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SNOW MOVEMENT-DRIFT CONTROL FOR AT-GRADE CAMPS

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Naval Civil Engineering Laboratory
Port Hueneme, California

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Technical Report

SNOW MOVEMENT–DRIFT CONTROL FOR AT-GRADE CAMPS

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SNOW MOVEMENT–DRIFT CONTROL FOR AT-GRADE CAMPS

Technical Report R-578

Y-F015-23-01-003

by

N. S. Stehle

ABSTRACT

Snow movement in polar areas creates logistical problems for at-grade, or surface, camps in areas of positive snow accumulation. Snow drift studies, which were made over a 4-year period around a single unprotected building and around a cluster of buildings in an area of positive snow accumulation on the Ross Ice Shelf near McMurdo Station, Antarctica, showed that at-grade camps will eventually become covered with drifting snow. Drift control measures, however, can be used to increase the usefulness of such camps.

The drift control measures developed in this report, which cover proper building orientation and camp layout with respect to the major storm winds, can be used to improve access and reduce maintenance for at-grade camps in areas of drifting snow. In addition, mobile foundations should be used for all buildings to facilitate camp moves when snowdrift becomes excessive, and small camps should be built on elevated snow platforms to extend their useful life.

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EVALUATION SHEET

Technical Report R-578

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Author N. S. Stehle

Task No. Y-F015-23-01-003

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INTRODUCTION

Drifting snow is a particularly critical problem in polar areas where there is no depletion of the annual supply of snow. The snow accumulates both uniformly and in drifts around any obstruction.[1,2] In the past, the snow has been allowed to bury at-grade, or surface, camps, but this presents problems of hampered access, added weight on the structures, and curtailed ventilation. In addition, some specialized buildings must be maintained free of snow. In order to study the problem of minimizing drift in at-grade camps, measurements were made around an unprotected building and on clusters of buildings on the Ross Ice Shelf at the NCEL camp from 1962 to 1967, and at the Williams Field camp[3,4,5,6] from 1965 to 1967. The results of this study show that although at-grade camps eventually become covered with snow, their usefulness can be increased by exercising certain drift control measures.

LOCATION

During these studies, the NCEL antarctic camp was located at the western extremity of the Ross Ice Shelf (Figure 1), about 3 miles south of McMurdo Station and Scott Base, which are situated on Ross Island. Williams Field lies to the east and McMurdo Sound to the west of the NCEL camp.

The climate of the McMurdo Sound region is characterized by low temperatures, frequent high winds, and drifting snow. At the NCEL and Williams Field camps, the prevailing winds are from the east, the major summer storm winds are from the south, and major winter storm winds are from the southeast. Over a period of 9 years, the average wind velocity was 13 knots, and the high daily average wind was 26 knots. The average annual snow accumulation was 0.9 foot per year during this period of observation.

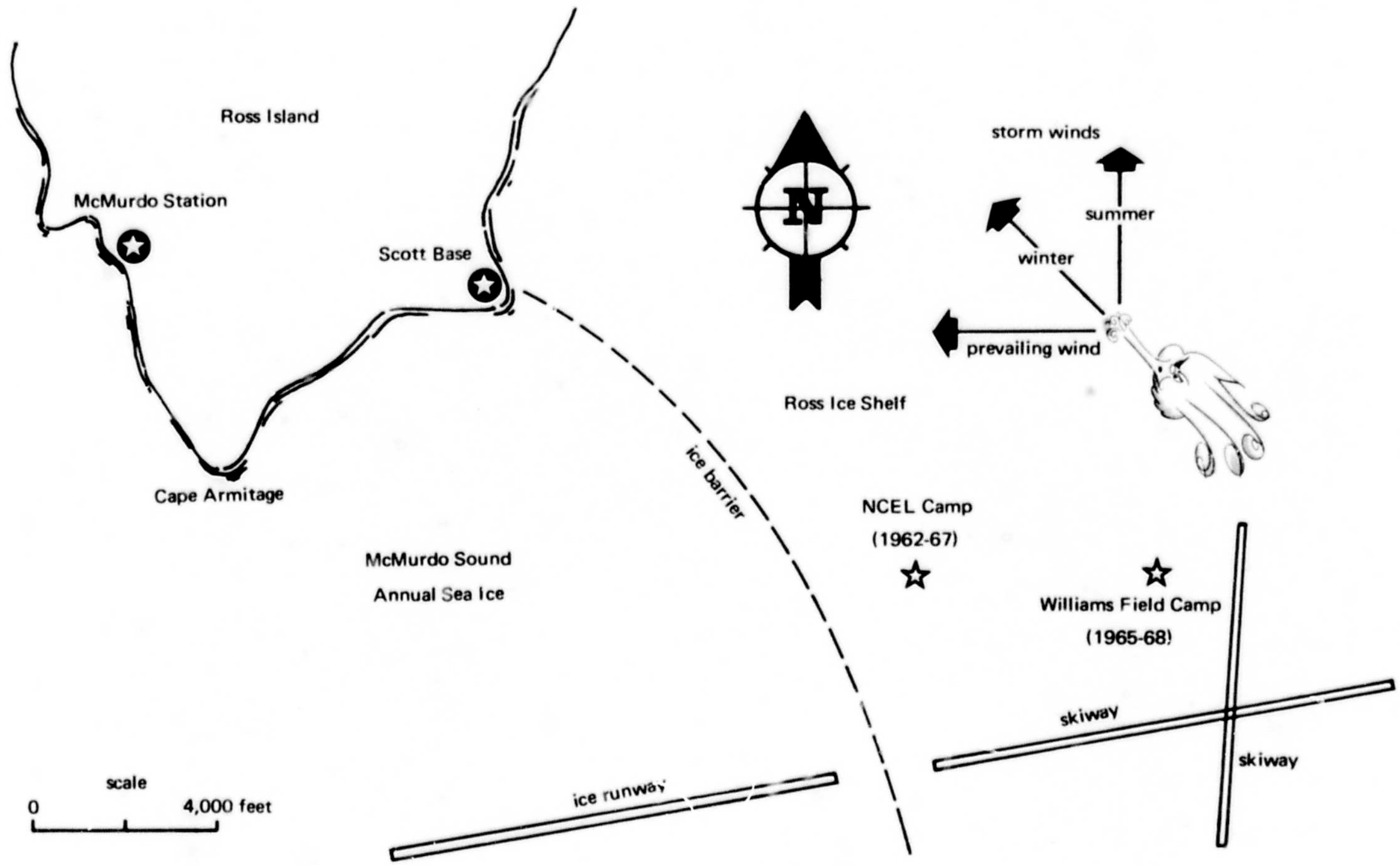

Figure 1. Map of McMurdo Area, Antarctica.

OBSERVATIONS

Protected Cluster of Buildings

During the austral summer of 1962-63, the major portion of the NCEL camp was constructed on a leveled, compacted, at-grade snow site on the Ross Ice Shelf (Figure 1). By January the camp consisted of a 16- by 32-foot Jamesway parallel with a 16- by 60-foot Jamesway, a 3- by 3-foot head, and two 8- by 20-foot wanigans. All rectangular buildings were oriented north-south, with the long axis parallel with the storm wind (Figure 2). Each Jamesway, in addition to the endwall entrances, had a sidewall entrance.

A 5-1/2-foot-high U-shaped snow wall, which was constructed upwind, reduced drift accumulation in the camp that summer. In February 1963, this wall was extended and widened to 12 feet on the sides for storage of equipment. In addition, two triangular-shaped, 5-1/2-foot-high secondary snow walls were built 100 and 200 feet upwind of this main wall; the outer one extended 200 feet either side of center, and the inner one about 100 feet either side. The grouping of the buildings behind the snow wall was designed to observe drift in a protected cluster of buildings.

After 1 Year. By November 1963, at the end of the first year, snow had drifted between the Jamesways to a depth of about 6 feet, and extended to the top of the entrance vestibules at the northeast end of both buildings (Figure 3). Drift snow was about 5 feet deep on the north end and east side of the buildings, with less than 2 feet on the south end and less than 1 foot on the west side. The area immediately adjacent to the south end of both buildings was scoured clear. After clearing the drift, the camp courtyard was about 2 feet below the natural snow surface. The snow around the Jamesways was cleared out early in November 1963, and the camp modified to consist of the following structures (Figure 2):

Two 16- by 64-foot Jamesways

One 16- by 56-foot Jamesway

Two 8- by 20-foot wanigans

One 3- by 3-foot head

In February 1964 the main 1963 drift wall was increased in height from 5-1/2 to 8 feet, and extended westward. In addition, two new 8-foot-high secondary walls were built upwind.

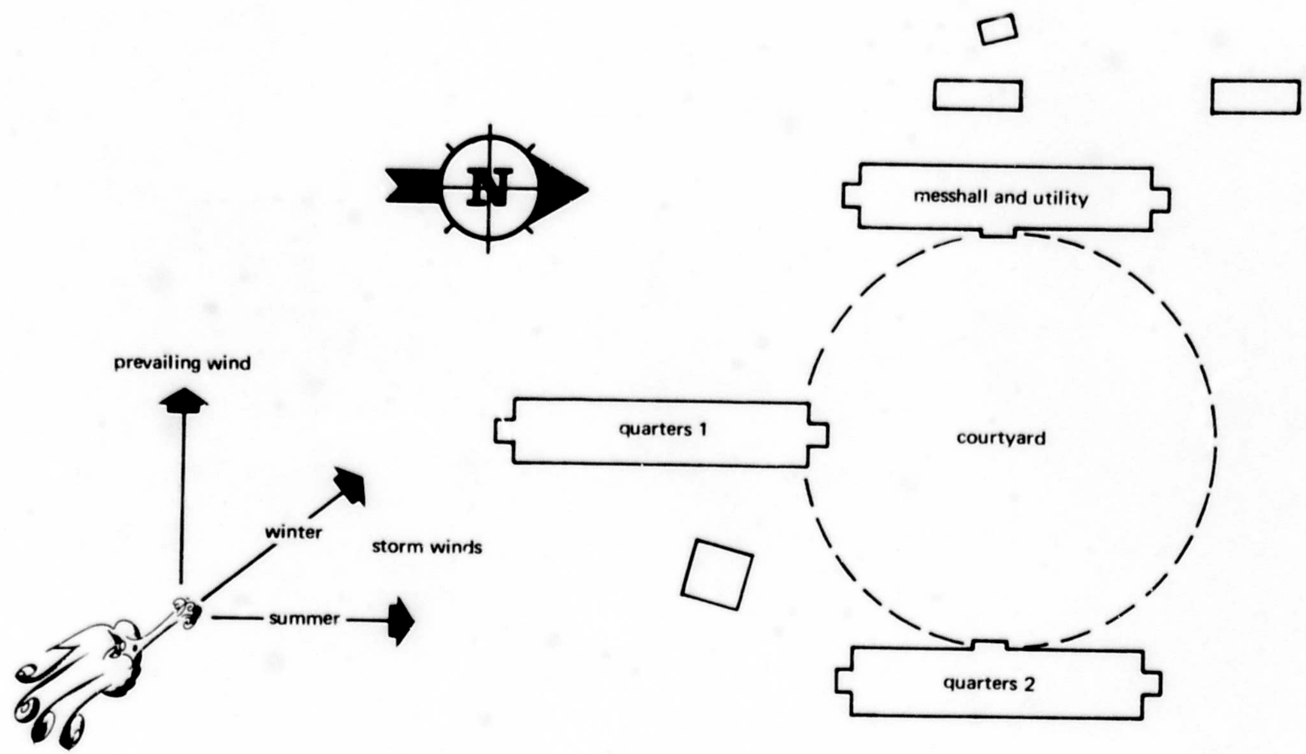

Figure 2. General NCEL camp layout as of November 1963.

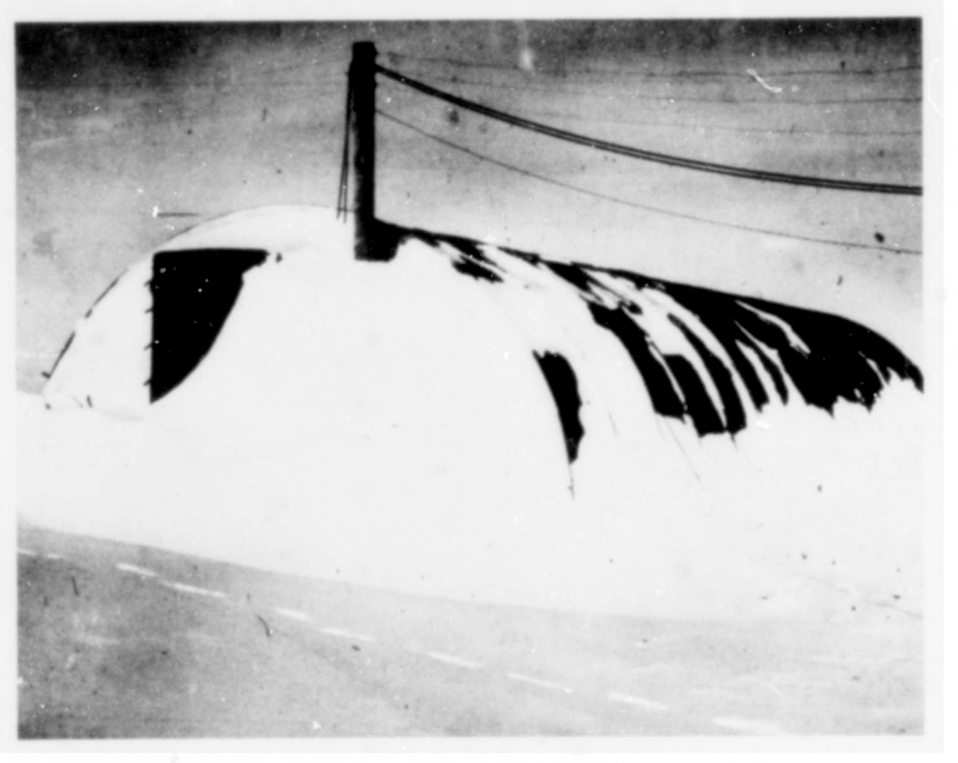

Figure 3. Snow drifted around the northern end of quarters 1 Jamesway after 1 year of accumulation (looking south).

After 2 Years. At the end of the second year, November 1964, drift had accumulated on both sides of the eastern end of the main drift wall and filled the courtyard with 7 feet of snow (Figure 4). Two feet of snow had accumulated between the buildings and the western end of the main wall and between the walls south of camp. Behind the main wall, the drift increased from 4 feet near the foot of the wall to 7 feet behind the building. In November 1964, 4,500 cubic yards of snow were cleared from the camp; about one-third was pushed over the main snow wall, and the rest was pushed out behind the camp. This left the camp 4 to 5 feet below the natural snow surface. Clearing of the camp was required after every storm during this third summer (1964-65); up to 1,500 cubic yards of snow accumulated during each storm. This snow was pushed out behind the camp. During this summer the endwall entrances could not be used unless dug out after every storm; consequently, only the sidewall entrances were used. By February 1965 the camp was 5 feet below the natural snow surface.

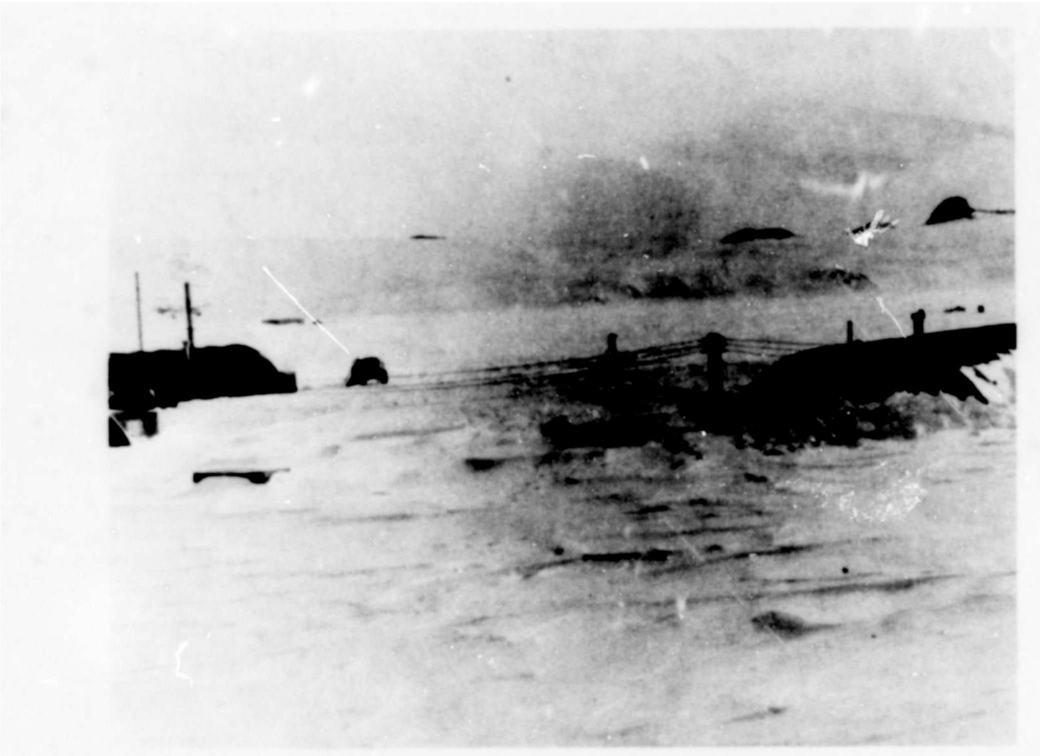

Figure 4. NCEL camp showing drift between quarters 1 and 2 after 2 years of drift accumulation (looking north).

After 3 Years. By November 1965, at the end of the third year, snowdrifts 6 to 10 feet deep covered the courtyard formed by the three Jamesways. The snow surface was 18 to 24 inches below the tops of the Jamesways (Figure 5) and completely covered the head. The 1964 snow walls were only faintly visible to the east of the camp. A small, relatively deep depression was cleared in the courtyard by the removal of 3,000 cubic yards of snow. Each storm drifted this depression with as much as two-thirds of what had originally been removed. Although the area cleared was smaller than the previous year, drifting during summer storms deposited more snow.

To help alleviate this situation, a trench parallel to the storm winds was excavated in the courtyard (Figure 6). This acted as a venturi and reduced drift accumulation in camp. By February 1966 the camp, except for one wanigan and the head, was about 7 feet below the natural snow surface; these two buildings had been relocated at-grade in January 1966. The floors in the remaining camp buildings were 1 to 3 feet below the snow level in the courtyard. During the rest of January and February 1966, any drifting which occurred in this area was cleared away so that by late February the camp area looked essentially like Figure 6.

Figure 5. NCEL camp after 3 years of drift accumulation (looking west).

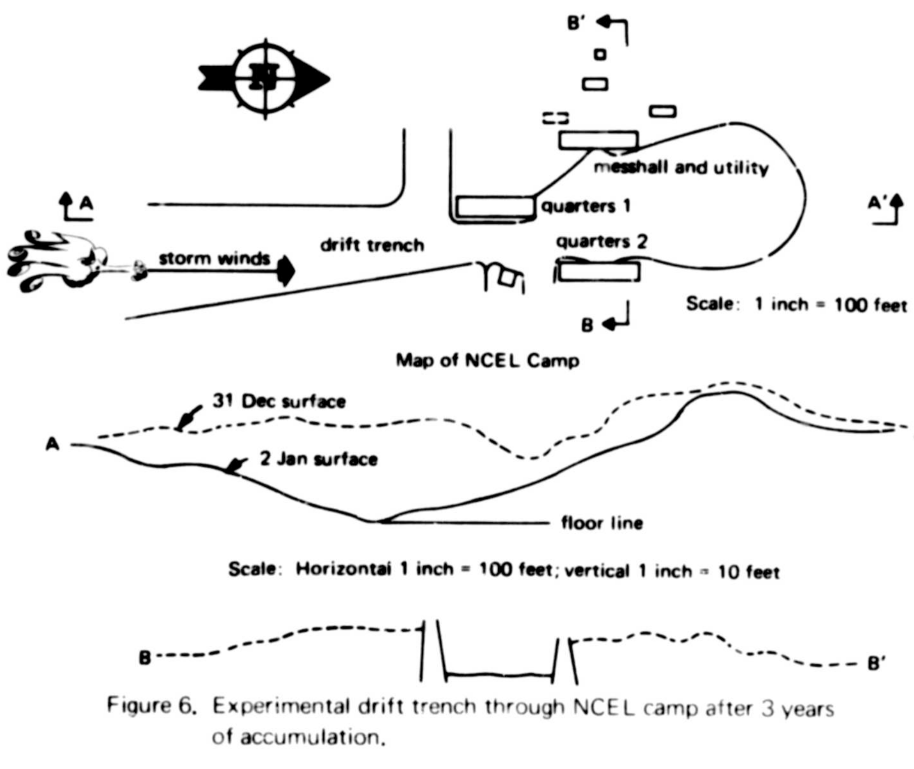

Figure 6. Experimental drift trench through NCEL camp after 3 years of accumulation.

After 4 Years. At the end of the fourth year in mid-October 1966, the NCEL camp was inundated with snow to the ridge of all three Jamesways in the main camp complex, a depth of about 10 feet. To open the camp for the DF-67 season, a north-south V-shaped trench parallel to the storm wind was cut level with the floor line between the two facing Jamesways: Quarters 2 and the utility building. Each end of the V-shaped trench extended up and out of the camp a distance of about 100 feet. The snow from the trench was feathered out around the camp area. Although succeeding storms deposited drift in the upwind end of the trench, none was of sufficient duration to cause drifting in the camp courtyard. Following each storm, the drift was dozed out of the upwind portion of the trench and feathered over the surface around the camp. Figure 7 shows drift around the camp buildings and storm drift in the upwind end of the trench prior to clearing.

Figure 7. NCEL camp after 4 years of drift accumulation; note upwind portion of the trench to right of Jamesway (looking south).

Because of the complete inundation of the camp, it was moved to a new location in December 1966, thus terminating observations on this at-grade cluster of buildings.

Unprotected Cluster of Buildings

The Williams Field camp, which was erected in its present location (Figure 1) in September 1965, consists of three rows of Jamesways, with 8 to 10 Jamesways in each row (Figure 8). All buildings are oriented with their long axis perpendicular to the major storm winds. In late February 1966 all of the buildings in the Williams Field camp were 1 to 2 feet above the surrounding surface due to ablation of the surrounding snow.

After 1 Year. In early October 1966, at the end of 1 year, the buildings along the south, or storm-wind side, of the Williams Field camp were covered with drift snow almost to the ridge line along the south side, and the floors in these buildings were several feet below the snow surface on the north side of the buildings (Figure 9). The snow surface was about level with the floor of the buildings along the north end of the camp. By mid-February 1967, ablation of the snow in the trafficked areas had reduced the snow level near entrances and in roadways 1 to 2 feet.

After 2 Years. By the end of the second year, October 1967, the buildings along the storm-wind side were covered with drift snow to within a foot or less of the ridge line (Figure 9). The other buildings in camp were 3 to 6 feet below the snow surface. Depth of burial of the camp averaged about 6 feet (Figure 10).

Single Unprotected Building

In late January 1963 a 28- by 56-foot T5M shop building was erected on an at-grade compacted-snow mat; the long axis was oriented north-south, parallel with the southerly storm winds. This building was situated on the snow surface 0.4 mile northeast of the NCEL camp in order to observe drift around a single, large unprotected building

After 1 Year. Maximum drift accumulation occurred during the winter on the north, or leeward, end, and on the west side. At the end of the first year, November 1963, the north end was drifted to roof height for about 8 feet from the building (Figure 11). Drifts formed 3-1/2 feet high on the west side, 2 feet high on the south end, and 1 foot high on the east side, up to 10 feet from the building. By February 1964 only the snow from the north end had been removed and feathered out to provide access to the building.

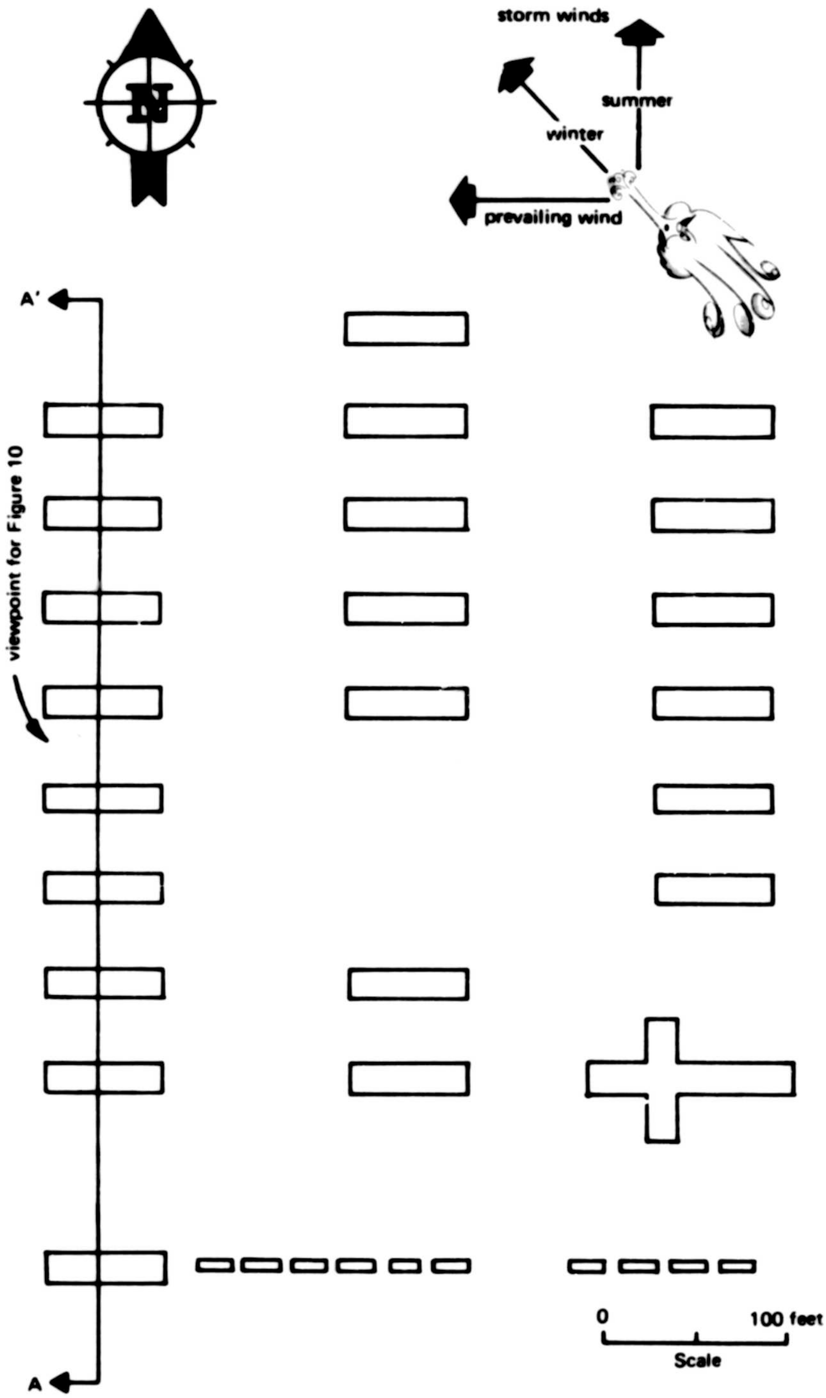

Figure 8. Plan view of Williams Field camp as of October 1965. Cross section A-A' shown in Figure 9.

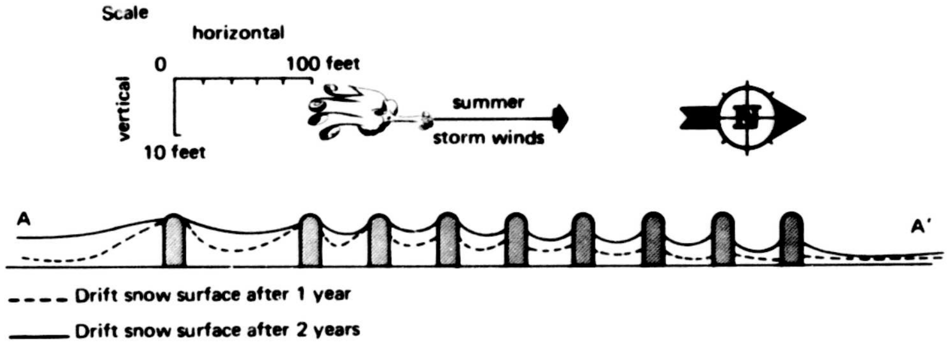

Figure 9. Generalized cross section of Williams Field camp showing drift snow accumulation after 1 and 2 years of accumulation (see Figure 8 for location of cross section).

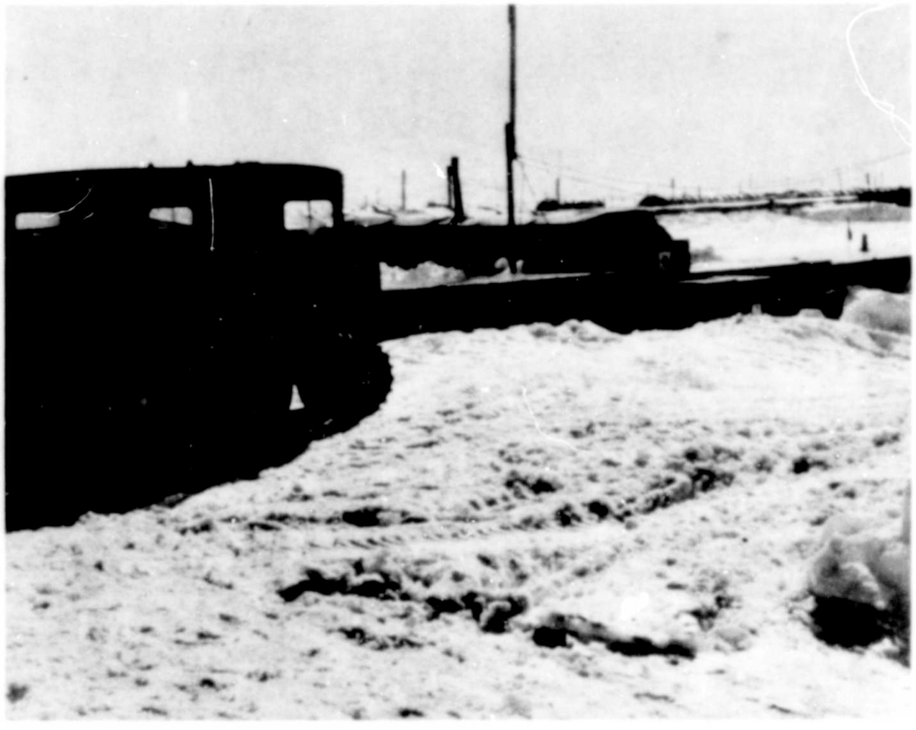

Figure 10. Drift snow in Williams Field camp after 2 years of accumulation; looking northeast along western edge of camp. (See Figure 8 for location.)

Figure 11. Drift snow around the NCEL T5M shop building after 1 year of accumulation (looking south).

After 2 Years. By November 1964, at the end of the second year, drift snow on the north end and west side had increased to the roof, filling the previously drift-free space between the 1963 drift and the building (Figure 12). All of the previously drift-free areas next to the building were filled with snow except for a small area near the southeast corner. In February 1965 all accumulated drift snow was cleared from around the T5M and was feathered out across the surrounding surface, leaving the building in a depression about 6 feet below the adjacent surface.

After 3 Years. By the end of the third year, October 1965 (Figure 13), the floor of the building was 7 to 8 feet below the surrounding snow surface, and the depression surrounding the building had filled in with 3 to 6 feet of snow 2 to 15 feet from the building. No snow was removed from around the building except to provide access.

After 4 Years. By mid-October of the fourth year, 1966, the T5M was inundated with snow to the eave line, a depth of about 14 feet (Figure 14). The north, or down-storm wind, end was cleared of snow, which was feathered out.

Observations on this single at-grade building were terminated in January 1967, when the T5M was dismantled and moved to a new location.

Figure 12. Drift snow around the T5M shop after 2 years of accumulation (looking south).

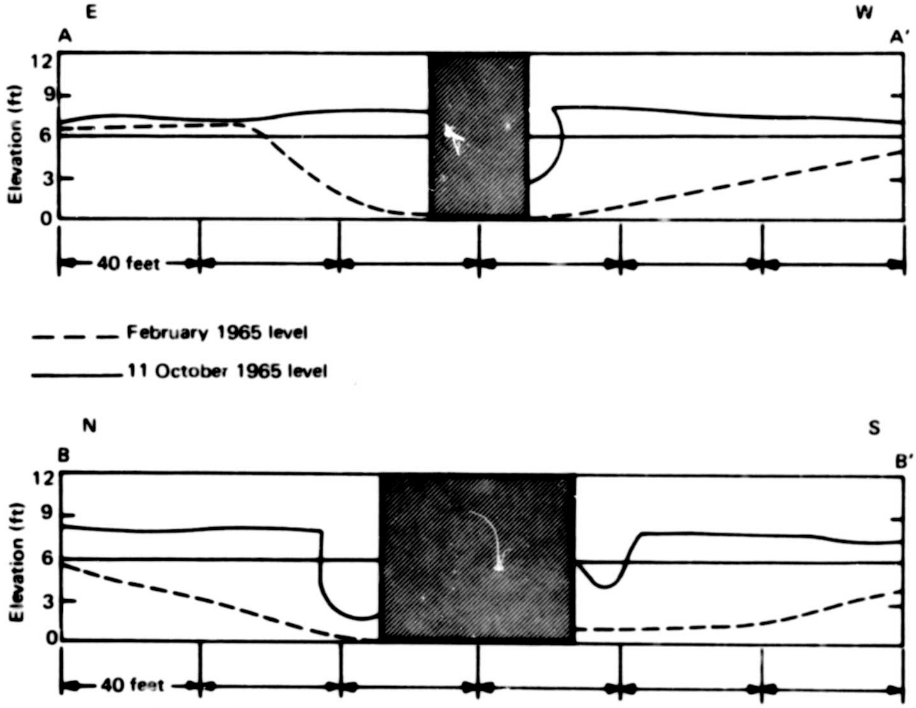

Figure 13. Profile of shop area after 3 years of accumulation.

Figure 14. Drift around T5M after 4 years of accumulation; the area in front of the doors has been cleared (looking south).

COMPARISON OF RATES

In comparing the amount of drift at the end of the first year of exposure, the three different building arrangements show distinct differences in drift accumulation (Figure 15). The snow berms upwind of the NCEL camp protected the camp buildings such that they accumulated only about 2 feet of drift (Figure 2) as opposed to the unprotected buildings of Williams Field which average about 3 feet of drift (Figure 9). In addition, the upwind buildings at Williams Field were almost completely inundated with snow. About 3 feet of drift also accumulated around the unprotected T5M shop building (Figure 11). The snow walls provided protection only during the first year.

In order to provide access to the NCEL camp buildings after only 2 years of accumulation (November 1964), 4,500 cubic yards of snow had to be moved. Drift snow continued to accumulate in this cleared area so that an additional 1,500 cubic yards had to be removed after every storm. Clearing was again required at the end of the third year (October 1965). At that time, however, a smaller, relatively deep depression was cleared and only 3,000 cubic yards were removed. Because of the greater depth of the cleared area, two-thirds of the depression was filled with snow after each storm, as opposed to one-third the previous year; this required the removal of 2,000 cubic yards after every storm.

After 4 years of exposure the NCEL camp and the T5M were completely covered with snow (Figures 7 and 14), although only about 4 feet of snow had accumulated on the surrounding natural surface. From Figure 15 it is apparent that the drift accumulation around the T5M during the fourth year was as great as that of the first 2 years combined, but the rate of accumulation during this time around the initially protected cluster of buildings was quite uniform. Even though the T5M shop building was 4 feet higher than the buildings in the NCEL camp, it was nearly covered with snow in the same 4-year period.

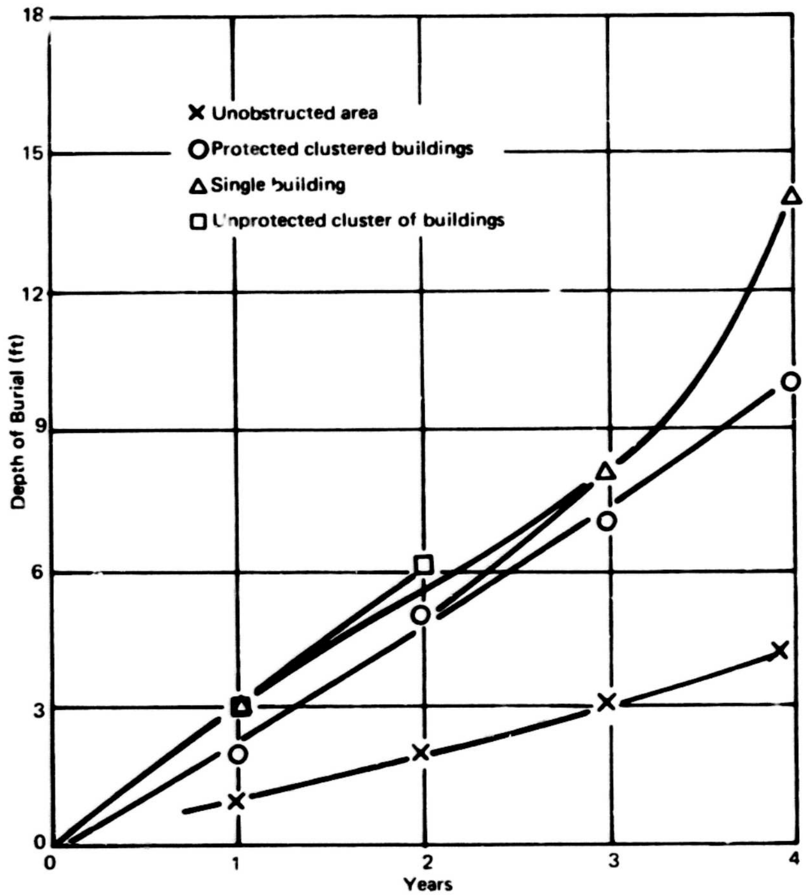

Figure 15. Average drift on an unobstructed area, around a single unprotected building, and around a cluster of buildings.

The total depth of drift around each of the building arrangements maintained approximately the same relationship to the total natural accumulation throughout the test period. Table 1 shows that the drift in the unprotected cluster of buildings and around the single building was about 3 times the total natural accumulation for each year, whereas the protected cluster started with about 2 times the drift during the first year and increased to about 2-1/2 times by the fourth year.

Table 1. Total Drift Accumulation Around Three Building Arrangements as Compared to the Total Natural Accumulation

Year	Total Natural Accumulation (ft)	Protected Cluster		Single Building		Unprotected Cluster	
		Total Drift (ft)	Increase Over Natural (times)	Total Drift (ft)	Increase Over Natural (times)	Total Drift (ft)	Increase Over Natural (times)
1	1	2.2	2.2	3	3	3	3
2	2	4.6	2.3	5.5	2.7	6	3
3	3	7.2	2.4	8.1	2.7	–	–
4	4	10	2.5	14	3.5	–	–

In the McMurdo area, where the average annual snow accumulation is about 1 foot per year, single buildings and camps become completely inundated with snow within 4 years. Precise information on drift accumulation around buildings versus annual accumulation is available only for the McMurdo area. However, general observations indicate that other coastal and some inland locations in Antarctica with greater annual snow accumulation, such as Little America Station, become covered within 2 years. Other inland areas, where the annual snow accumulation is less, drift in more slowly.

As pointed out by Moser[7] and later confirmed by Reese,[8] and by Roots and Swithinbank,[9] drift around buildings can be minimized by avoiding the coalescence of drift; this can be accomplished by placing the buildings in a line perpendicular to the storm wind because major drifts form down-wind. Buildings oriented with their long axis perpendicular to the wind form a short drift the length of the building on the leeward side; those oriented with the long axis parallel to the storm wind form a long, narrow shallower drift on the leeward side. Consequently, drift in the NCEL camp could have been lessened if the three Jamesways (Figure 2) had been aligned perpendicular to the storm wind rather than with the central one offset upwind. This building caused the drift which normally accumulates downwind to form between the other two buildings. The smaller buildings should also have been set to the side rather than upwind in order to prevent drift around them from accumulating around other buildings.

Drift accumulation in the Williams Field camp also was accentuated by arrangement of buildings (Figure 8). Nearly complete burial of the windward buildings occurred because they were placed with the long axis perpendicular to the storm winds. Distance between buildings was such that the short, deep leeward drifts from the upwind building coalesced with drift on the windward side of the downwind building (Figure 9).

Drift accumulation was greater in the Williams Field camp during this first year than in the NCEL camp because Williams Field was completely unprotected, the buildings were downwind of others, and each building was oriented so the long axis was perpendicular to the storm winds. As the windward buildings at Williams Field are buried and present a smooth surface, the buildings downwind will become further drifted in.

The amount of drift accumulation could have been decreased considerably at Williams Field by rotating the camp layout 90 degrees (Figure 16). With such a layout, the three long rows of buildings would be perpendicular to the storm winds, with the long axis of each building parallel with the storm wind. In addition, the ends of the buildings in each row should be placed close together as in a train, and the camp roadways should parallel the long axis of the buildings. To provide access with such a plan, all buildings would need sidewall entries, since the ends would be drifted in.

RELATED RESEARCH

Preliminary scale model tests[10] in the NCEL wind duct have shown that several years of accumulation can be simulated in a few hours, and that the rate of drift accumulation around the types of at-grade polar buildings presently in use can be reduced by orienting them 45 degrees to the storm wind. These tests have also shown that buildings elevated on solid platforms 2 to 4 feet above the surrounding surface have much less drift than when directly on the surface.

Field studies of drift around elevated roads and storage areas[1, 11] have shown that drift is minimal until the surface of the surrounding area becomes level with the elevated area. The length of time it is drift-free depends on the initial elevation and the rate of annual snow accumulation.

To elevate a camp of three Jamesways and associated buildings similar to the NCEL camp would require a 300- by 100-foot area about 4 feet high, or 4,500 cubic yards of snow. This is a reasonable amount of snow to move considering that 4,500 cubic yards had to be moved to clear the courtyard of the NCEL camp after two years of exposure, particularly since elevating would increase the life of the camp by at least one year. To elevate a camp the size of Williams Field camp, however, would require an area 500 by 620 feet, 4 feet high; this amounts to 45,000 cubic yards of snow or 10 times the amount for the NCEL camp. Not only would this take longer but snow would have to be transported farther. Consequently, size would definitely limit the feasibility of elevating surface camps.

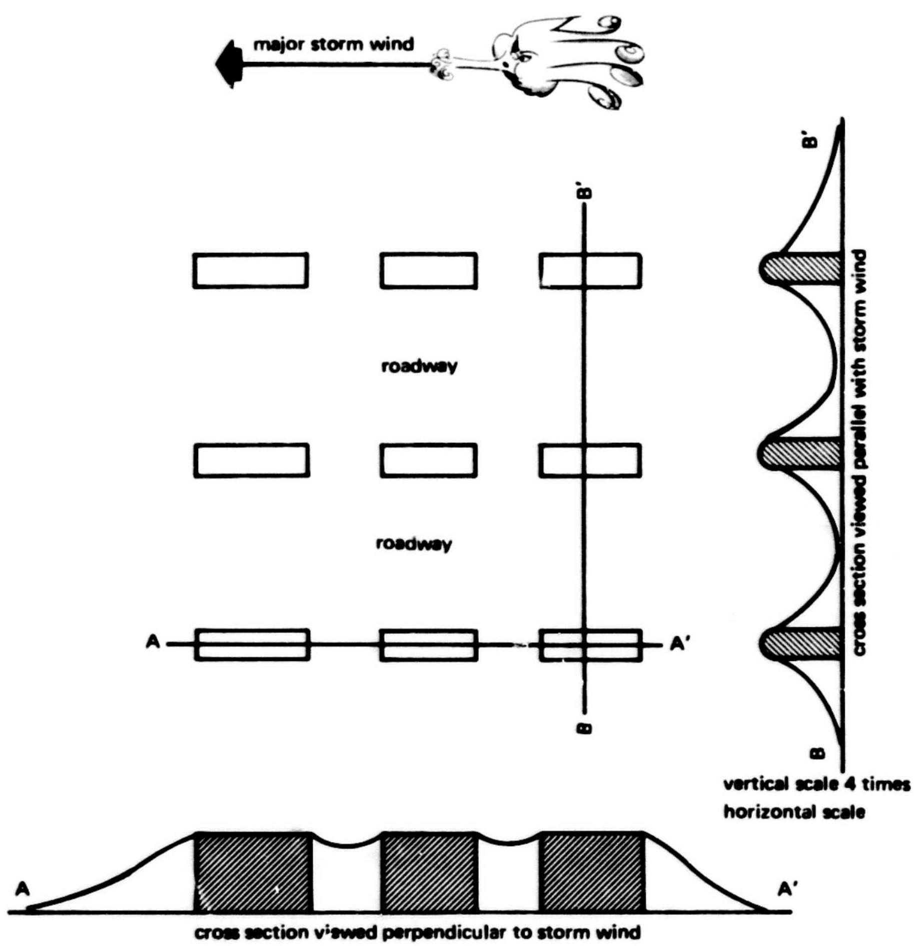

Figure 16. Illustrative layout of multi-building camp and expected drift pattern.

Ordinarily, when a Jamesway building is relocated, it must be completely disassembled, regardless of the distance to be moved. When the labor involved in this is compared with the labor to keep a camp accessible, there is little justification for moving the camp any sooner than is necessary. To provide a rapid means for relocating completely assembled Jamesway buildings in the same general area, NCEL developed a mobile foundation[12, 13] for Jamesways up to 64 feet long. Relocation of a Jamesway erected on such a mobile foundation can be made at any time with minimum manpower, lost-time occupancy, and building damage. Foundations of this type could also be used with other polar buildings.

DRIFT CONTROL MEASURES

Regardless of the size of a camp located in an area of drifting snow, the following measures should be used to minimize drift and to make relocation as easy as possible:

1. Orient the buildings 45 degrees to the summer storm wind with the long axis parallel to the winter storm wind where these directions are 45 degrees apart, as in the McMurdo area. Elsewhere, approach this arrangement as closely as possible.

2. Place the buildings in a line perpendicular to the winter storm wind sufficiently far apart to avoid coalescence of drift. 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.

3. Treat equipment and material as a separate line of buildings, placed far enough apart to prevent coalescence of drift.

4. Where at all possible, erect the buildings on mobile foundations so that they can be easily moved when drift becomes a problem.

5. Because a building is an obstacle to the wind, each will accumulate drift snow and some clearing will be necessary. Consequently, arrange the buildings so that there is sufficient room to permit easy clearing.

Small camps should be elevated on snow platforms when 5,000 cubic yards or less of snow are required to build the platform. In addition to the above drift control measures, the following measures should also be observed when setting up an elevated camp:

1. The platform should be constructed about 4 feet above the surrounding snow surface for a 2-year life in an area with an annual accumulation of snow of 1 foot or less; where accumulation is greater, the elevation will have to be greater or the life expectancy will be less.

2. Drift accumulation will increase downwind of an elevated camp; therefore, other buildings or supplies should not be located in close proximity downwind of an elevated area.

FINDINGS

1. In areas of positive snow accumulation, at-grade, or surface, buildings eventually become covered with drifting snow, with the length of time depending on the rate of annual accumulation.

2. Drift accumulation around the at-grade buildings on the snowfields around McMurdo Station, Antarctica, can be controlled sufficiently to permit easy access with a minimum of snow removal for periods up to 3 years; the effectiveness of such control for at-grade buildings at other Antarctic locations depends on the rate of annual snow accumulation at specific locations.

3. Drift control measures developed in this report for at-grade buildings in areas of positive snow accumulation cover:

a. Proper orientation of the buildings with respect to the direction of the major storm winds.

b. Arrangement of the buildings, supplies, and equipment to prevent coalescence of drifts.

4. Mobile foundations for at-grade buildings on drifting snowfields can be used to facilitate movement of these buildings when the accumulated drift becomes unmanageable.

5. The useful life of small at-grade camps on snow can be extended economically up to 2 years by erecting such camps on 4-foot-high snow platforms where the volume of snow required for the platform does not exceed 1 year's accumulation in the camp area, or about 5,000 cubic yards on the snowfields around McMurdo Station.

CONCLUSION

At-grade camps in areas of positive snow accumulation will eventually become covered with drifting snow, but use of drift control measures will increase the usefulness of such camps.

RECOMMENDATIONS

1. The drift control measures developed in this report, which include proper building orientation and camp layout with respect to major storm winds, should be used to improve access and reduce maintenance for at-grade camps on drifting snowfields.

2. Mobile foundations should be used for all buildings to facilitate camp moves because of excessive snowdrift.

3. Small camps should be built on elevated snow platforms to extend their useful life.

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Naval Facilities Engineering Command, Washington, D. C.

13. ABSTRACT

Snow movement in polar areas creates logistical problems for at-grade, or surface, camps in areas of positive snow accumulation. Snow drift studies, which were made over a 4-year period around a single unprotected building and around a cluster of buildings in an area of positive snow accumulation on the Ross Ice Shelf near McMurdo Station, Antarctica, showed that at-grade camps will eventually become covered with drifting snow. Drift control measures, however, can be used to increase the usefulness of such camps.

The drift control measures developed in this report, which cover proper building orientation and camp layout with respect to the major storm winds, can be used to improve access and reduce maintenance for at-grade camps in areas of drifting snow. In addition, mobile foundations should be used for all buildings to facilitate camp moves when snowdrift becomes excessive, and small camps should be built on elevated snow platforms to extend their useful life.

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