROBISHER BAY	80	80	73	79	79	81	77	79	77	78	76	79	58
GLADMAN POINT	87	90	82	85	92	87	72	-	-	-	-	73	77
HALL BEACH	88	86	81	85	86	85	80	77	-	-	-	79	72
INUVIK	-	-	-	-	-	-	-	-	-	-	-	-	-
LONGSTAFF BLUFF	88	83	77	82	88	88	80	75	-	-	-	80	96
NOTTINGHAM ISLAND	87	89	84	87	91	90	85	77	71	74	76	82	69
PELLY BAY	89	89	78	85	92	85	77	-	-	-	-	79	99
TUKTOYAKTUK	89	83	77	81	88	89	76	74	-	-	71	80	99
(10 Stations with Complete Data)													
TOTALS	869	861	807	849	875	867	810	768	732	746	739	792	767
AVERAGE OF MEAN HUMIDITY VALUES	87	86	81	85	88	87	81	77	73	75	74	79	77

The last column refers to the mixing ratio in grains per pound of dry air for the highest dew point recorded.

Source: Climatic Normals, Vol. 4, Humidity, Canada, Dept. of Transport, Meteorological Branch, Toronto, 1968.

APPENDIX I-E

CLOUD NORMALS FOR SETTLEMENTS FROM LATITUDES 60°N TO 70°N.

VILLAGE	SPRING M	SUMMER J	J	A	S	AUT. O	WINTER N	D	J	F	M	A	YR	
AKLAVIK	6.6	6.3	6.7	7.3	7.8	7.6	6.9	5.9	5.5	5.3	5.0	5.6	6.4	M.C.
	58	53	58	65	73	71	63	51	46	46	43	48	56	ER. 8-10/10
	15	20	21	18	13	12	12	15	14	15	15	15	16	3-7/10
	27	27	21	17	14	17	25	34	40	39	42	38	28	0-2/10
BAKER LAKE	6.9	7.4	6.7	6.9	7.9	7.9	5.5	5.0	4.5	3.5	4.4	5.1	6.0	M.C
	61	64	53	55	71	74	54	40	35	32	37	44	52	FR. 8-10/10
	16	19	28	23	16	13	14	16	17	16	17	16	17	3-7/10
	23	17	19	22	13	13	32	44	48	52	46	40	31	0-2/10
CAMBRIDGE BAY	6.9	7.6	6.8	6.9	8.4	7.3	5.1	4.6	4.2	3.8	3.9	4.6	5.8	
	62	67	58	62	79	68	43	36	34	30	30	36	50	
	12	16	19	19	12	11	16	16	15	17	17	17	16	
	26	17	23	19	9	21	41	48	51	53	53	47	34	
CAPE DYER	7.4	6.5	6.3	6.8	7.4	6.9	5.7	5.5	5.6	5.3	3.8	4.6	6.0	
	67	54	49	55	66	60	48	55	46	43	26	32	49	
	19	24	29	26	22	22	19	20	21	21	23	22	22	
	14	22	22	19	12	18	33	35	33	36	51	46	29	
CAPE HOPES ADVANCE	7.9	7.4	6.9	7.4	7.8	7.6	7.4	6.6	5.4	4.9	5.3	5.9	6.7	
	73	67	57	64	69	72	71	63	45	40	44	51	60	
	14	17	26	22	21	19	16	15	18	19	20	18	18	
	13	16	17	14	10	9	13	22	37	41	36	31	22	
CAPE PARRY	7.2	7.4	6.8	7.3	8.2	8.5	5.7	4.6	4.3	4.2	3.4	5.4	6.1	
	65	65	56	63	78	82	48	35	34	31	24	43	52	
	17	22	27	23	14	10	19	20	19	21	18	22	19	
	18	13	17	14	8	8	33	45	47	48	58	35	29	
CHESTERFIELD	7.3	6.9	6.1	6.1	7.9	7.7	5.7	4.2	3.8	3.3	4.4	5.1	5.7	
	68	61	49	52	74	73	50	36	32	27	37	45	50	
	12	17	26	22	14	12	14	12	13	12	15	12	15	
	20	22	25	26	12	15	36	52	55	61	48	43	34	

M.C. (mean cloud)
FR. (frequency)

APPENDIX I-E (cont.)

	SPRING		SUMMER			AUT.		WINTER						
	M	J	J	A	S	O	N	D	J	F	M	A	YR	
CLYDE	6.9	6.6	6.9	7.6	8.2	7.4	5.9	4.4	4.8	4.4	3.7	4.4	5.9	M.C.
	62	57	60	69	76	67	54	36	41	37	31	35	52	8-10/10
	15	18	21	16	13	14	12	15	14	15	15	18	16	3-7/10
	23	25	19	15	11	19	34	49	45	48	54	47	32	0-2/10
COPPERMINE	6.9	6.7	6.6	7.3	8.1	8.0	6.4	5.2	5.2	4.5	4.9	5.4	6.3	
	62	56	57	66	77	75	56	47	47	39	43	47	56	
	14	20	23	19	13	12	17	15	15	16	16	17	16	
	24	24	20	15	10	13	27	38	38	45	41	36	28	
CORAL HARBOUR	7.0	7.3	6.8	7.1	8.0	6.8	5.8	4.4	4.4	4.3	4.6	5.2	6.0	
	64	66	59	63	75	61	50	37	35	36	38	45	52	
	15	17	21	21	14	15	15	13	16	15	15	15	16	
	21	17	20	16	11	24	35	50	49	49	47	41	32	
FROBISHER BAY	7.4	7.5	7.1	7.7	8.0	8.0	6é8	5.5	4.8	4.9	4.7	5.3	6.5	
	67	68	64	69	76	74	61	47	42	41	38	45	58	
	17	16	23	21	15	15	16	18	16	18	18	18	17	
	16	16	13	10	9	11	23	35	42	41	44	37	25	
HALL BEACH	6.2	6.9	6.7	7.0	8.6	7.3	5.7	5.1	4.4	4.6	4.0	5.4	6.0	
	51	61	57	62	83	65	49	40	34	35	29	45	51	
	20	18	22	19	12	17	16	22	21	21	20	19	19	
	29	21	21	19	5	18	35	38	45	41	51	36	30	
NOTTINGHAM ISLAND	7.9	7.1	6.1	7.0	7.9	8.6	7.3	5.7	4.6	4.8	4.3	5.2	6.4	
	73	64	51	62	74	81	66	49	39	40	35	44	57	
	14	16	20	17	13	11	15	16	15	16	14	16	15	
	13	20	29	21	13	8	19	35	46	44	51	40	28	
RESOLUTION ISLAND	7.9	7.2	7.3	7.8	7.8	7.9	8.1	8.1	7.1	6.1	6.1	6.4	7.3	
	73	74	64	73	72	72	75	74	62	51	49	55	66	
	13	14	19	10	14	17	14	16	20	20	25	20	17	
	14	12	17	17	14	11	11	10	18	29	26	25	17	

.....totals

APPENDIX I-E (cont.)

	SPRING		SUMMER			AUT.		WINTER					
	M	J	J	A	S	O	N	D	J	F	M	A	YR
TOTALS	100.4	98.8	93.8	100.2	112	107.5	88	74.8	68.6	63.9	62.5	73.6	87.1
	906	877	792	880	1043	995	788	646	572	528	504	615	761
	213	254	325	276	206	200	215	229	234	242	248	244	239
	281	269	283	244	151	205	397	535	594	627	648	541	400
AVERAGES	7.2	7.1	6.7	7.2	8.0	7.7	6.3	5.3	4.9	4.6	4.5	5.3	6.2
DATA TO BE USED FOR	65	63	57	63	74	71	56	46	41	38	36	44	54
LATITUDE 65°N.	15	18	23	20	15	14	15	16	17	17	18	17	17
	20	19	20	17	11	15	29	38	42	45	46	39	29

Source:

Climatic Normals, Sunshine, Cloud, Pressure and Thunderstorms, Vol. 3, Canada, Dept. of Transport, Meteorological Branch, Toronto, 1968

APPENDIX 1-F TABLE 1

SOLAR RADIATION DATA FOR LATITUDE 65°N (megajoules/m^2hr.) - Bright Sun Conditions

Total daily global, diffuse and ground reflected radiation for each month for horizontal surfaces and for eight orientations for vertical surfaces, with sunrise and sunset times and total number of hours of sunlight. (Data generated by computer program by Marius Thériault, Dept. de Géographie, Université Laval). Interference coefficient (facteur de trouble) = 0.04; water thickness in the atmosphere 0.5cm; ground reflection 0.60 for the months of September to May and 0.20 for the months of June to August.

		VERTICAL SURFACES			HORIZONTAL			SUN TIMES AND TOTAL HOURS		
MONTH	DIR.	GLOBAL	DIFFUSE	REFL-GRD.	GLOBAL	DIFFUSE	REFL-GRD.	SUNRISE	SUNSET	NO. HRS.
15 Jan.	S.	8.264	3.686	0.214	0.217	0.491	0.0	9.77	14.23	4.45
	S.W.	5.746	2.446	"						
	W.	1.384	0.665	"						
	N.W.	0.503	0.289	"						
	N.	0.478	0.264	"						
	N.E.	0.503	0.289	"						
	E.	1.384	0.665	"						
	S.E.	5.746	2.446	"						
15 Feb.		19.292	5.052	1.024	3.413	1.039	0.0	7.97	16.03	8.05
		14.099	5.052	"						
		5.675	1.593	"						
		1.760	0.656	"						
		1.584	0.560	"						
		1.760	0.656	"						
		5.675	1.593	"						
		14.099	3.650	"						
15 Mar.		26.856	5.050	2.916	9.719	2.010	0.0	6.30	17.70	11.40
		22.974	5.196	"						
		14.371	3.941	"						
		6.353	1.933	"						
		4.131	1.215	"						
		6.353	1.933	"						
		14.371	3.941	"						
		22.974	5.196	"						

APPENDIX 1-F (cont.)

		VERTICAL SURFACES			HORIZONTAL			SUN TIMES AND TOTAL HOURS		
MONTH	DIR.	GLOBAL	DIFFUSE	REFL-GRD.	GLOBAL	DIFFUSE	REFL-GRD.	SUNRISE	SUNSET	NO. HRS.
15 Apr.	S.	28.102	3.761	5.613	18.771	2.972	0.0	4.55	19.45	14.90
	S.W.	27.900	4.541	"						
	W.	23.127	5.001	"						
	N.W.	14.373	3.657	"						
	N.	8.713	2.252	"						
	N.E.	14.373	3.657	"						
	E.	23.127	5.001	"						
	S.E.	27.900	4.541	"						
15 May		27.780	3.366	8.029	27.764	3.793	0.0	2.85	21.15	18.30
		29.671	4.048	"						
		29.220	5.201	"						
		22.000	4.638	"						
		16.391	3.660	"						
		22.000	4.638	"						
		29.220	5.201	"						
		29.671	4.048	"						
15 June		21.381	3.407	3.131	31.208	4.407	0.0	1.50	22.50	21.01
		23.845	4.002	"						
		26.088	5.523	"						
		21.392	5.942	"						
		17.518	5.756	"						
		21.392	5.942	"						
		26.088	5.523	"						
		23.845	4.002	"						

APPENDIX 1-F (cont.)

		VERTICAL SURFACES			HORIZONTAL			SUN TIMES AND TOTAL HOURS		
MONTH	DIR.	GLOBAL	DIFFUSE	REFL-GRD.	GLOBAL	DIFFUSE	REFL-GRD.	SUNRISE	SUNSET	NO. HRS.
15 July	S.	21.653	3.317	2.913	29.128	4.043	0.0	2.15	21.85	19.70
	S.W.	23.892	3.941	"						
	W.	24.901	5.226	"						
	N.W.	18.666	4.924	"						
	N.	13.709	4.153	"						
	N.E.	18.666	4.924	"						
	E.	24.900	5.226	"						
	S.E.	23.892	3.941	"						
15 Aug.		23.261	3.451	2.202	22.018	3.236	0.0	3.84	20.16	16.32
		24.135	4.126	"						
		21.045	4.808	"						
		12.799	3.780	"						
		6.890	2.572							
		12.799	3.780	"						
		21.045	4.808	"						
		24.135	4.162	"						
15 Sept.		27.342	4.267	3.921	13,070	2.308	0.0	5.57	18.43	12.86
		24.955	4.760	"						
		17.624	4.150	"						
		9.102	2.420	"						
		5.452	1.487	"						
		9.102	2.420	"						
		17.624	4.150	"						
		24.955	4.760	"						

APPENDIX 1-F (cont.)

		VERTICAL SURFACES			HORIZONTAL			SUN TIMES AND TOTAL HOURS		
MONTH	DIR.	GLOBAL	DIFFUSE	REFL-GRD.	GLOBAL	DIFFUSE	REFL-GRD.	SUNRISE	SUNSET	NO. HRS.
15 Oct.	S.	23.062	5.289	1.663	5.542	1.343	0.0	7.26	16.75	9.49
	S.W.	17.668	4.187	"						
	W.	8.629	2.231	"						
	N.W.	2.996	0.908	"						
	N.	2.403	0.740	"						
	N.E.	2.996	0.908	"						
	E.	8.629	2.231	"						
	S.E.	17.668	4.187	"						
15 Nov.		12.513	4.425	0.420	1.400	0.704	0.0	9.06	14.94	5.88
		8.849	3.007	"						
		2.671	1.049	"						
		0.849	0.429	"						
		0.798	0.378	"						
		0.849	0.429	"						
		2.671	1.049	"						
		8.849	3.007	"						
15 Dec.		3.493	1.504	0.068	0.227	0.184	0.0	10.49	13.51	3.02
		2.413	0.986	"						
		0.450	0.227	"						
		0.176	0.108	"						
		0.167	0.099	"						
		0.176	0.108	"						
		0.450	0.227	"						
		2.413	0.986	"						

APPENDIX 1-F TABLE 2

SOLAR RADIATION DATA FOR LATITUDE 45°N (megajoules/m^2hr.) - Bright Sun Conditions

Total daily global, diffuse and ground reflected radiation for each month for horizontal and vertical surfaces with sunrise and sunset times and total number of hours of sunlight. (Data from computer program, Marius Thériault, Université Laval). Interference coefficient (facteur de trouble) 0.08; water thickness in atmosphere 1.30 cm; ground reflection 0.20.

	VERTICAL SOUTH FACING SURFACES			HORIZONTAL			SUN TIMES AND TOTAL HOURS		
MONTH	GLOBAL	DIFFUSE	REFL-GRD.	GLOBAL	DIFFUSE	REFL-GRD.	SUNRISE	SUNSET	NO. HRS.
15 Jan.	21.122	6.654	0.716	7.163	2.045	0.0	7.53	16.47	8.95
15 Feb.	22.264	5.589	1.134	11.339	2.715	0.0	6.89	17.11	10.22
15 Mar.	21.175	4.383	1.730	17.296	3.638	0.0	6.14	17.86	11.72
15 Apr.	17.678	3.757	2.374	23.741	4.642	0.0	5.34	18.66	13.33
15 May	14.322	3.501	2.815	28.151	5.177	0.0	4.67	19.33	14.67
15 June	12.715	3.455	3.011	30.111	5.410	0.0	4.30	19.70	15.40
15 July	13.281	3.439	2.916	29.162	5.271	0.0	4.45	19.55	15.10
15 Aug.	15.940	3.556	2.554	25.536	4.828	0.0	5.04	18.96	13.93
15 Sept.	19.618	3.977	1.981	19.809	4.004	0.0	5.80	18.20	12.40
15 Oct.	21.960	5.063	1.361	13.614	3.106	0.0	6.58	17.42	10.85
15 Nov.	21.592	6.308	0.842	8.423	2.248	0.0	7.31	16.70	9.39
15 Dec.	20.331	6.733	0.621	6.206	1.866	0.0	7.70	16.30	8.60

APPENDIX I-G TABLE I

WIND DIRECTION PERCENTAGE FREQUENCY, AVERAGE WIND SPEED IN MILES PER HOUR, MAXIMUM OBSERVED HOURLY SPEED, GUST SPEED AND PROBABLE MAXIMUM GUST FOR MAXIMUM SPEED, FOR LATITUDES 60°N to 70°N.

VILLAGE	% FREQUENCY OF DIRECTION w = winter, s = summer									WIND SPEEDS MPH					
	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	CALM	FIRST HIGHEST	SECOND	THIRD	MAX. HRLY.	MAX. GUST	MAX. GUST MAX. HRLY. SPEED
BAKER LAKE	30w 24s		19w 12s	8w 15s				25w 22s	8 7	18.2N	12.4E	15.2NW	59N	110	103
CAMBRIDGE BAY	13w 17s	15w 15s					19w 13s	23w 15s	5 2	14.8NW	13.9N	12.5W	55	70	77
CAPE DYER		10w 7s	16w 11s		7w 9s	7w 11s	14w 18s	14w 13s	23 19	15.1NW	12.5N	9.7W	80	110	109
CAPE HOPES ADVANCE				10w 17s		15w 10s	12w 12s	38w 33s	2 0.5	20.4SE	9.6NW	19.2E	66		91
CAPE PARRY			23w 27s				21w 12s	12w 15s	10 4	16.8E	13.5NW	13.4W	55E	62	77
CHESTERFIELD	23w 15s	8w 12s			7w 12s			42w 24s	4 2	15.7NW	14.4NE	13.7N	55SW		77
CLYDE	20w 16s		10w 9s		9w 11s			26w 29s	11 4	10.7NW	6.2W		60SW		83
COPPERMINE	9w 17s	6w 22s				34w 10s	29w 15s		3 1	12.5NW	11.7SW	9.8W	46NW		65
CORAL HARBOUR	30w 20s	14w 13s	13w 12s					27w 17s	5 4	15.2NE	14.1E	13.8N	90NE	81	122
FROBISHER BAY	10w 6s			11w 27s				34w 23s	28 14	15.6NW	12.9SE	12.6E	80NW	97	109
HALL BEACH	13w 19s		7w 9s				13w 8s	45w 24s	3 3	15.7NW	15.0N	13.9E	62NW	79	86
INUVIK		10w 16s	21w 17s				10w 10s	14w 17s	23 7	9.4NW	7.4N	7.2S	40NW	68	57
NOTTINGHAM ISLAND		19w 20s			11w 13s	11w 14s	10w 13s	17w 2	4	13.9SW	12.9NE	12.2S	60		83
RESOLUTION IS. C.	17w 13s						19w 16s	25w 235	2 1	24.5NW	24.0N	23.1W	118NE		158

The average % frequency of calm periods for the winter is 9% and 5% for the summer.

APPENDIX I-G (cont.)

TABLE 2 (Taken from columns 10, 11 and 12, table 1.)

NUMBER OF VILLAGES PER WIND DIRECTION FOR HIGHEST REGISTERED WIND SPEEDS

1st highest wind speed	2nd highest wind speed	3rd highest wind speed
9 - NW	5 - N	5 - W
1 - N	2 - NW	3 - E
1 - NE	2 - NE	2 - N
1 - E	2 - E	2 - S
1 - SE	1 - W	1 - NW
1 - SW	1 - SW	
	1 - SE	

Average maximum observed hourly speed is 66 mph.

Average observed gust speed is 85 mph.

Average probable maximum gust for maximum hourly speed is 93mph.

TABLE 3

NO. OF 1ST, 2ND OR 3RD DOMINANCE OF WIND DIRECTION	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	
(3 POINTS) 1ST DOMINANCE	2w	1w	3w			1w		7w	
	3s	2s	2s	1s			1s	6s	
(2 POINTS) 2ND DOMINANCE	3w			1w		1w	6w	5w	
	4s	2s		1s		1s	1s	6s	
(1 POINT) 3RD DOMINANCE	3w	5w	3w		1w	1w	2w	1w	
	2s	2s	2s	1s	3s	1s	6s	1s	
TOTAL POINTS	15	8	12	2	1	6	14	32	w
	19	12	8	6	3	3	11	31	s
TOTAL	32	20	20	8	4	9	25	63	

THE THREE DOMINANT DIRECTIONS ARE 1ST N.W.
2ND N.
3RD W.

THE THREE MOST FREQUENT HIGH WIND SPEEDS ARE 1ST NW at 14.4 mph.
2ND N at 14.8 mph.
3RD W at 12.5 mph.
3RD E at 14.8 mph.

APPENDIX I-G (cont.) TABLE 4

AVERAGE WIND SPEEDS FOR ALL DIRECTIONS

SETTLEMENT	J	F	M	A	M	J	J	A	S	O	N	D	AVERAGE
BAKER LAKE	16.2	16.6	14.9	14.1	14.1	13.1	12.1	11.8	13.6	14.5	14.1	13.4	14.0
CAMBRIDGE BAY	13.5	12.3	11.8	12.1	12.5	12.9	12.5	13.2	14.2	14.4	12.4	11.8	12.8
CAPE DYER	11.2	9.5	7.8	8.1	8.8	7.8	6.9	7.2	9.6	10.5	9.3	10.1	8.9
CAPE HOPES ADVANCE	16.4	17.9	16.1	16.2	16.1	14.5	14.3	15.9	19.9	20.1	20.7	19.6	17.3
CAPE PARRY	11.8	10.7	11.9	12.4	12.0	13.1	11.6	12.1	12.7	13.9	12.2	12.2	12.2
CHESTERFIELD	14.2	16.4	14.2	13.4	13.0	11.6	10.0	12.7	15.8	17.4	16.1	14.3	13.6
CLYDE	5.5	7.2	5.0	4.7	6.6	7.0	6.4	6.6	8.1	8.8	7.4	5.3	6.6
COPPERMINE	11.8	9.8	9.8	8.9	8.9	8.4	9.3	10.7	10.8	11.5	11.2	11.6	10.2
CORAL HARBOUR	12.8	13.2	11.0	12.2	13.1	12.5	11.5	12.5	13.5	13.7	14.5	13.2	12.8
FROBISHER BAY	9.7	9.7	8.7	10.6	12.4	10.7	8.3	8.5	11.1	12.5	11.4	10.3	10.3
HALL BEACH	13.5	15.0	13.4	12.9	13.3	11.9	10.8	12.1	15.5	15.9	14.7	12.8	13.5
INUVIK	4.4	4.2	5.8	6.7	7.6	8.2	7.5	7.2	6.8	5.9	4.4	4.4	6.1
NOTTINGHAM ISLAND	9.0	10.8	9.5	11.8	12.4	11.3	10.1	11.2	10.9	13.4	12.6	10.8	11.2
RESOLUTION ISLAND	25.7	25.7	24.2	21.5	19.4	20.3	17.4	19.3	22.0	22.8	22.4	24.9	22.1
C. WARWICK - TOTAL	175.7	179	164.1	165.6	170.2	163.3	148.7	161	184.5	195.3	183.4	174.8	171.6
- AVERAGE	12.6	12.8	11.7	11.8	12.2	11.7	10.6	11.5	13.2	14.0	13.1	12.5	12.3

- AVERAGE WIND SPEED WINTER (N, D, J, F, M, A.) = 12.4 mph. (5.5 m/s)
SUMMER (J, J, A, S.) = 11.8 mph. (5.3 m/s)

Source: Canadian Normals - Wind 1955-1972, Vol. 3, Environment Canada, Downsview, Ont., 1975

APPENDIX II-A

CALCULATION OF RADIATION VALUES TO BE USED FOR SUN AND SHADE CONDITIONS IN PENWARDEN'S EQUATION.

FEBRUARY

	VERTICAL			HORIZONTAL		
	GLOBAL	DIFFUSE	REFL-GRD.	GLOBAL	DIFFUSE	REFL-GRD.
S.	19.292	5.052	1.024	3.413	1.039	0.0
S.W.	14.099	3.650	"			
W.	5.675	1.593	"			
N.W.	1.760	0.656	"			
N.	1.584	0.560	"			
N.E.	1.760	0.656	"			
E.	5.675	1.593	"			
S.E.	14.099	3.650	"			
TOTAL	63.994	17.410				
AVERAGE	7.993	2.176	1.024			

RATIO AV. GLOBAL VERT./GLOBAL HOR. 7,993/3.413 = 2.342 MJ/m^2h AV./DAY.
RATIO AV. DIFF. + REFL./GRD./AV. GLOBAL VERT. = 3.200/7.993 = 0.40
MEAN DAILY GLOBAL SOLAR RADIATION IN LANGLEYS = 75 (TITUS & TRUHLAR, 1969).
LENGTH OF DAY IN HOURS 8.05

RADIATION RECEIVED PER SQ. M. VERT. SURFACE IN SUN = S_{sun}

$$= \frac{\text{MEAN DAILY GLOBAL RAD.}}{\text{NO. HRS. IN DAY}} \times 11.6111 \times \text{RATIO } \frac{\text{AV. GLOBAL VERT.}}{\text{GLOBAL HOR.}}$$

11.6111 = CONVERSION FACTOR LANGLEYS TO w/m^2

$$= \frac{75}{8.05} \times 11.6111 \times 2.342 = 253.351 \text{ w/m}^2$$

RADIATION RECEIVED PER SQ. M. VERT. SURFACE IN SHADE = S_{shade}

$$= \frac{\text{M.D.G. RAD.}}{\text{NO. HRS. IN DAY}} \times 11.6111 \times \frac{\text{RATIO AV. DIFF. + REFLECTED GRD.}}{\text{AV. GLOBAL VERT.}}$$

$$= \frac{75}{8.05} \times 11.6111 \times 0.40 = 43.271 \text{ w/m}^2$$

S_{sun} WITH 60% CLOTHES ABSORPTIVITY FACTOR (AULICIEMS, DE FREITAS AND HARE 1973, pp. 6-8) = 253.35 X 0.6 = <u>152.011</u> w/m^2

S_{shade} WITH 60% CLOTHES ABSORPTIVITY FACTOR
= 43.271 X 0.6 = <u>25.963</u> w/m^2

APPENDIX II-A (cont.)

MAY

	VERTICAL			HORIZONTAL		
	GLOBAL	DIFFUSE	REFL/GRD.	GLOBAL	DIFFUSE	REFL/GRD.
S.	27.780	3.366	8.029	26.764	3.793	0.0
S.W.	29.671	4.048	"			
W.	29.220	5.201	"			
N.W.	22.000	4.638	"			
N.	16.391	3.660	"			
N.E.	22.000	4.638	"			
E.	29.220	5.201	"			
S.E.	29.671	4.048	"			
TOTAL	205.953	34.8				
AV.	25.744	4.35	8.029	AV. DIFFUSE & REFL/GRD. = 12.379		

RATIO AV. GLOBAL VERT/GLOBAL HOR. = 25.744/26.764 = 0.962
RATIO AV. DIFF. & REFL-GRD./AV. = 12.379/25.744 = 0.481
MEAN DAILY GLOBAL SOLAR RADIATION IN LANGLEYS = 525
LENGTH OF DAY IN HOURS 18.30

RADIATION RECEIVED PER SQ. M. VERT. SURFACE IN SUN = S_{sun}

$$= \frac{525}{18.30} \times 11.6111 \times 0.962 = 320.447 \text{ w/m}^2$$

RADIATION RECEIVED PER SQ. M. VERT. SURFACE IN SHADE = S_{shade}

$$= \frac{525}{18.30} \times 11.6111 \times 0.481 = 160.224 \text{ w/m}^2$$

S_{sun} WITH 60% CLOTHES ABSORPTIVITY FACTOR = 320.447 X 0.60 = 192.268 w/m^2

S_{shade} WITH 60% CLOTHES ABSORPTIVITY FACTOR = 160.224 X 0.60 = 96.134 w/m^2

APPENDIX II-A (cont.)

JULY

	VERTICAL			HORIZONTAL		
	GLOBAL	DIFFUSE	REFL/GRD.	GLOBAL	DIFFUSE	REFL/GRD.
S.	21.653	3.317	2.913	29.128	4.043	0.0
S.W.	23.892	3.941	"			
W.	24.901	5.226	"			
N.W.	18.666	4.924	"			
N.	13.709	4.153	"			
N.E.	18.666	4.924	"			
E.	24.901	5.226	"			
S.E.	23.892	3.941	"			
TOTAL	170.28	35.652				
AV.	21.285	4.457	2.913	AV. DIFF. & REFL/GRD. =		7.370

RATIO AV. GLOBAL VERT/GLOBAL HOR. = 21.285/29.128 = 0.731
RATIO AV. DIFF. & REFL-GRD./AV. GLOBAL VERT. = 7.370/21.285 = 0.346
MEAN DAILY GLOBAL SOLAR RADIATION IN LANGLEYS = 450
LENGTH OF DAY IN HOURS 19.70

RADIATION RECEIVED PER SQ. M. VERT. SURFACE IN SUN = S_{sun}

$$= \frac{450}{19.70} \times 11.6111 \times 0.731 = 193.882 \text{ w/m}^2$$

RADIATION RECEIVED PER SQ. M. VERT. SURFACE IN SHADE = S_{shade}

$$= \frac{450}{19.70} \times 11.6111 \times 0.346 = 91.769 \text{ w/m}^2$$

S_{sun} WITH 60% CLOTHES ABSORPTIVITY FACTOR = 193.882 X 0.60 = 116.329 w/m^2

S_{shade} WITH 60% CLOTHES ABSORPTIVITY FACTOR = 91.769 X 0.60 = 55.061 w/m^2

APPENDIX II-A (cont.)

OCTOBER

	VERTICAL			HORIZONTAL		
	GLOBAL	DIFFUSE	REFL-GRD.	GLOBAL	DIFFUSE	REFL-GRD.
S.	23.062	5.289	1.663	5.542	1.343	0.0
S.W.	17.668	4.187	"			
W.	8.629	2.231	"			
N.W.	2.996	0.908	"			
N.	2.403	0.740	"			
N.E.	2.996	0.907	"			
E.	8.629	2.231	"			
S.E.	17.668	4.187	"			
TOTAL	84.051	20.681				
AVERAGE	10.51	2.585	1.663	AV. DIFF. & REFL-GRD. = 4.248		

RATIO AV. GLOBAL VERT/GLOBAL HOR. = 10.51/5.542 = 1.896
RATIO AV. DIFF. & REFL-GRD./AV. GLOBAL VERT. = 4.248/10.51 = 0.404
MEAN DAILY GLOBAL SOLAR RADIATION IN LANGLEYS = 75
LENGTH OF DAY IN HOURS 9.49

RADIATION RECEIVED PER SQ. M. VERT. SURFACE IN SUN = S_{sun}

$$= \frac{75}{9.49} \times 11.6111 \times 1.896 = 173.982 \text{ w/m}^2$$

RADIATION RECEIVED PER SQ. M. VERT. SURFACE IN SHADE = S_{shade}

$$= \frac{75}{9.49} \times 11.6111 \times 0.404 = 37.072 \text{ w/m}^2$$

S_{sun} WITH 60% CLOTHES ABSORPTIVITY FACTOR = 173.982 X 0.60 = 104.389 w/m^2

S_{shade} WITH 60% CLOTHES ABSORPTIVITY FACTOR = 37.072 X 0.60 = 22.243 w/m^2

APPENDIX II-B

DATA USED IN PENWARDEN'S EQUATION TO GENERATE COMFORT CURVES

Eq'n: $T_b - T_a = \frac{M}{A_{Du}} R_b + k \frac{M}{A_{Du}} R_c + \left[k \frac{M}{A_{Du}} + S \right] \left[4.2 + 13u^{0.5} \right] -1$

T_b = BODY CORE TEMP . . . . . 37°C

T_a = AIR TEMP . . . . . .(calculated)

$\frac{M}{A_{Du}}$ = METABOLIC RATE OF HEAT PRODUCTION PER SQ. M. OF BODY SURFACE IN w/m^2 (LEVEL WALKING @ 0.09 m/s (2mph)). $125w/m^2$

k = PROPORTION OF METABOLIC HEAT DISSIPATED BY MEANS OTHER THAN EVAPORATION 0.8

R_b = THERMAL RESISTANCE OF BODY TISSUES m^2 deg. C/W

. . . . . onset of sweating	0.04
. . . . . comfortable	0.065
. . . . . onset of shivering	0.09

R_c = THERMAL RESISTANCE OF CLOTHING m^2 deg. C/W (1clo. = 0.155 m^2 c/w)

0.0 clo.	= 0.000
0.5	= 0.078
1.0	= 0.155
1.5	= 0.233
2.0	= 0.310
2.5	= 0.388
3.0	= 0.465
3.5	= 0.543
4.0	= 0.620
4.5	= 0.698
5.0	= 0.775

S = SOLAR HEAT INPUT PER SQ. M. OF BODY SURFACE w/m^2 S_{sun} = IN SUN S_{shade} = IN SHADE

OCTOBER	S_{sun}	= 104.389
. . . . .	S_{shade}	= 22.243
FEBRUARY	S_{sun}	= 152.011
. . . . .	S_{shade}	= 25.963
MAY	S_{sun}	= 192.268
. . . . .	S_{shade}	= 96.134
JULY	S_{sun}	= 116.329
. . . . .	S_{shade}	= 55.061

u = WIND SPEED m/sec . . . . . 0 to 10 m/s

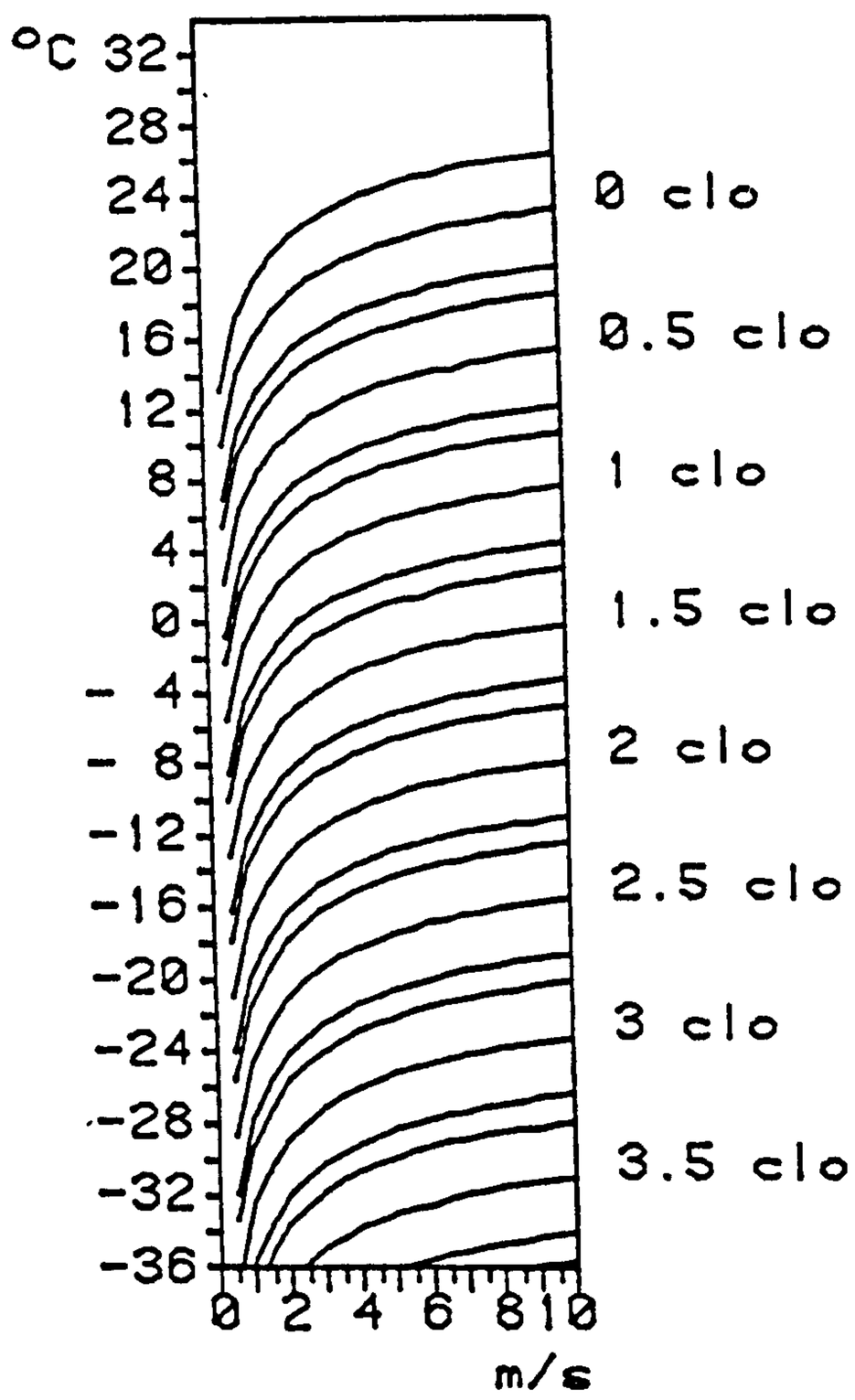
$(4.2 + 13\ u^{0.5})^{-1}$ = THERMAL RESISTANCE BETWEEN CLOTHING AND SURROUNDINGS m^2 deg. C/W

APPENDIX II-C

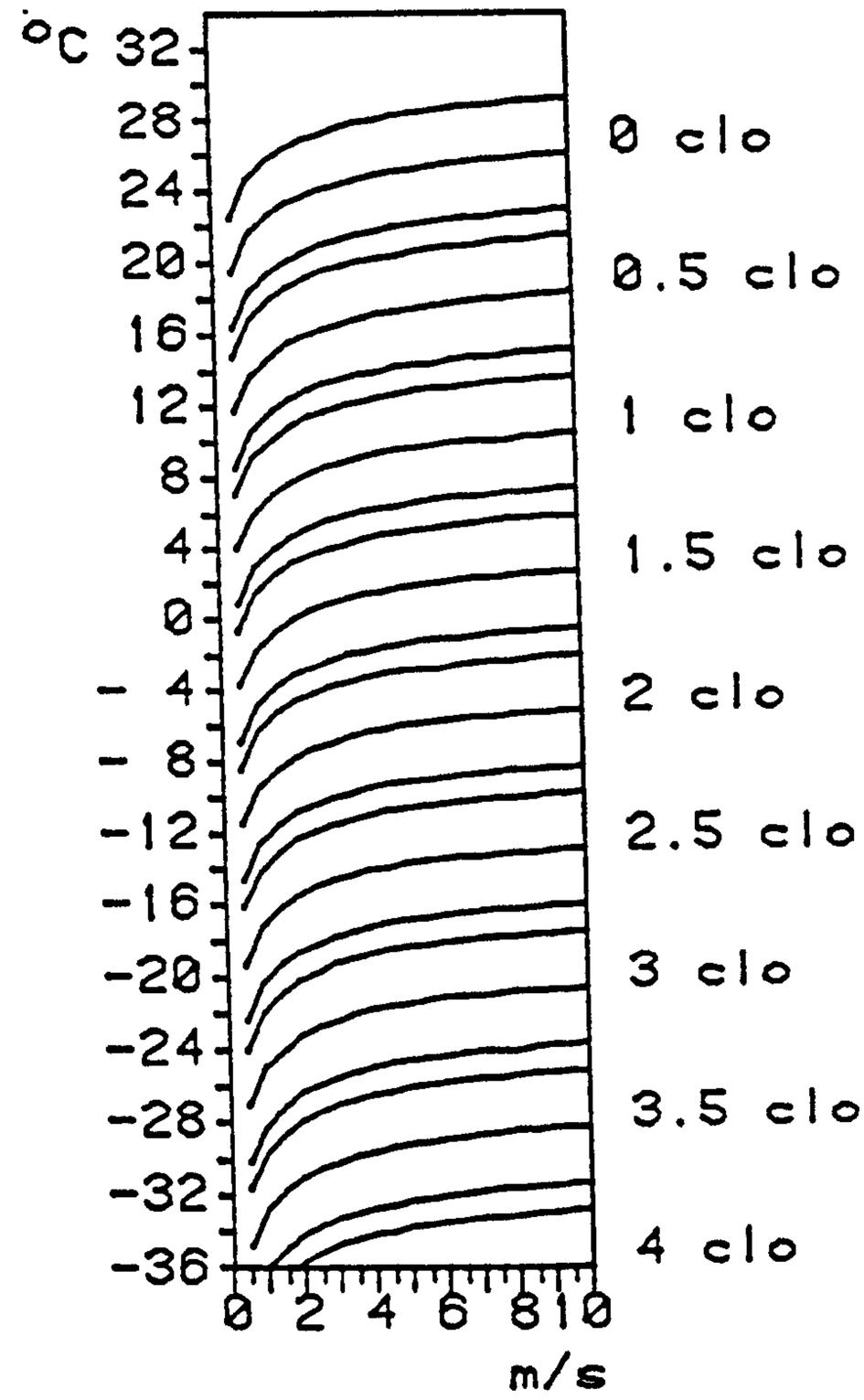
COMFORT CURVES IN SUN AND SHADE FOR LATITUDE 65°N

Curves based on data in II-A and II-B and generated
by a computer program written by Takashi Nakajima
Ecole d'Architecture, Université Laval, Québec, Canada.

COMFORT CURVES FOR THE MONTH OF FEBRUARY FOR A M/A_{Du} OF 125
(M/A_{Du} of 125 ≈ walking at 2.5 mph.)



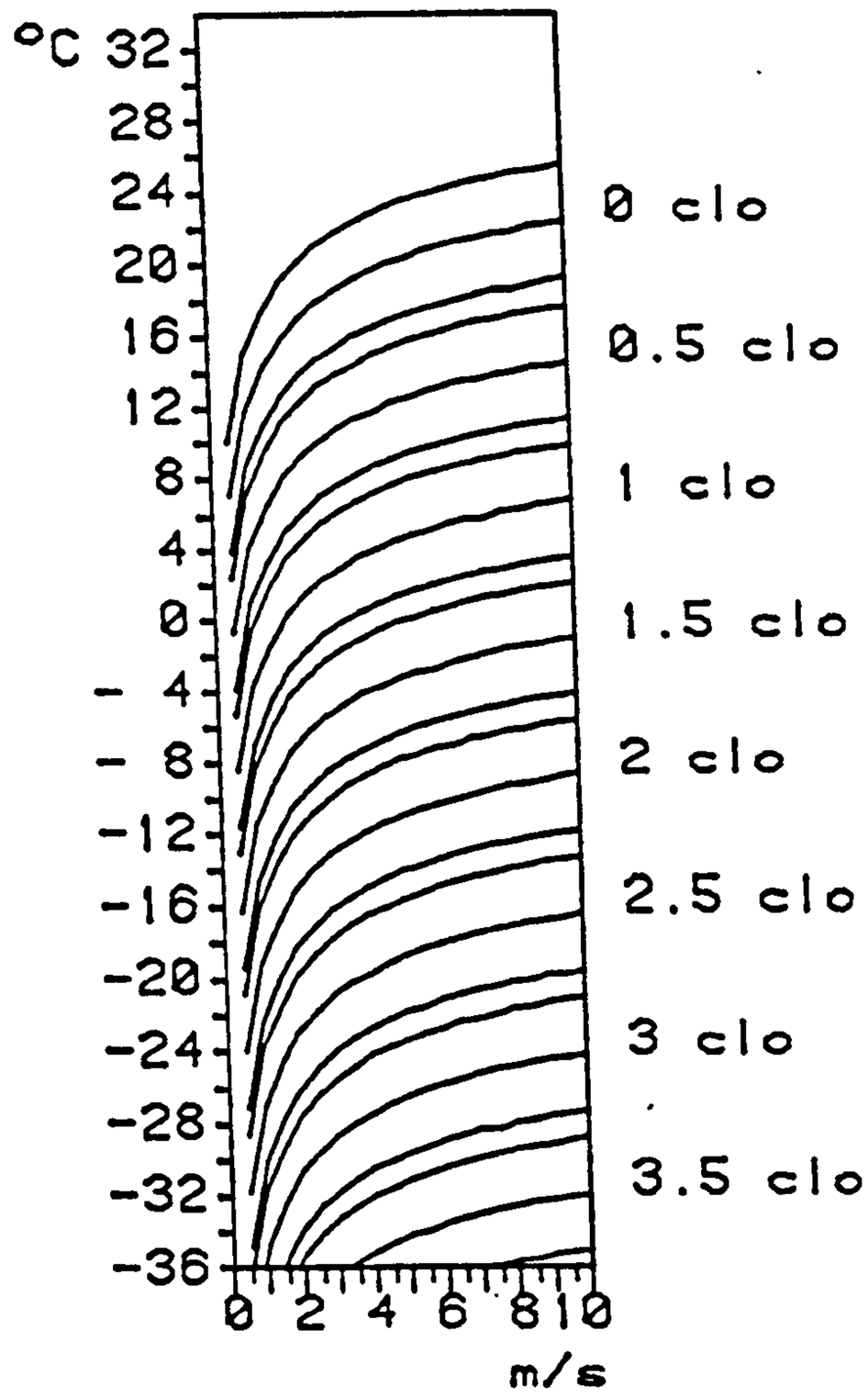
Comfort conditions in full sun
S = 152.0



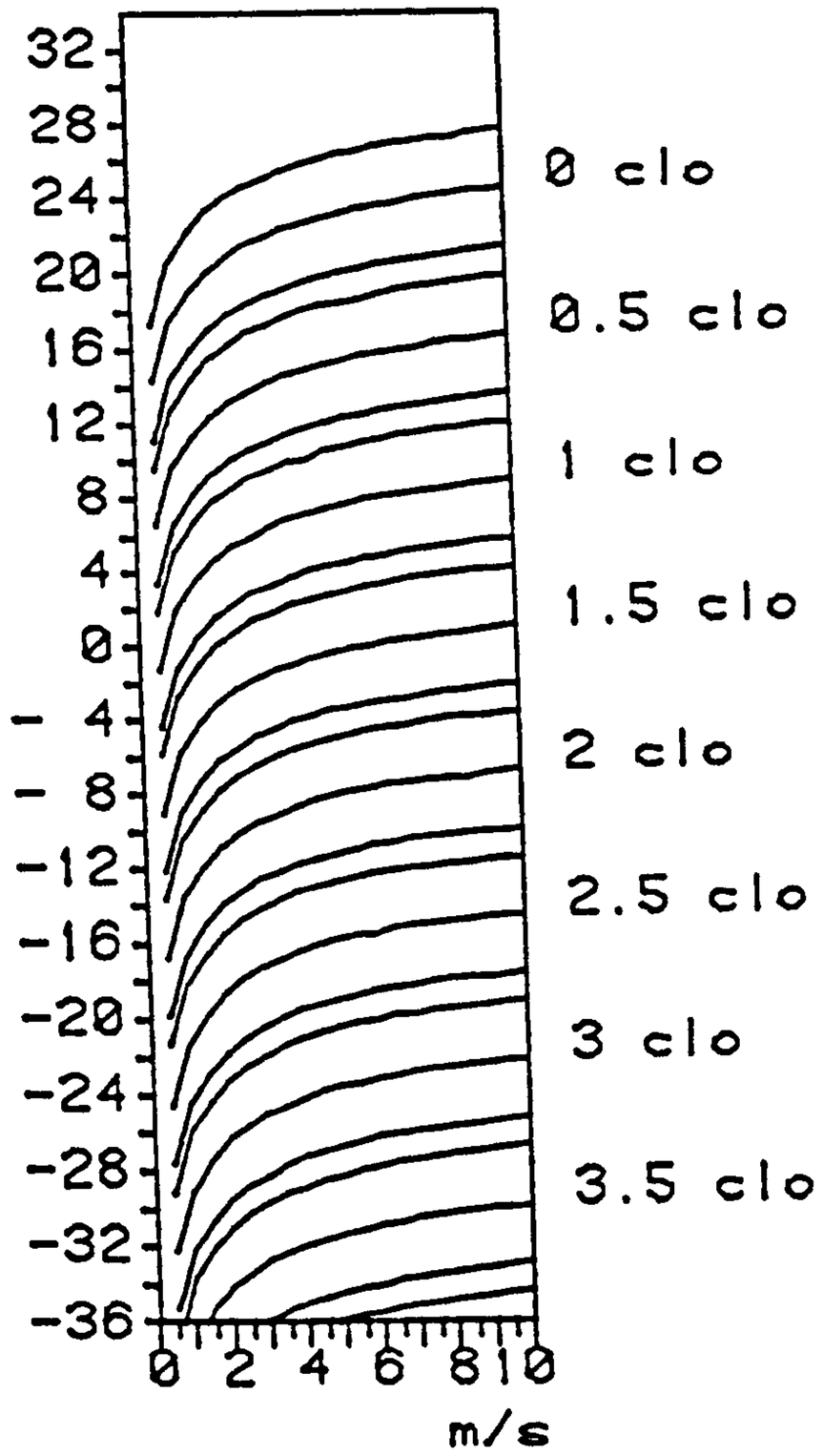
Comfort conditions in shade
S = 26.0

APPENDIX II-C (cont.)

COMFORT CURVES FOR THE MONTH OF MAY FOR A M/A_{Du} OF 125



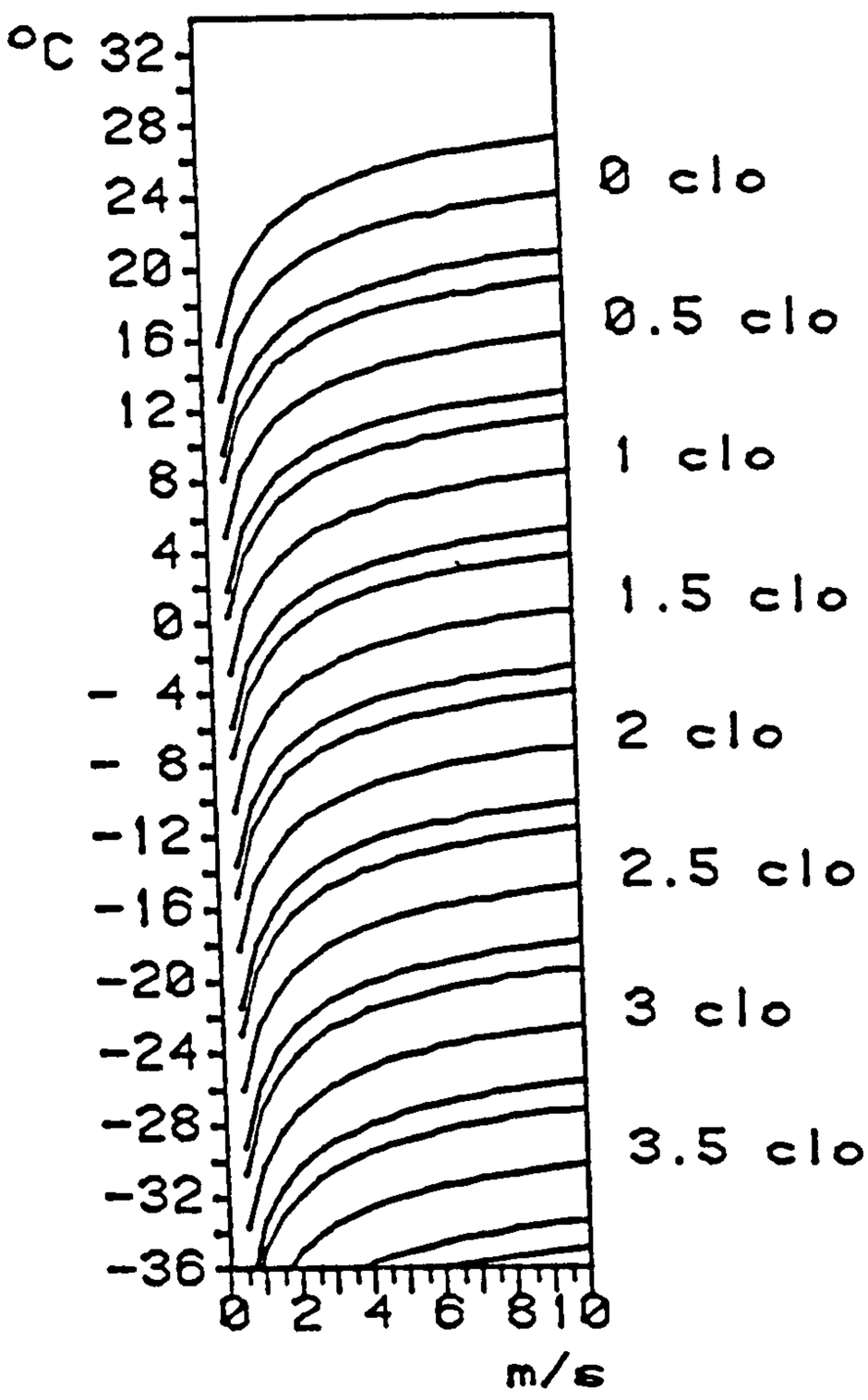
Comfort conditions in full sun
S = 192.3



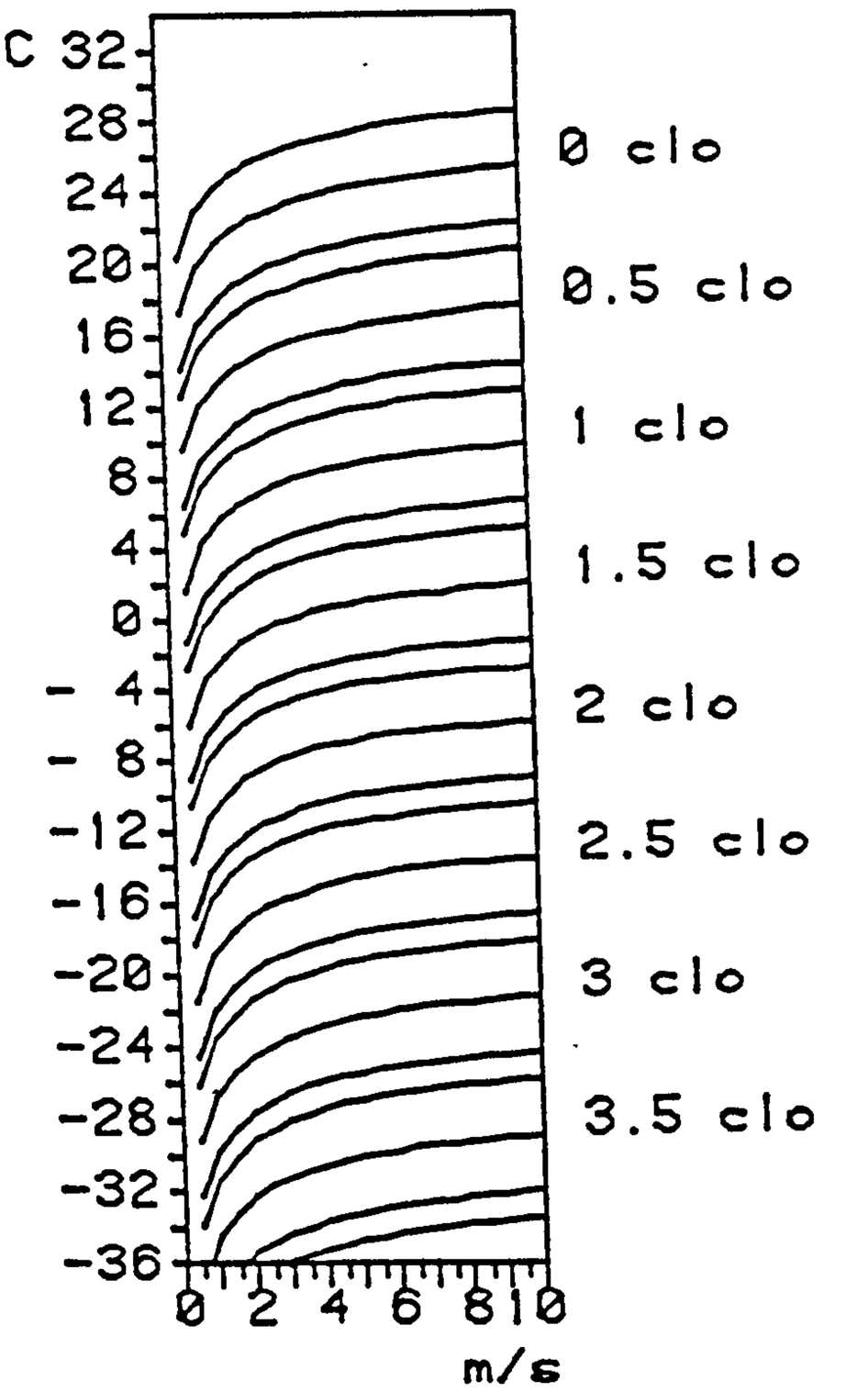
Comfort conditions in shade
S = 96.1

APPENDIX II-C (Cont.)

COMFORT CURVES FOR THE MONTH OF JULY FOR A M/A_{Du} OF 125



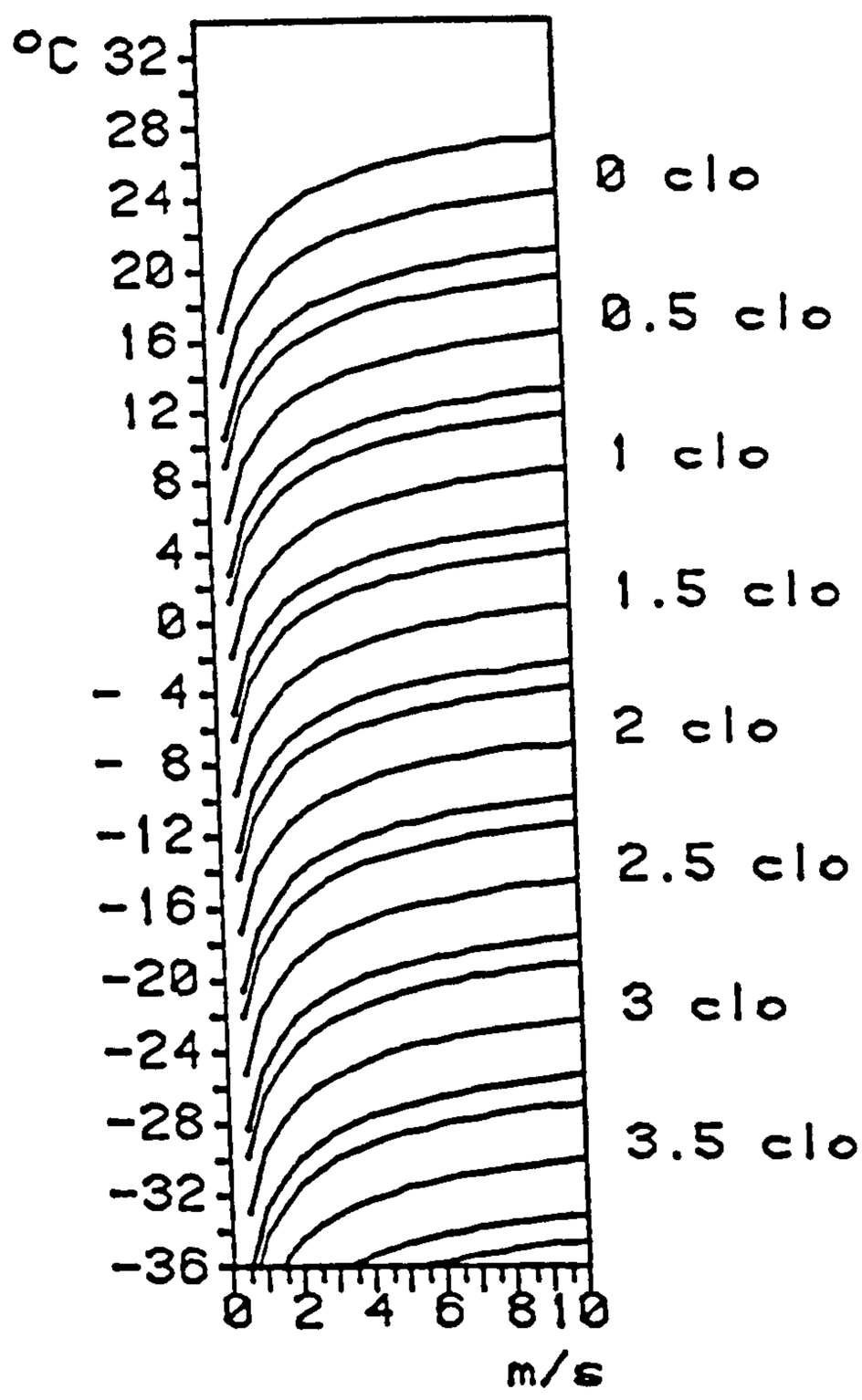
Comfort conditions in full sun
S=116.3



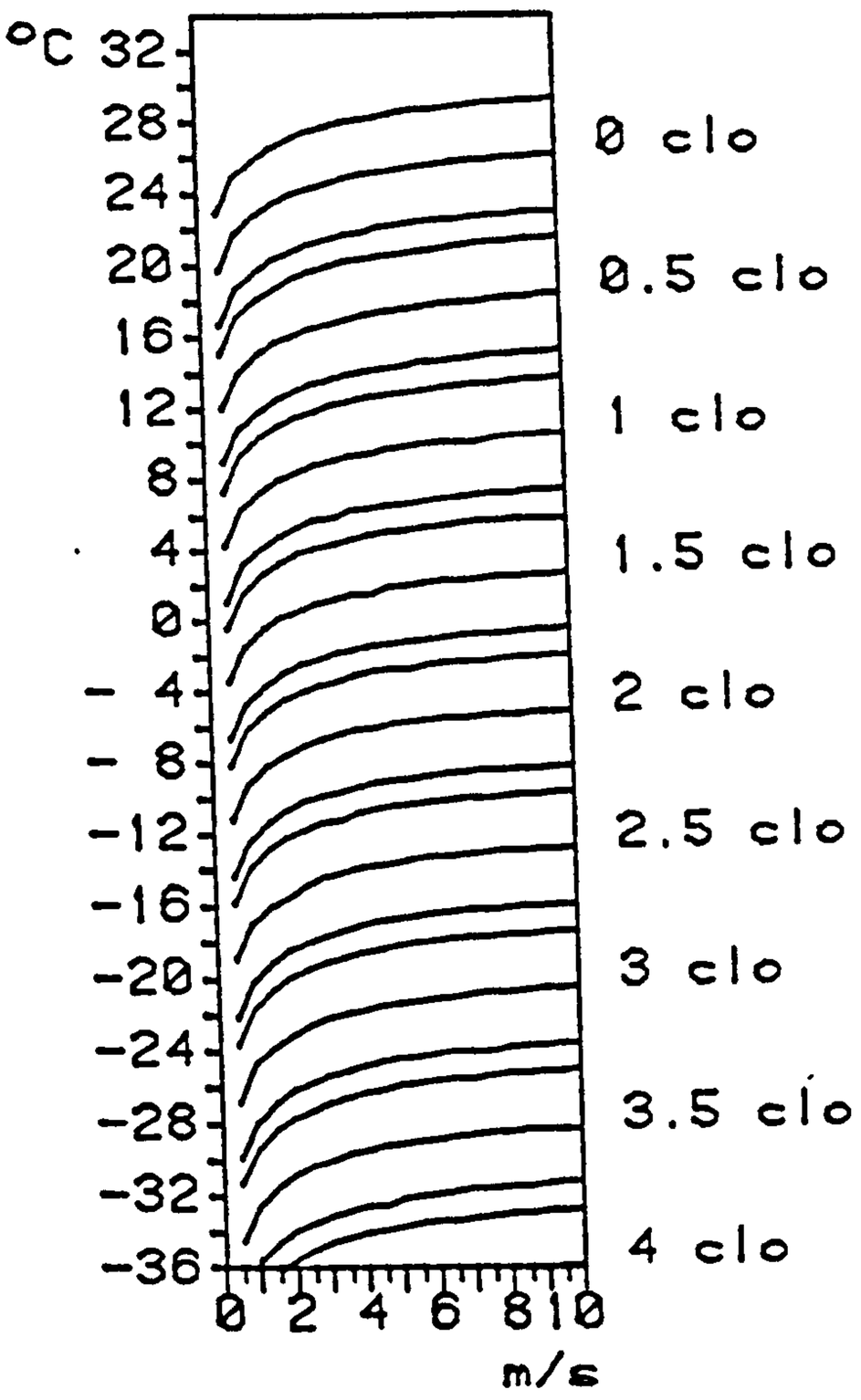
Comfort conditions in shade
S=55.1

APPENDIX II-C (Cont.)

COMFORT CURVES FOR THE MONTH OF OCTOBER FOR A M/A_{Du} OF 125



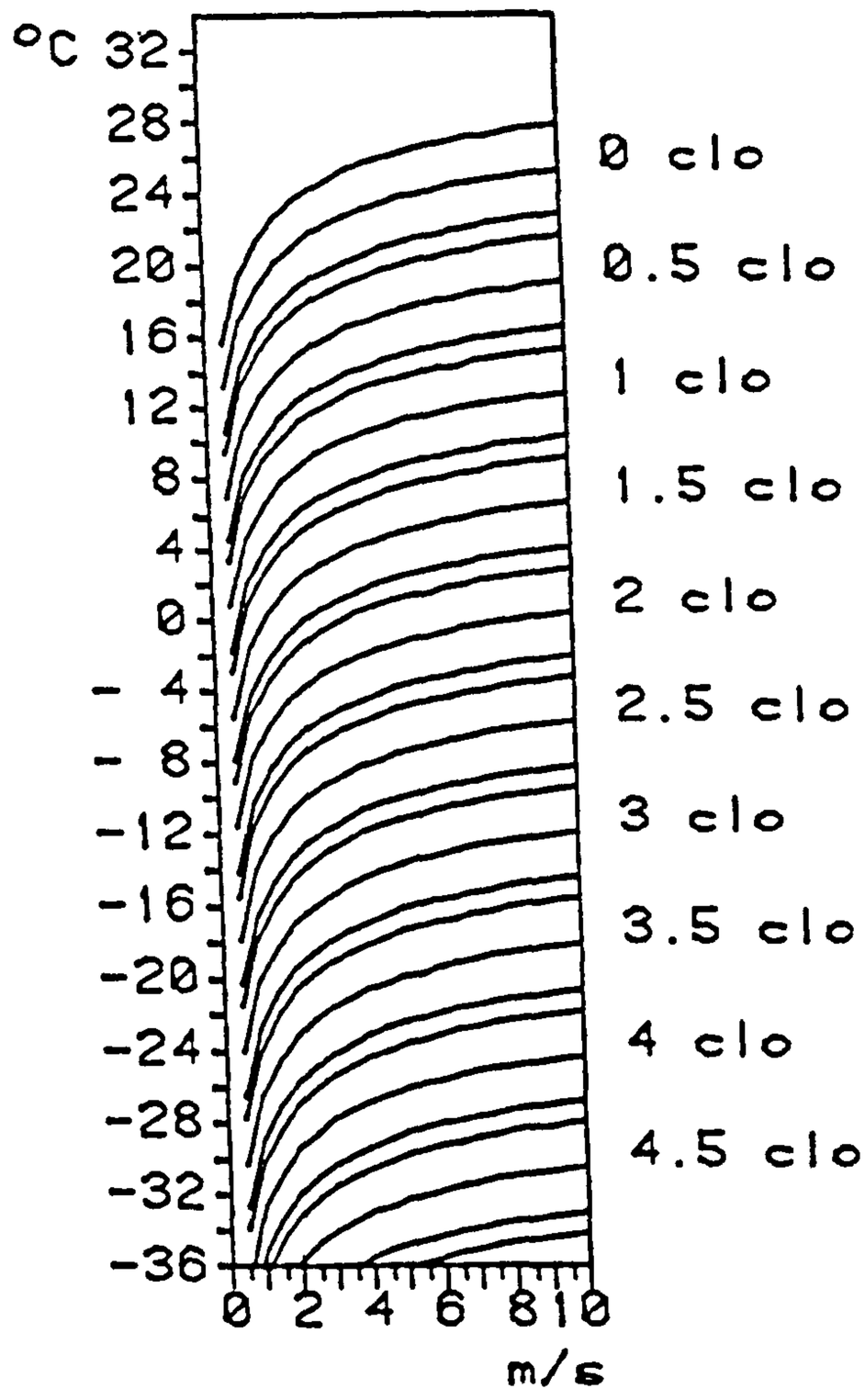
Comfort conditions in full sun
S=104.4



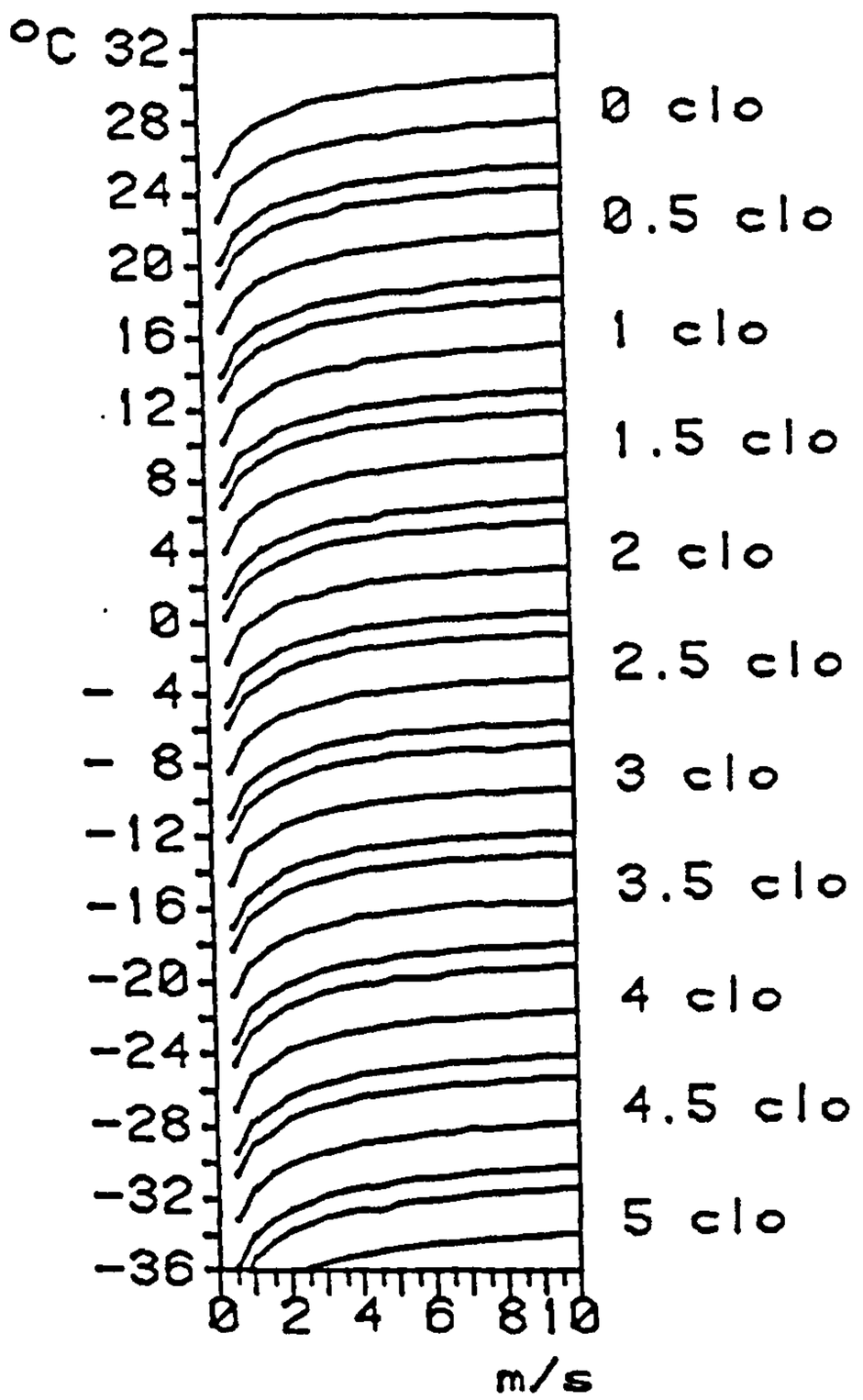
Comfort conditions in shade
S=22.2

APPENDIX II-C (Cont.)

COMFORT CURVES FOR THE MONTH OF FEBRUARY FOR A M/A_{Du} of 100
(M/A_{Du} of 100 ≈ strolling at 1.5 mph.)



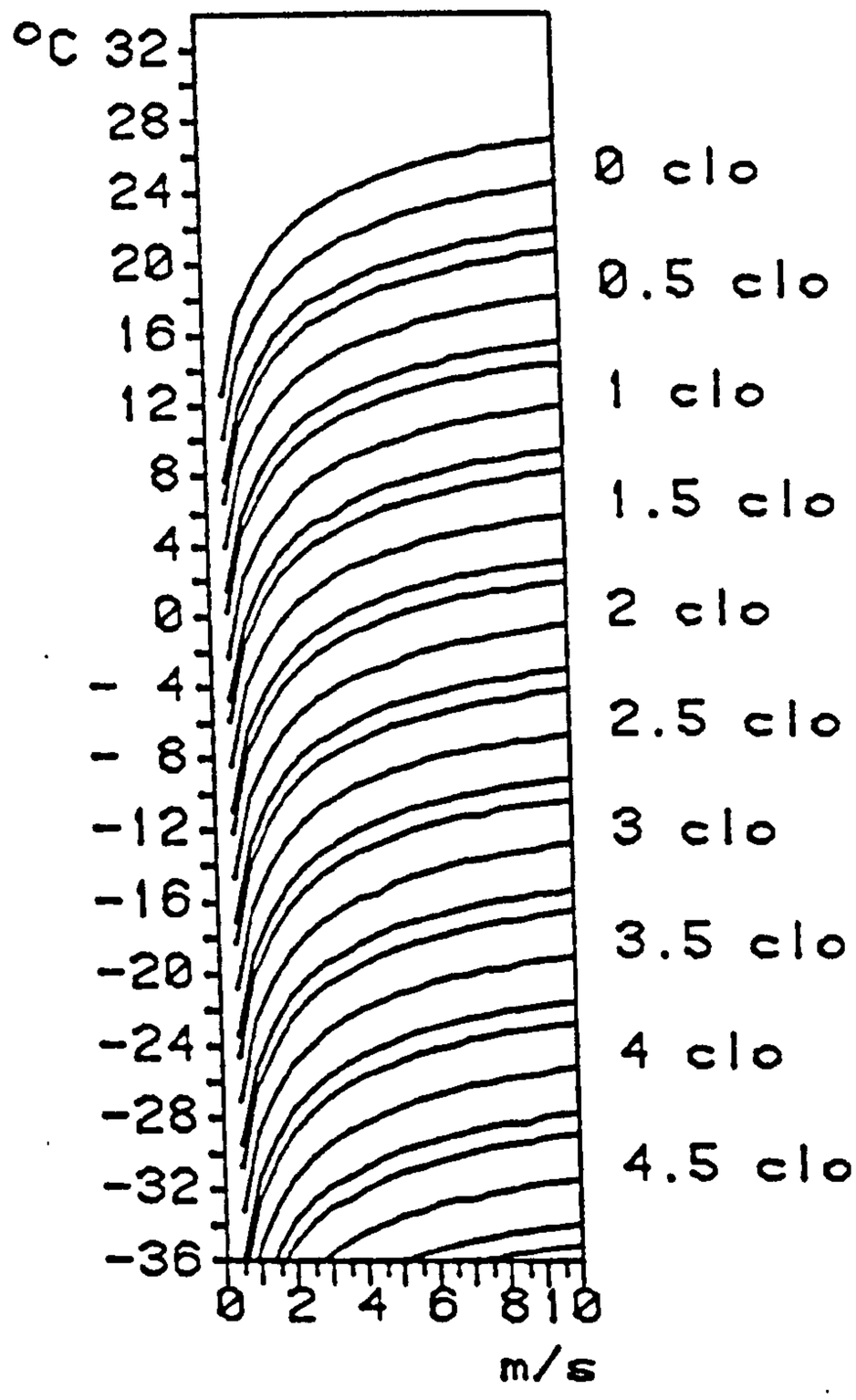
Comfort conditions in full sun
S = 152.0



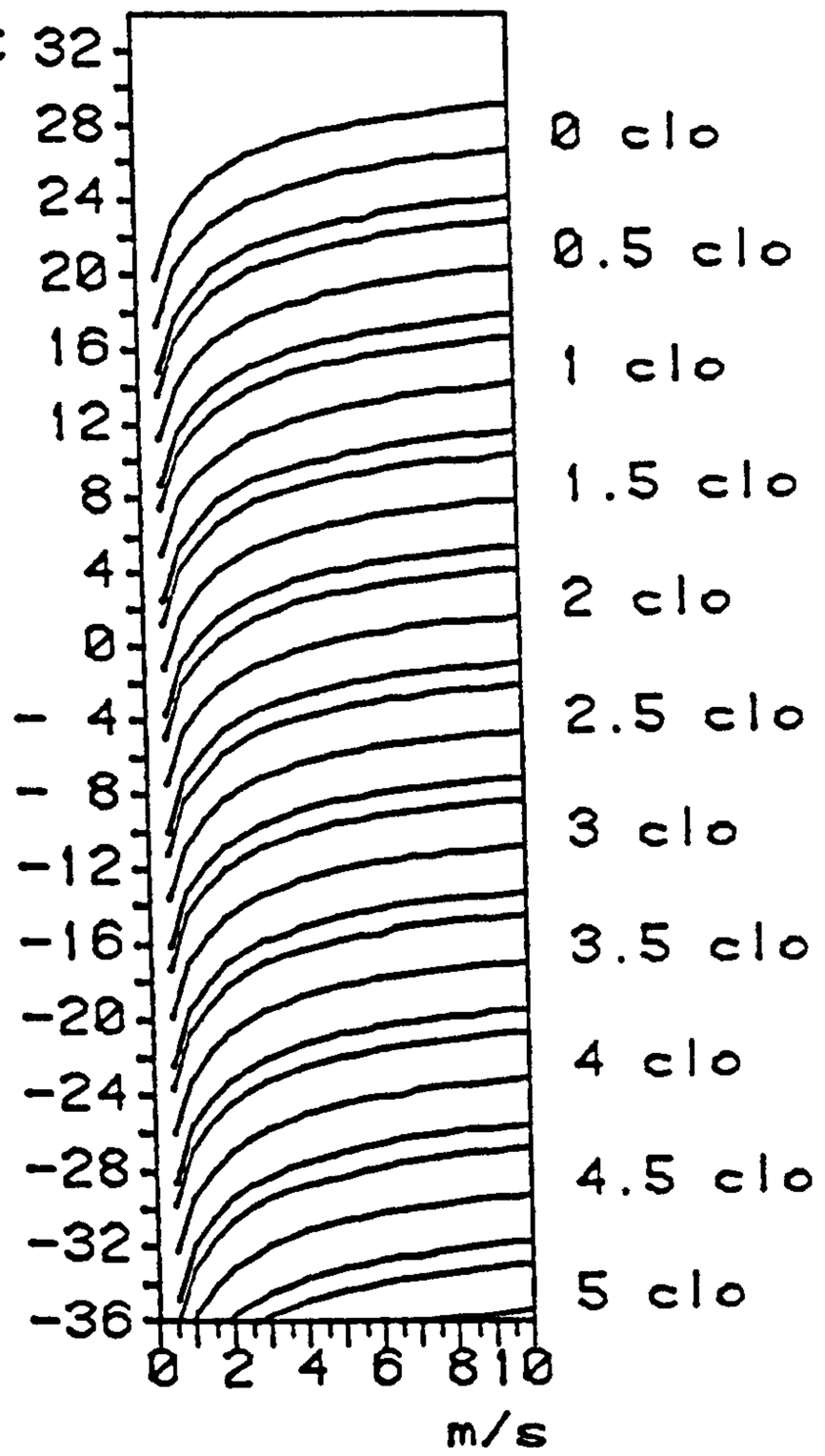
Comfort conditions in shade
S = 26.0

APPENDIX II-C (Cont.)

COMFORT CURVES FOR THE MONTH OF MAY FOR A M/A_{Du} OF 100



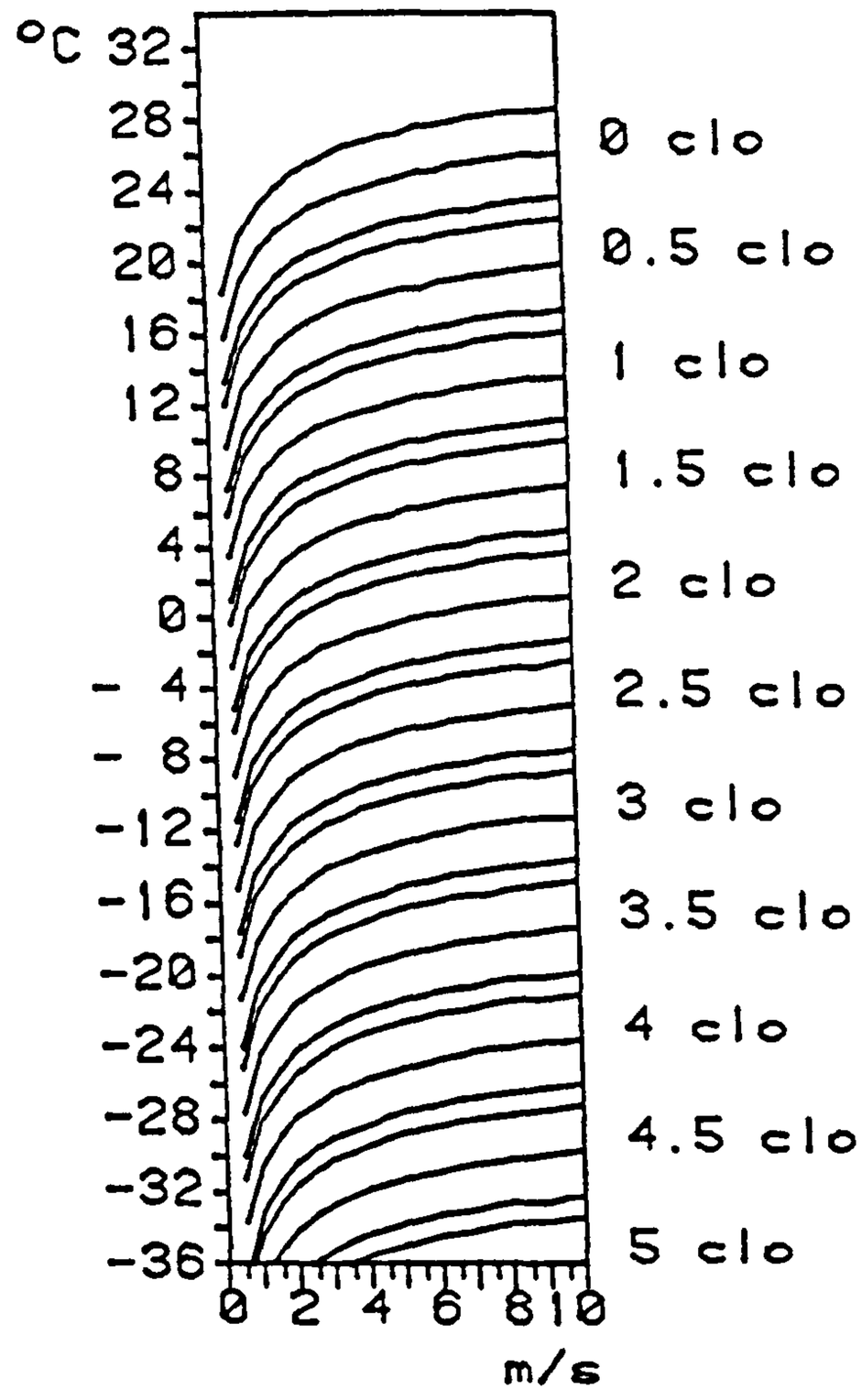
Comfort conditions in full sun
S=192.3



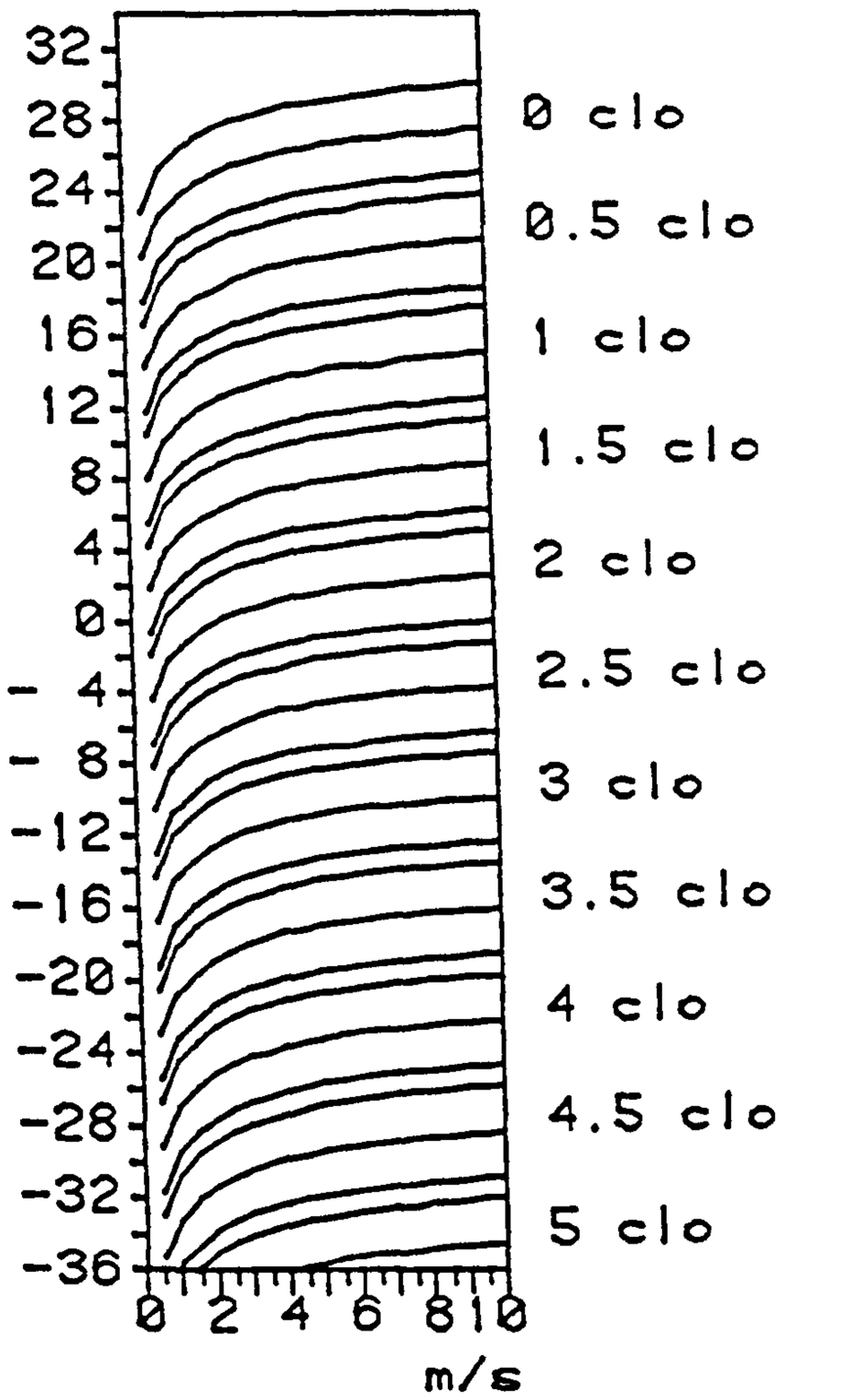
Comfort conditions in shade
S=96.1

APPENDIX II-C (Cont.)

COMFORT CURVES FOR THE MONTH OF JULY FOR A M/A_{Du} OF 100



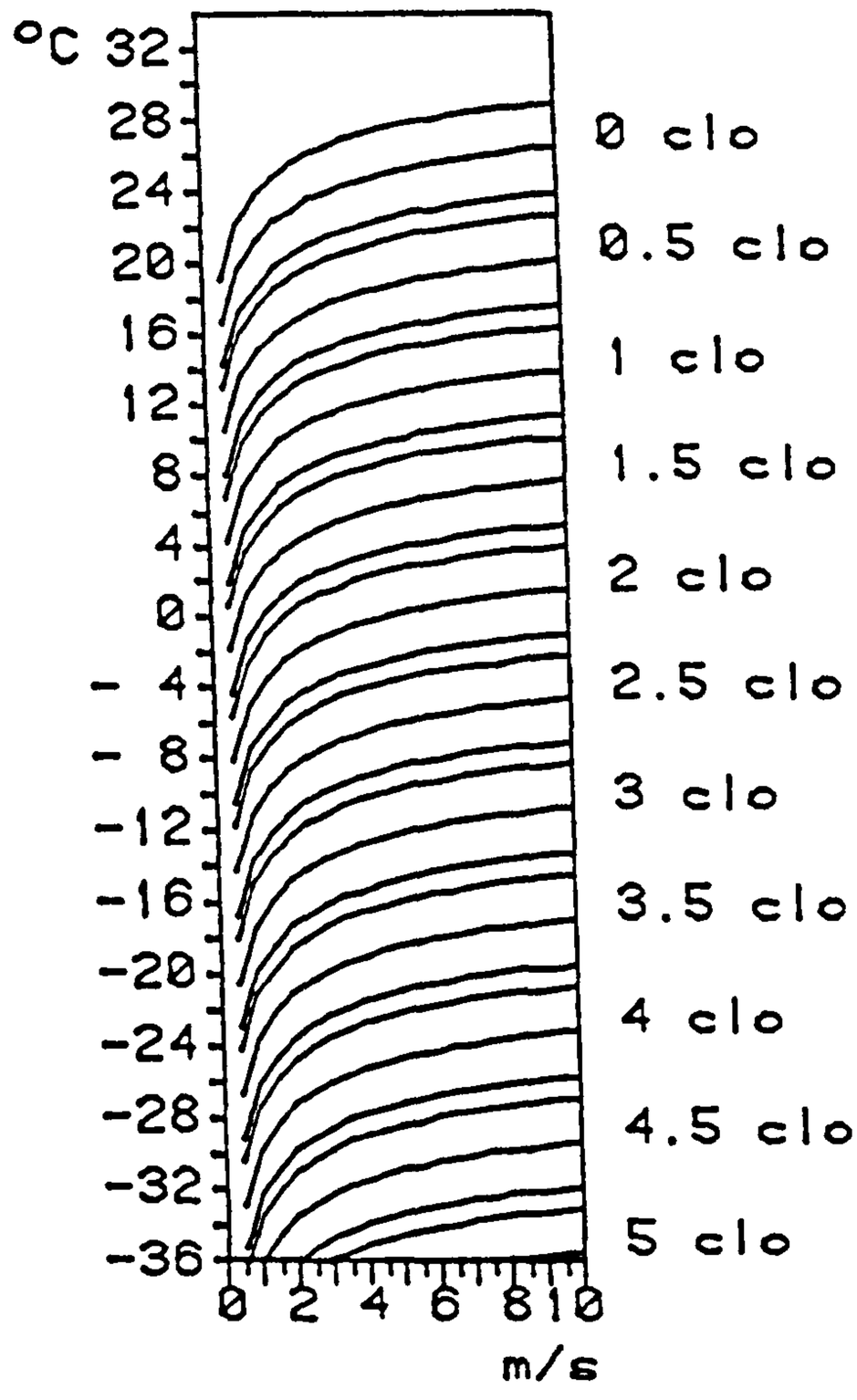
Comfort conditions in full sun
S = 116.3



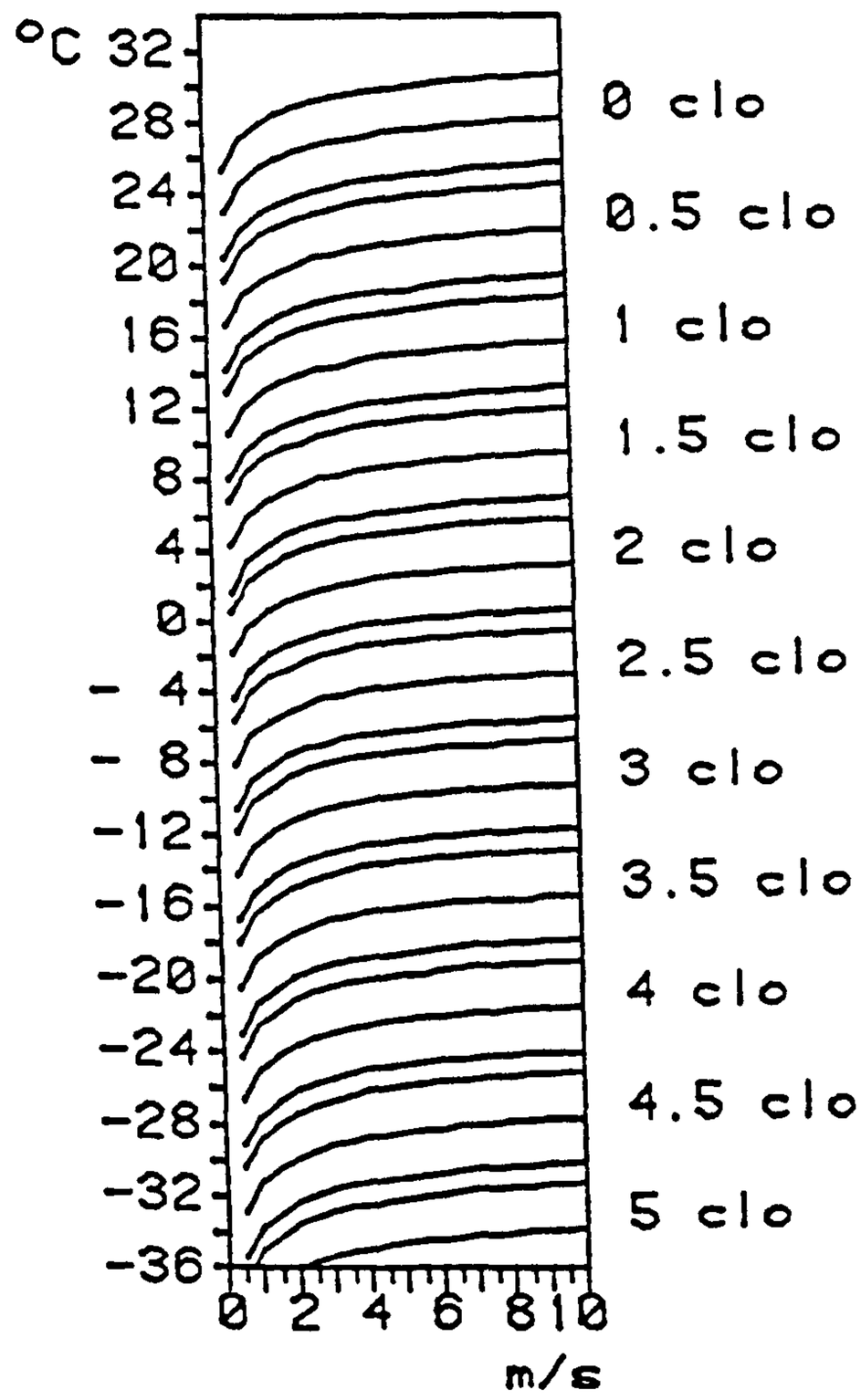
Comfort conditions in shade
S = 55.1

APPENDIX II-C (Cont.)

COMFORT CURVES FOR THE MONTH OF OCTOBER FOR A M/A_{Du} OF 100



Comfort conditions in full sun
S=104.4



Comfort conditions in shade
S=22.2

APPENDIX II-D

CALCULATIONS FOR SOLAR ALTITUDE (Alt.) AND AZIMUTH (Az.) FOR LATITUDE 65°N

SOLAR ALTITUDE

Formula: sin Alt.= cos D cos L cos H + sin D sin L

where D = declination

summer - 21 June	+23.5°
mid equinox-summer - 6 May, 5 August	+11.8°
equinox - 21 March, 21 September	0°
mid equinox-winter - 6 November, 5 February	-11.8°
winter - 21 December	-23.5°

N.B. declination with a - value gives for sin factor a - sin value and for cos factor gives a + cos value.

L = latitude

H = local hour, H = 0 for 12:00 and each hour = 15°
eg. 11:00 and 13:00 = 15°, 10:00 and 14:00 = 30°.

Summer: 12:00 sin Alt.= cos 23.5° cos 65° cos 0° + sin 23.5° sin 65°
= 0.750, Alt.= 48°40'
10:00 and 14:00 sin Alt.= 0.698, Alt.= 44°20'
9:00 and 15:00 sin Alt.= 0.636, Alt.= 39°30'
8:00 and 16:00 sin Alt.= 0.556, Alt.= 33°50'

Mid Equinox-Summer
12:00 sin Alt.= 0.600, Alt.= 36°50'
10:00 and 14:00 sin Alt.= 0.545, Alt.= 33°
9:00 and 15:00 sin Alt.= 0.479, Alt.= 28°40'
8:00 and 16:00 sin Alt.= 0.393, Alt.= 23°10'

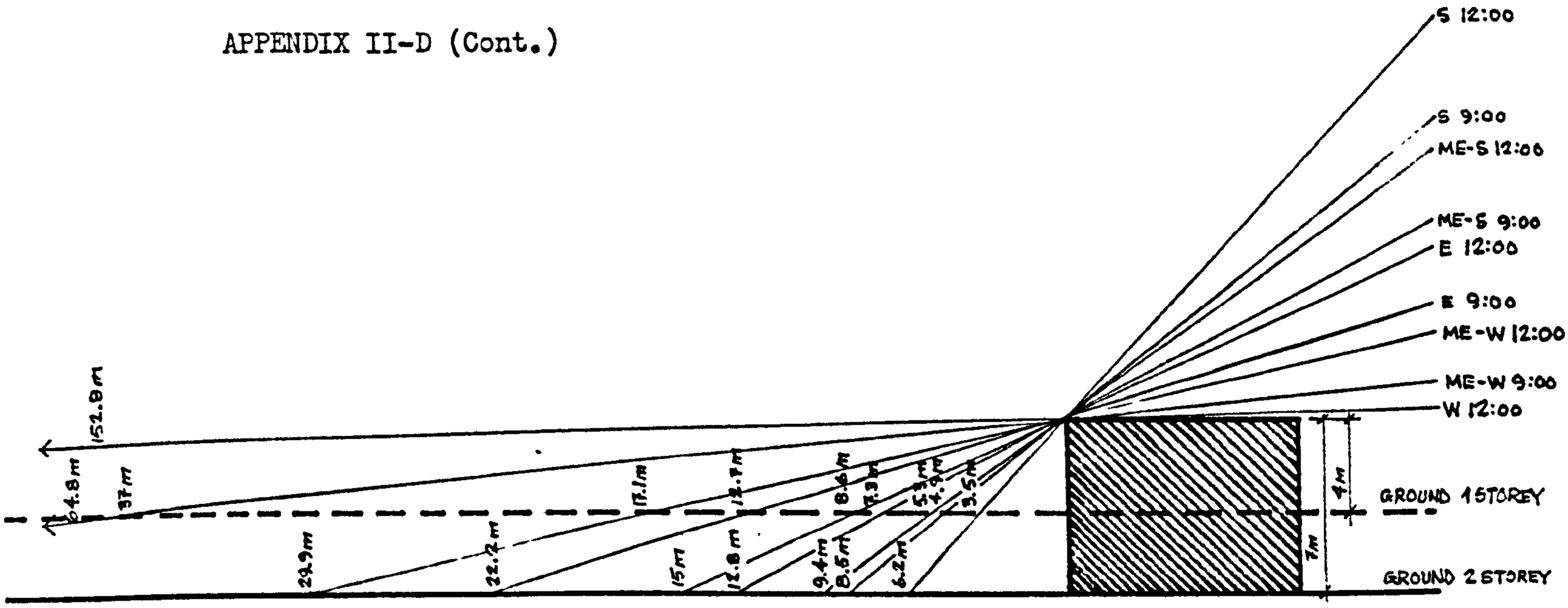
Equinox
12:00 sin Alt.= 0.423, Alt.= 25°
10:00 and 14:00 sin Alt.= 0.366, Alt.= 21°30'
9:00 and 15:00 sin Alt.= 0.299, Alt.= 17°30'
8:00 and 16:00 sin Alt.= 0.212, Alt.= 12°20'

Mid Equinox-Winter
12:00 sin Alt.= 0.228, Alt.= 13°10'
11:00 and 13:00 sin Alt.= 0.214, Alt.= 12°20'
10:00 and 14:00 sin Alt.= 0.173, Alt.= 10°
9:00 and 15:00 sin Alt.= 0.107, Alt.= 6°10'
8:00 and 16:00 sin Alt.= 0.021, Alt.= 1°10'

Winter
12:00 sin Alt.= 0.026, Alt.= 1°30'

To find the length of the shadow the trigonometric formula for right-angled triangles was used. Length of shadow = ht. of bldg. cot solar Alt.
eg. L= 4m (ht. of bldg.) cot 1°30' (solar Alt. winter 12:00) = 152.8m.

APPENDIX II-D (Cont.)



Dwg. 1. Length of shadows cast by one and two storey buildings for various seasons at latitude 65°N.

CALCULATIONS FOR SOLAR AZIMUTH AT LATITUDE 65°N

Formula : sin Az. = cos D sin H / cos Alt.

Summer

12:00 sin Az. = cos 23.5° sin 0° / cos 44°20'
= 0.0 , Az. 0°

10:00 and 14:00 sin Az.=0.641, Az.=39°50'

9:00 and 15:00 sin Az.=0.840, Az.=57°10'

8:00 and 16:00 sin Az.=0.956, Az.=73°

Mid Equinox-Summer

10:00 and 14:00 sin Az.=0.583, Az.=35°40'

9:00 and 15:00 sin Az.=0.789, Az.=52°10'

8:00 and 16:00 sin Az.=0.923, Az.=67°20'

Equinox

10:00 and 14:00 sin Az.=0.538, Az.=32°30'

9:00 and 15:00 sin Az.=0.741, Az.=47°50'

8:00 and 16:00 sin Az.=0.886, Az.=62°20'

Mid Equinox-Winter

11:00 and 13:00 sin Az.=0.260, Az.=15°10'

10:00 and 14:00 sin Az.=0.497, Az.=29°50'

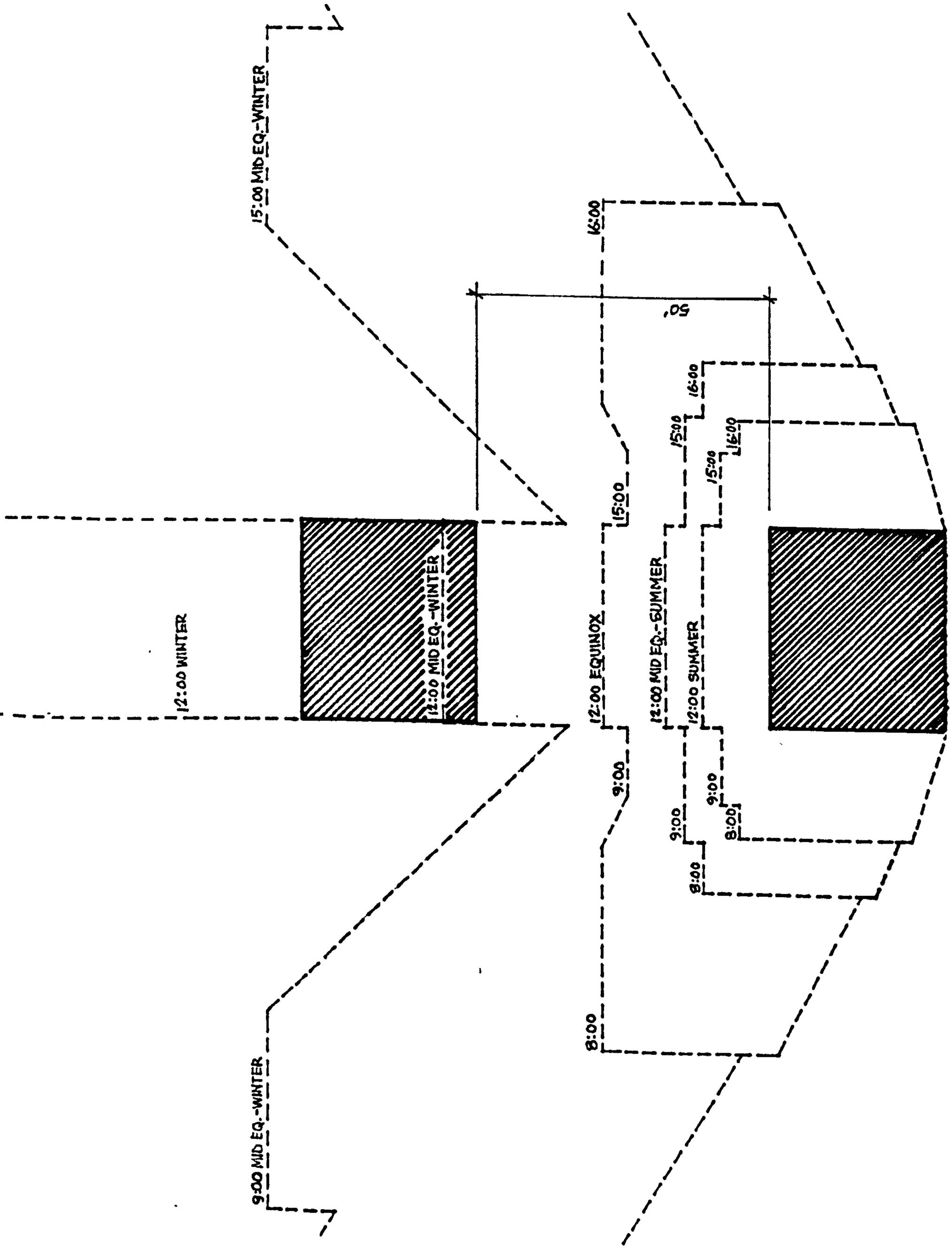
9:00 and 15:00 sin Az.=0.696, Az.=44°10'

8:00 and 16:00 sin Az.=0.849, Az.=58°10'

Winter

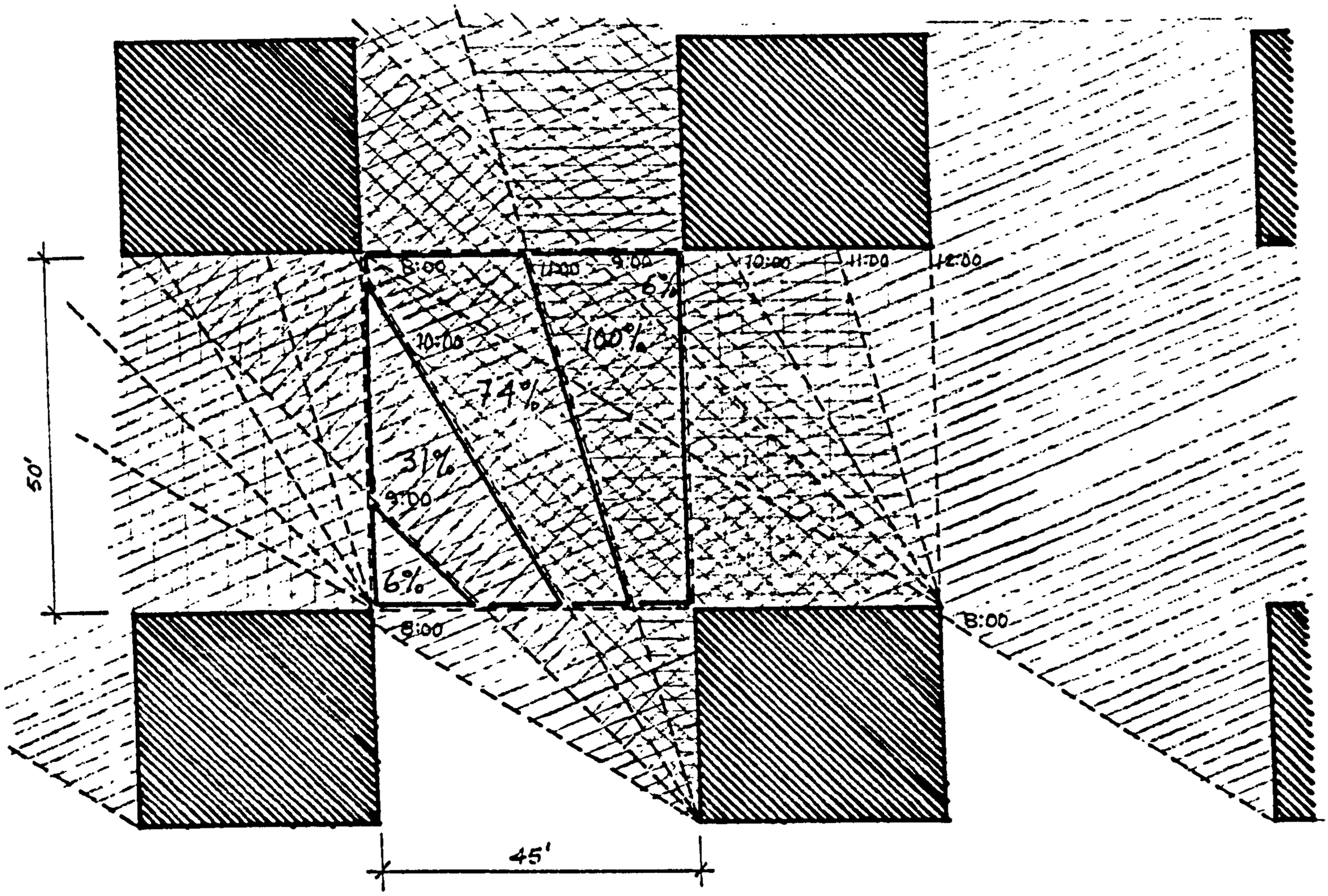
12:00 Az.=0°

APPENDIX II-D (cont.)



Dwg. 2. Plan of shadows cast by one-storey house for various seasons at latitude 65°N.

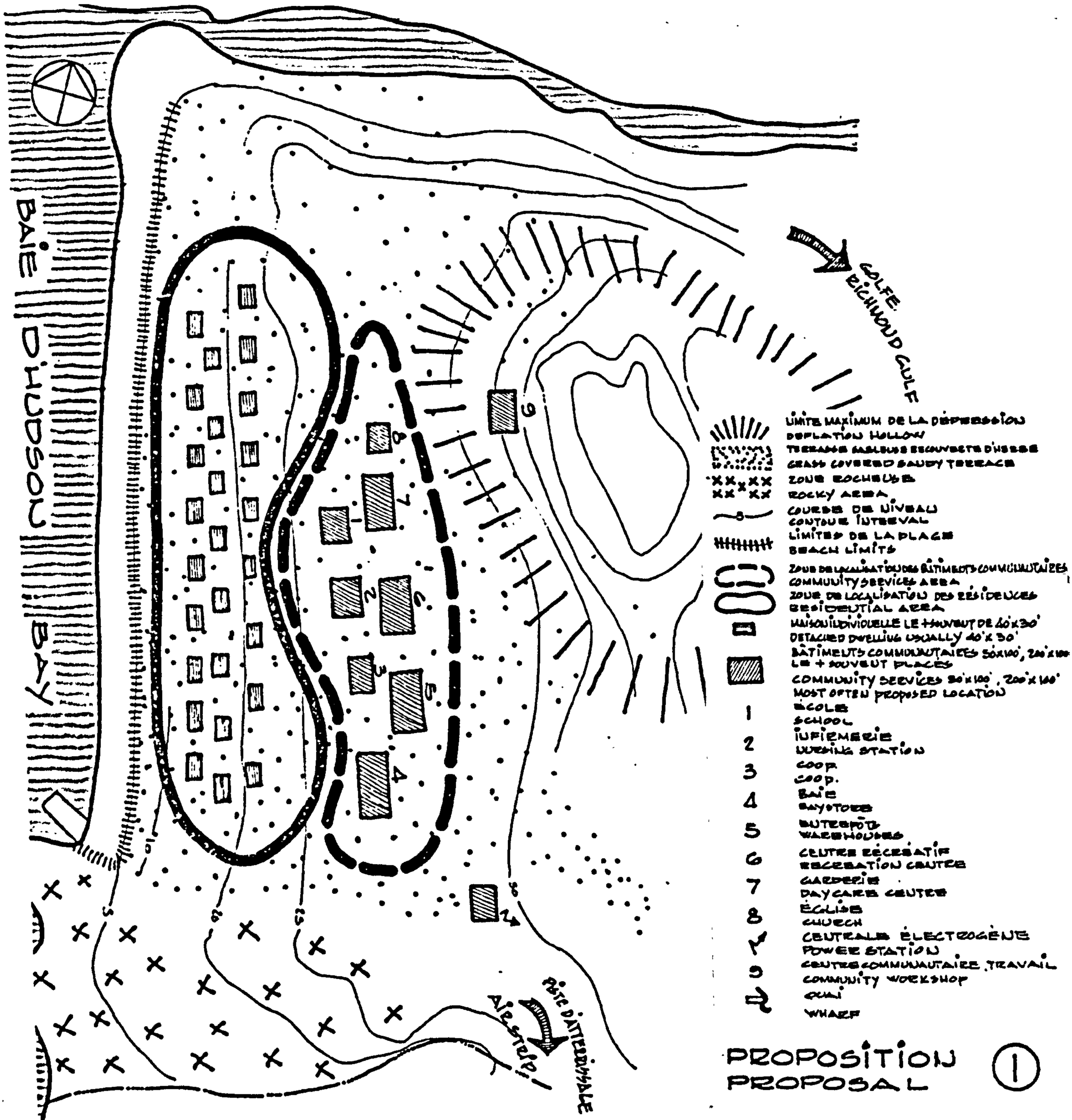
APPENDIX II-D (cont.)



8:00 and 16:00 - 100% in shade
9:00 and 15:00 - 12% in sunlight
10:00 and 14:00 - 31% in sunlight
11:00 and 13:00 - 74% in sunlight
12:00 - 100% in sunlight

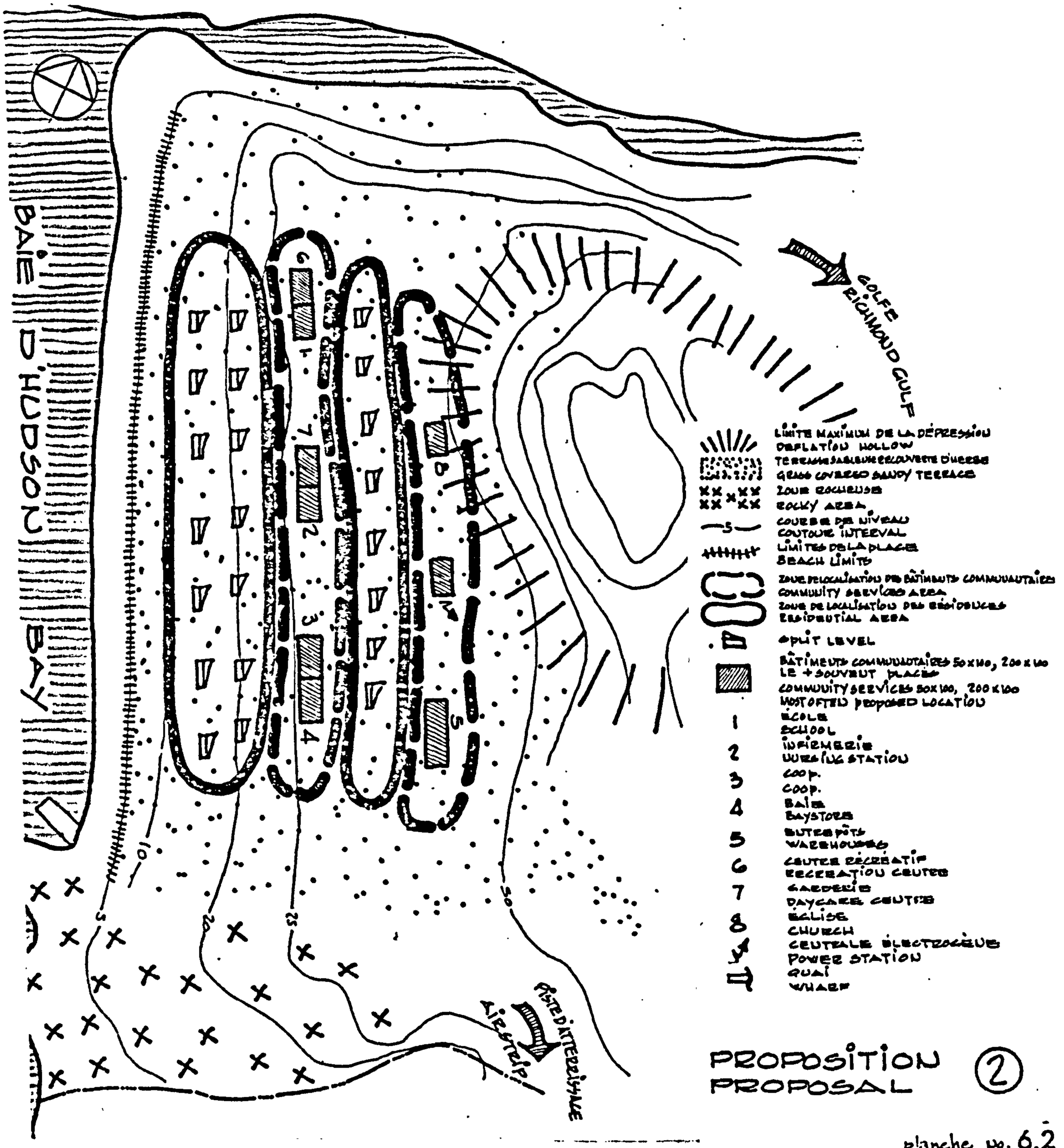
Dwg. 3. Plan of shadows between houses at normal house spacing showing percentage of space in sunlight at mid equinox-winter for Lat. 65°N.

APPENDIX III-A



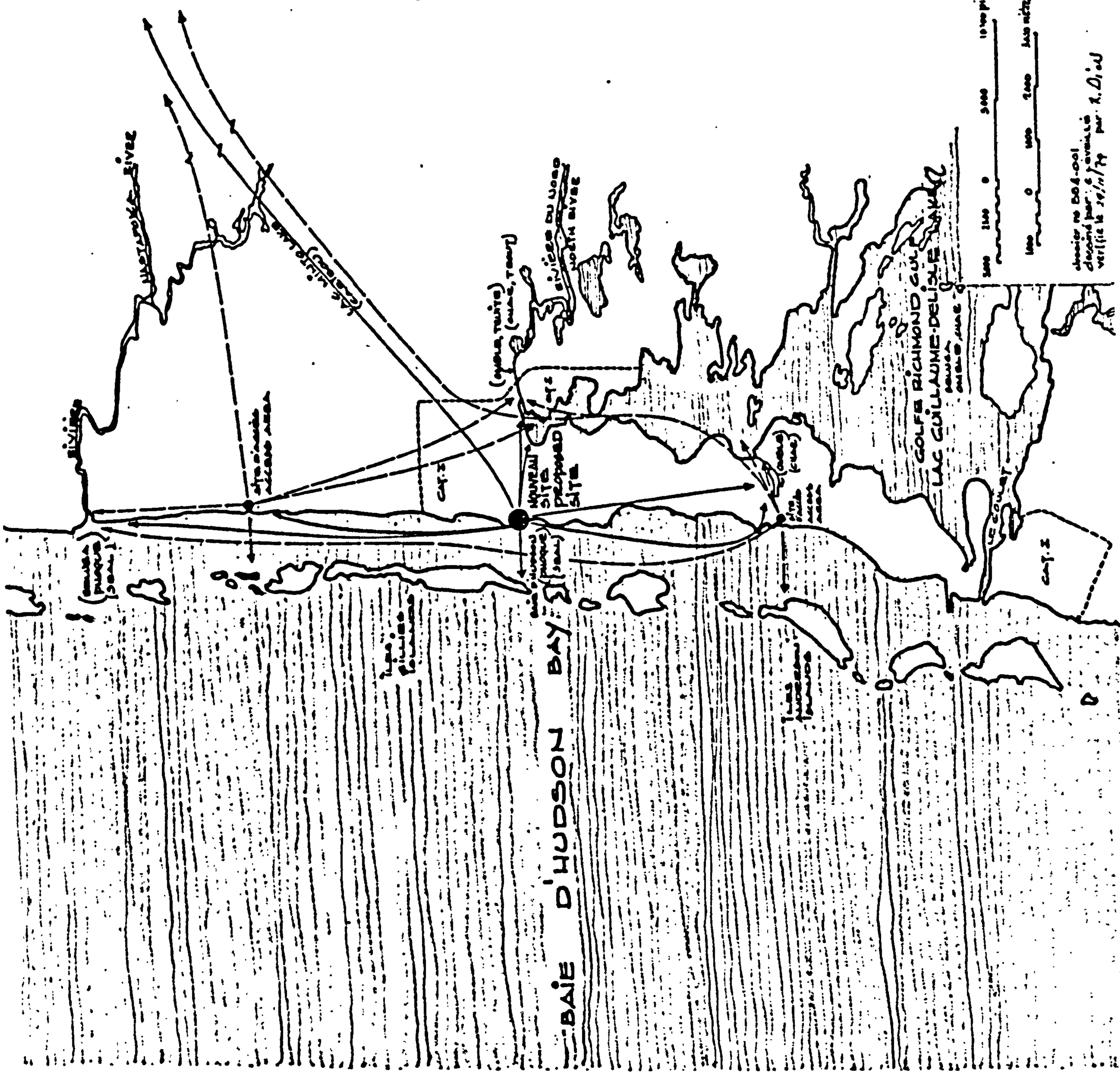
Map 1. Example of a plan for Richmond Gulf generated by Inuit (Pluram, 1979).

APPENDIX III-B



Map 2. Example of a plan for Richmond Gulf generated by Inuit (Pluram, 1979).

APPENDIX III-C



Map 3. Plan of Richmond Gulf Region showing off-shore islands (Pluram, 1979).