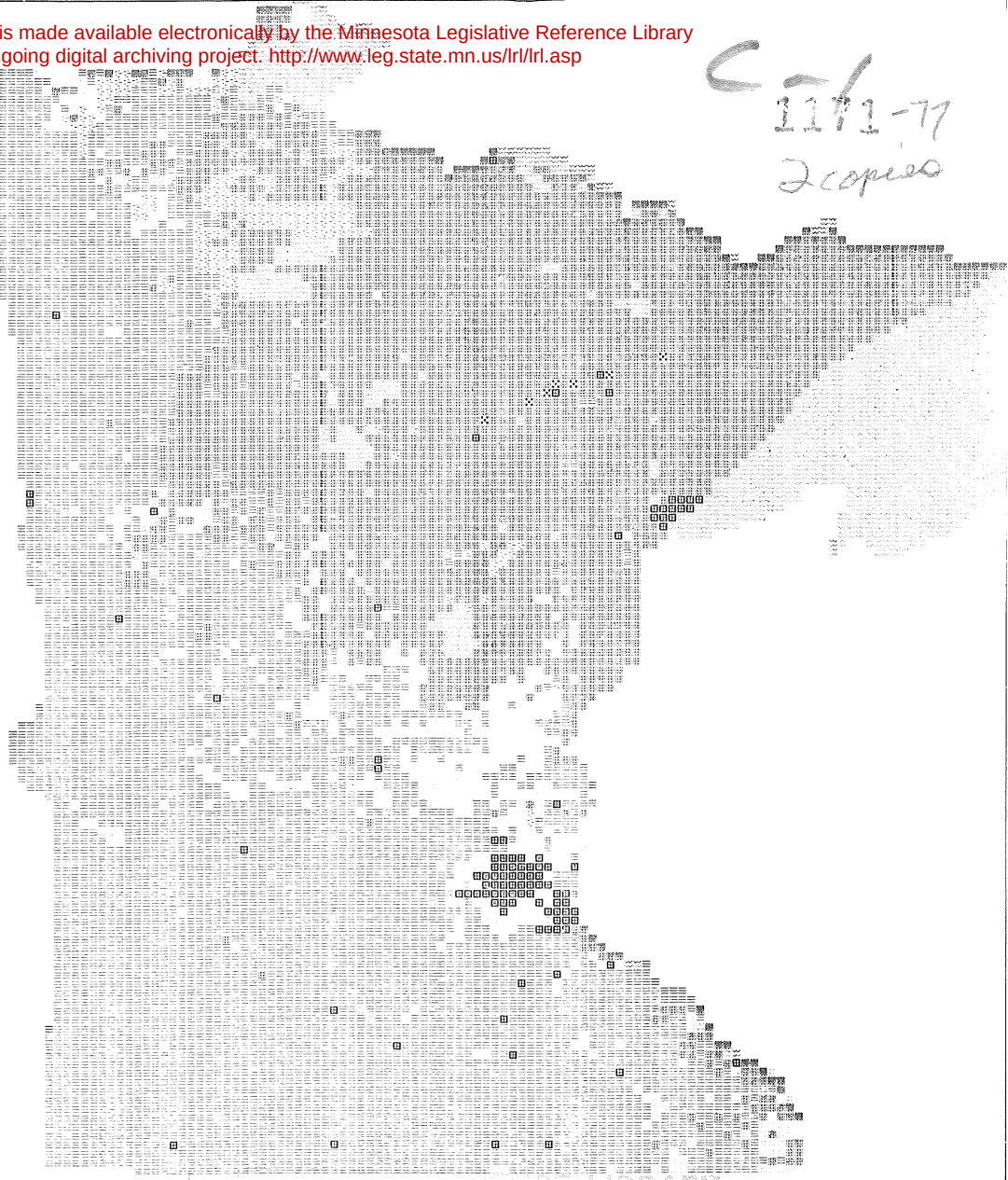
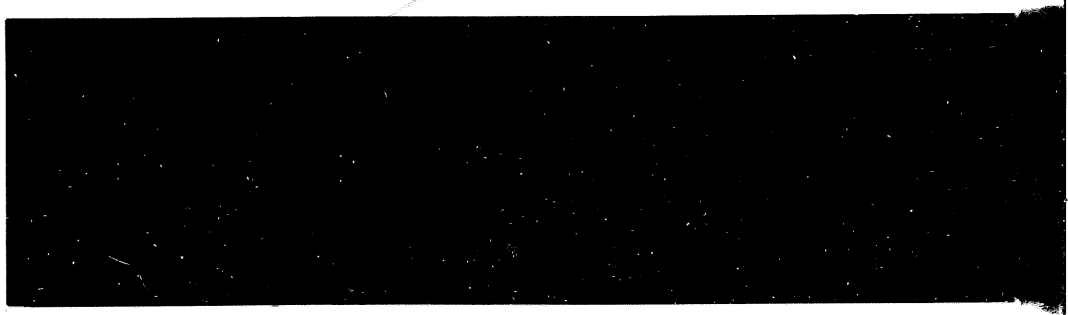
MLMIS





MINNESOTA LAND MANAGEMENT INFORMATION SYSTEM

UNIVERSITY OF MINNESOTA
CENTER FOR URBAN AND REGIONAL AFFAIRS

STATE PLANNING AGENCY

LAND COVER CHANGE IN THE MESABI IRON RANGE 1969 - 1975

5020

DWIGHT BROWN
MARTIN ROLLER
JAMES KENNA
JOHN SMILEY
LETITIA CAVALIER

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PURPOSE AND SCOPE

The Mesabi Iron Range area land cover is the most drastically dynamic in Minnesota. Changes are dominantly associated with the extraction of iron ore and ancillary facilities. A typical cycle of change includes: clearing associated with exploration, clearing prior to pit excavation, and/or construction of a tailings basin, excavation and/or dumping, and finally revegetation or inundation of abandoned mine features.

The purpose of this report is to explore the significance of annual changes on the land cover map and to evaluate the application of LANDSAT image analysis for mapping these changes at topographic map scale for the 28 quadrangles covering the Mesabi Range (Figures 1 and 2). The Arrowhead Regional Development Commission (ARDC) provided guidance as to what content and which format would best satisfy their data needs for planning purposes.

METHODS AND PRODUCTS

The methods of interpretation and land cover change mapping used were taken from Brown, et.al.[1]

Quadrangle centered Ektachrome slides were copied from back lighted 1:1,000,000 scale LANDSAT MSS system corrected color transparencies using a single lens reflex camera fitted with an extension tube. The slides were projected on the wall and registered on each 1:24,000 scale quadrangle used as a base map. The slide to map registration procedure was greatly facilitated by using a remote focus, zoom lens slide projector and two person interpretation teams. All available non-winter time periods were used for 1972 through 1975.

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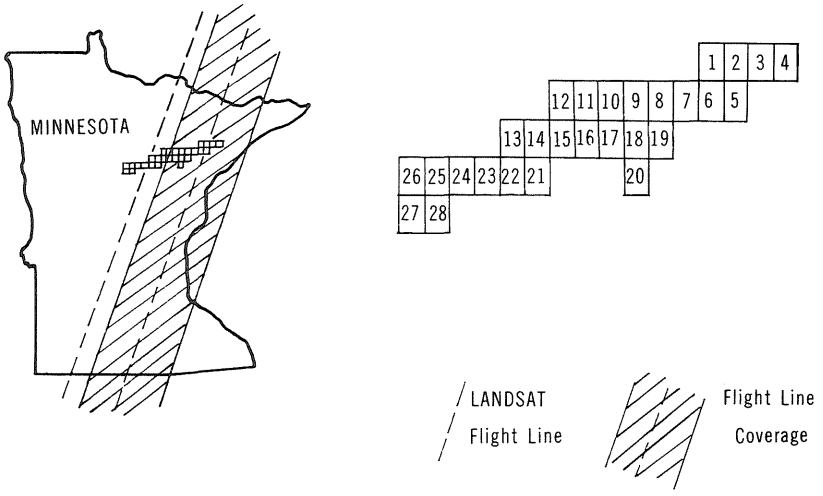
[1] Brown, D. A., Skaggs, R. H., Smiley, J. M., and Stern, E., Monitoring Surface Water Dynamics in Minnesota, Minnesota Land Management Information System Series #5014, University of Minnesota, 1975.



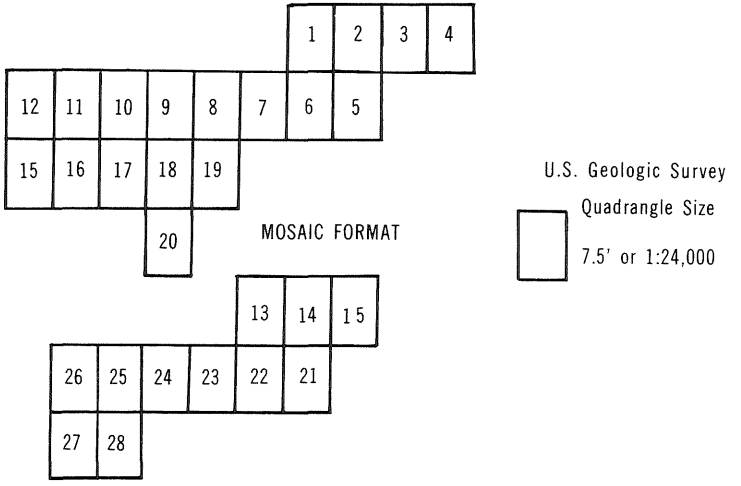
LANDSAT IMAGERY USED

7.3" Color Composite Film Positives

Scale 1:1000000

1972	1974	1975
1057-16311, 18 September	1652-16311, 6 May	2107-16195, 09 May
1973	1705-16235, 28 June	2125-16195, 27 May
	1706-16293, 29 June	2143-16200, 14 June
1255-16322, 4 April	1742-16282, 4 August	2180-16253, 21 July
1309-16313, 28 May	1795-16203, 26 September	2198-16250, 8 August
1345-16313, 3 July		

Figure 1. Location of Study Area. Mesabi Iron Range



1. Embarrass
2. Isaac Lake
3. Babbitt
4. Babbitt N.E.
5. Allen
6. Aurora
7. Biwabik
8. McKinley
9. Virginia
10. Kinney
11. Dewey Lake S.E.
12. Dewey Lake
13. Nashwauk
14. Keewatin
15. Hibbing
16. Buhl
17. Kirk
18. Eveleth
19. Gilbert
20. Zim
21. Silica
22. Pengilly
23. Calumet
24. Bovey
25. Cohasset East
26. Cohasset West
27. Siseebakwet Lake
28. Grand Rapids

Figure 2. Quadrangle Index

All of the U.S. Geological Survey topographic quadrangles used were photo revised in 1969 and provided the best recent topographic map scale portrayal of land cover in the Mesabi Range. These maps were used both as the mapping base and as the beginning time period for analysis. Starting with 1972 and continuing annually through 1975, land cover change was interpreted from 2" x 2" color slide copies of areas on LANDSAT 1 and 2 images that corresponded to each of the U.S.G.S. topographic quadrangles covering the Mesabi Range extractive activities.

Two person teams compiled the annual quad based overlays that were later assembled into a composite showing 1969 quad base cover and changes that were interpreted from analysis of images for 1972, 1973, 1974 and 1975. All available data on mining activity provided by mining companies and governmental agencies were used to train and guide interpreters. This included June, 1972 high altitude aerial Ektachrome infrared photography by NASA at scales of 1:120,000 and 1:60,000 for the central portion of the Mesabi Range. The composite maps yielded the basic data for magnitude of change calculations as well as the portrayal of the spatial pattern of change.

The composite of the time period changes were used to produce quadrangle scale overlay on a correctable double matte surface drafting film for each of the 28 1:24,000 quadrangles. These were intended for use by field personnel and designed to facilitate updating and correction with future satellite and field information. The reproduction costs prevented inclusion of these products in this report. For purposes of illustration, 1:62,500 scale photo reductions of these quads are included in Appendix I.

The 1:24,000 scale composites were also used as a data base for measuring change by class and by year. The gross characteristics of change are discussed in the section on analysis of change. A file describing individual parcels of land cover change has been created for use by the ARDC and the Minnesota Department of Natural Resources (DNR). These data are summarized for inclusion as Appendix II of this report which shows acreage and date of change by class of change for each quadrangle.

ANALYSIS OF CHANGE

Land cover of the 902,496 acre study area has undergone some significant changes in the 1969-1975 time period. Human disturbances of the presettlement land cover pattern of forests, lakes, and marshes has centered around iron ore extractive industries. Prior to European settlement of the study area less than 5 percent of the area was covered by lakes and marshes with the remainder forested. By 1969 about 60,000 acres or 6.5 percent had been changed to extractive industry and another 6 to 7 percent of the forest had been cleared for farm fields and other open land.[2]

Between 1969 and 1975 the expansion of the iron ore industry's extractive features, including pits, mine dumps, and tailings basins, have expanded by 9025 acres (Table 1). The 15 percent increase in extractive features needs to be added to the 10,843 acres of clearings and the 2,224 acres of water expansion in reservoirs and old mine pits during the same time period to fully appreciate the impact of iron ore resources use on land cover in the area. Although not all of the clearings are directly linked to future extractive industry, much is.

Not all of the Mesabi Range shares in this rapid rate of land cover change. In fact high rates of change are found in three areas.

The most dramatic land cover changes in the Mesabi Range have been in the heart of the Range in the Kinney - Virginia area (see Figure 3). The Kinney quadrangle surface cover has accounted for 26 percent of all changes in the 1969-1975 time period (Table 2). Second ranked in terms of surface cover change is the adjacent Virginia quadrangle with 8.1 percent of the Range's cover change. The major elements of change are a new pit and tailings basin associated with the development of the Minntac operation.

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[2] Based on calculations from MLMIS data presented in Borchert, J. R., 1974, Perspectives on Minnesota Land Use - 1974, Minnesota Land Management Information System Report Number 6, University of Minnesota.

MESABI IRON RANGE LAND COVER CHANGE

1969 - 1975

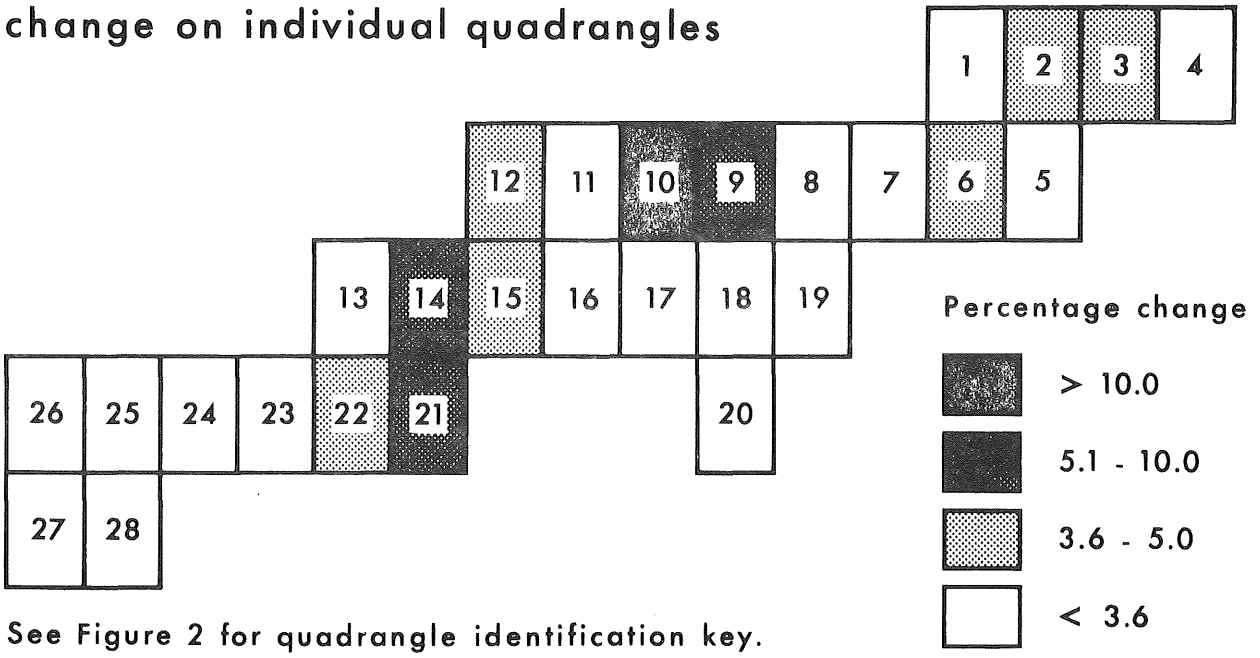
BY CLASS OF LAND COVER

Class	Acres
Iron Mine Pits	2,433
Iron Mine Dumps	1,770
Tailings Basin	4,822
Gravel Pits	114
Water Filled Pits and Reservoirs	2,224
Natural Lakes	56
Open Areas	10,843
TOTAL	22,262

TABLE 1

DISTRIBUTION OF MESABI RANGE LAND COVER CHANGE: 1969-1975

Percentage of total Mesabi Range change on individual quadrangles



See Figure 2 for quadrangle identification key.

FIGURE 3

ACREAGE OF LAND COVER CHANGE FOR THE TEN
MOST RAPIDLY CHANGING MESABI RANGE QUADRANGLES
1969 - 1975

Quadrangle	Acres of Change on Quad.	Percent of Total Mesabi Range Land Cover Change Accounted for by Quad.	
		On Quad.	Cummulative
Kinney	5,897	26.5	26.5
Virginia	1,725	7.7	34.2
Keewatin	1,675	7.5	41.7
Silica	1,575	7.1	48.8
Pengilly	939	4.2	53.1
Aurora	899	4.0	57.1
Hibbing	875	3.9	61.0
Isaac Lake	871	3.9	64.9
Dewey Lake	870	3.9	68.9
Babbitt	855	3.8	72.7
Other 18 Quads.	6,081	27.3	100.0
TOTAL	22,262	100.0	

TABLE 2

A second foci of high rates of land cover change is in the Keewatin, Silica, and Pengilly quadrangles area which respectively had 7.5, 7.1, and 4.2 percent of the Range's surface cover change from 1969 to 1975. The Butler and National taconite operations are the primary causes with tailings basin and ore pit expansion as the major elements. A third foci is the eastern end of the Range where the Aurora, Dewey Lake, and Babbitt quadrangles respectively account for 4.0, 3.9, and 3.8 percent of the areas change.

The change rates in the eastern end of the Range are deceptive because the bulk of the change takes place in the early development of a mine facility when tailings basins are constructed and mine areas are stripped of overburden. These areas dominated by Reserve and Erie Mining were well developed prior to 1969. Together these ten quadrangles account for almost three quarters of the land cover changes in the Range. The Kinney quadrangle alone accounts for almost as much change as the 18 quadrangles, which have the least change.

EVALUATION OF RESULTS

Map Accuracy

Accuracy of mapped data is, unfortunately, most difficult to evaluate. No standards exist for evaluation of the accuracy of the kind of maps produced here. In fact, no standards exist stating accuracy requirements for land cover data for different purposes by various agencies with land based resourse analysis, policy formulation, planning, and management responsibility.

The best available information is what most agency personnel would ask for. At the present time much of the land cover change information that exists in the Mesabi Range relates directly to mining activities and is based largely on self reporting of past changes by mining companies. The result is a patchwork map ranging from no information to data based on a wide variety of standards. Potentially the weakest link is the monitored acting as monitors. Some standard source of information needs to be available to resourse managers to evaluate the adequacy and veracity of self reported information.

The dynamics of Mesabi Range land cover, the posterior interpretation of annual changes, and the lack of annual synoptic maps of uniform quality and aerial photography after 1969 combine to make the evaluation of LANDSAT updated U.S. Geological Survey quadrangle land cover maps highly subjective. Field checking in 1976 cannot reconstruct the extent of a tailings pile or location of a mine wall in 1973. Where image contrast is high, such features can be determined to within ± 200 feet; we cannot, however, count on such features always locating themselves in a high color contrast area.

Based on July 1976 field checks of land cover change elements in 7 of the more complex quadrangles, discussions with mine company personnel, mining maps, and DNR mines personnel all but a very few aerial units appeared to be of the correct size, shape, location, and classification.

1. The discrepancies were a commercial development interpreted clearing at a highway intersection and a railroad loading operation interpreted as unidentified use.
2. An uncertain interpretation of water in Wacoutah mine extension was correct although it was incorrectly mapped in the 1969 photo revision of the U.S.G.S. quadrangle base.
3. Interpretation of one linear feature was incorrect. A feature interpreted as three separate lines to Mahoning Lakes was actually just one road.

Cost

The cost of producing the maps is broken down into steps. Updates on an annual bases need not include all steps. It should also be realized that the figures here include six very detailed, four average and 18 simple quads averaged together. In addition, it includes the learning process for the two interpreters. Table 3 illustrates the cost of producing a quadrangle base and four annual interpretations.

The total time for 28 quads and four time periods was 469 hours, or 19.75 per quad. A one time period update of the existing quads would average just over 4.25 hours per quadrangle and would include selecting imagery, slide production, projection and interpretations, checking changes with ground truth, any corrections, recording changes, redrafting, and editing. This would total about 120 man hours per year for the whole Mesabi Range.

LABOR FOR PRODUCTION OF MAPS AND STATISTICS OF CHANGE

Step	Base Compilation and Four Time Periods		*Hours for Annual Update Per Quad
	Hours for 28 Quads	Hours per Quadrangle	
Draft Base Map	84	3.00	0.00
Select Imagery	4	.14	.07
Make Quad Centered Slides	24	.86	.21
Project/Register & Interpret Change	168	6.00	1.50
Check with Ground Truth	28	1.00	.25
Correct and Revise	56	2.00	.50
Color Key Changes for each Year	28	1.00	.25
Record Change, Location & Size	28	1.00	.25
Ink Drafting	105	3.75	1.00
Final Editing & Corrections	28	1.00	.25
TOTAL	553	19.75	4.28

* These figures reflect exclusion of steps that need not be repeated and the inclusion of estimated additional time because of the smaller scale of annual operations.

TABLE 3

Material costs for each quad, excluding the necessary LANDSAT imagery, light table, single lens reflex camera and remote focus-zoom lens projector for annual updates should run under $10 per quadrangle. Where changes are very modest no separate drafting film overlay needs to be made and changes can be noted on the original overlays, incurring only slide production costs and pro rata share of imagery costs. Single time period coverage, without cloud cover, presently costs as little as $12 if EROS data center has produced a master or $62 if they have not. Double these costs should be assumed as normal to obtain completely cloud free conditions at the desired times in the Mesabi Range. This amounts to a per quad cost minimum of $.43 to a more realistic maximum of $4.43 per quad. This would bring realistic annual update material costs to about $175 for the 28 quadrangles.

Summary Evaluation

The primary advantages of LANDSAT updates of quad based land cover maps lies in the cost, synoptic coverage, uniform quality data, and short time lag between image time and map completion. These advantages should not escape careful scrutiny. Cost must be considered a major advantage. No other system of resource mapping can come close to the cost of LANDSAT data for updating quads. However, the cost, regardless of how small, should yield a product that meets the demands placed on the data.

Lag time has two components, the first, which is out of the hands of LANDSAT data users, is the delay between NASA acquisition of images and customer receipt, which may range from 3 to 8 weeks. The other is interpretation and map update time which is under the control of the data user and can expand or contract depending on dedication to the task.

Synoptic coverage is usually an advantage, and it is difficult to imagine that non synotic coverage would be of greater value in studies of this type. The characteristic of uniform quality of the data may be more subject to question. Data quality -- specifically that based on resolution cell size and image contrast -- is even more open to question. What is sufficient in areas of relatively large features with high contrast between dissimilar land covers may not be satisfactory for areas of smaller parcels and lower contrasts.

Basically the question boils down to do management decisions require analysis of all parcels even below 10 acres in size? Is it necessary for planning decisions to always have the parcel boundaries as portrayed on maps within 100 feet of there true ground location (1/20" on 1:24,000 scale map)? And do you require more detailed breakdown of extractive feature classifications to make your daily operational decisions than is used in this report? If the answers to any of these questions is yes, than at least some data for some areas or at some time periods must be derived from different sources.

Future LANDSATS may possess these needed greater capabilities. However, until this is demonstrated needs for remote sensing data not satisfied by LANDSAT must be met by some other system. For users with such demands a multi-stage/multi-scale approach using aerial photography at regular multi-year intervals and LANDSAT imagery at seasonal or annual intervals should have some appeal.

The present LANDSAT 1 and 2 systems yield products capable of making highly accurate, low cost maps of land cover change in the Mesabi Range. The quadrangle maps produced can easily be digitized for data entry into the Minnesota Land Management Information System (MLMIS). The MLMIS system presently uses 40 acre data cells; but LANDSAT updates of significant changes such as clearing and extractive activities should be practical for data cells down to 10 acres.

Applications

In the final analysis it is impossible to evaluate or forecast the effect of LANDSAT based land cover change data. There are no controls. No one is randomly selecting to use or not use it in individual identical decision making situations. Thus, we cannot separate managerial ability from data quality. We can only assume that with better data, better managers will make better decisions than they would with poor or outdated information.

The only accurate evaluation of any information source lies in the quality of the human decisions and in the evaluation of whether or not the data played any positive or negative role in leading to the decision.

Has the use of the new information source led the decision makers to make better or poorer decisions? Hopefully, all decision makers would use such hindsight evaluation for future corrections.

In the last analysis, it is doubtful that any resource manager or planner, whose data needs (not aspirations) can be met by LANDSAT system data, presently has anywhere nearly enough information to guide decision making beyond the hunch or so called educated guess[3] category.

SUMMARY AND CONCLUSIONS

The magnitude of short term changes in land cover in the Mesabi Range area in the 1969 - 1975 period indicates that the iron ore industry plays a very significant role in both the economic development and environmental alterations of the Mesabi Range. Well over half of the land cover change of the six years are directly related to mining activity. Although land cover changes amount to only a few percent of the 28 quadrangles area included in the study, over 18 percent of the Kinney quadrangle land cover changed in six years. Not only is this undoubtedly the most intensive change in Minnesota, it also constitutes the most drastic alteration of land cover.

Recent land cover change has three major foci: (1) the Kinney-Virginia area, (2) the Silica-Kewatin-Pengilly-Hibbing-Dewey Lake area, and (3) the Isaac Lake-Babbitt-Aurora area. These are listed in order of importance based upon quadrangle analysis and acreage of cover change. Spatial variations in cover change do not necessarily reflect variations in mine output because changes are most dramatic in the period of minesite development.

Creation of open land through clearing, logging, or fires is areally the most important single class and cover change. Development and expansion of mine pits, dumps, and tailings basins are almost equal in areal importance in recent years.

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[3] Educated guess is a term used to scare away criticism and make others believe that the guesser knows what's what.

The methodology employed in this research, the use of LANDSAT images to generate 1:24,000 scale quadrangle overlays of change, appears to be highly suitable for mapping the classes of change found in the Mesabi Range against a dominant forest-marsh-water background. Accurate maps can be made and updated including areas greater than 10 acres with visual interpretation and minimal equipment.

This system is sufficiently accurate, rapid and inexpensive to warrant strong consideration as an annual update tool for MLMIS land cover in dynamic areas such as the Mesabi Range. Because of this ability a research program has been initiated to merge these data into the MLMIS data base, thus enabling the analysis of land cover change with other variables. This will allow the merging of LANDSAT data into a data management system for policy formulation, planning, and resource management.

ACKNOWLEDGEMENTS

This work was partially supported by a NASA contract, #20985 to the Minnesota State Planning Agency and carried out under contract with the State Planning Agency. The authors express special thanks to Earl Nordstrand, Arrowhead Regional Development Commission, Godfrey Zakula and Roger Johnson, the Department of Natural Resources, Richard Skaggs, the Department of Geography, Mai Trude, Map Library, and Joan Prochaska and George Orning, the Minnesota Land Management Information System study at the University of Minnesota and numerous personnel of private mining companies operating in the Mesabi Range.

APPENDIX I

QUADRANGLE MAPS OF LAND COVER CHANGE IN THE MESABI IRON RANGE

LEGEND FOR MAPS OF

LAND COVER CHANGE ON THE MESABI IRON RANGE

1969 - 1975

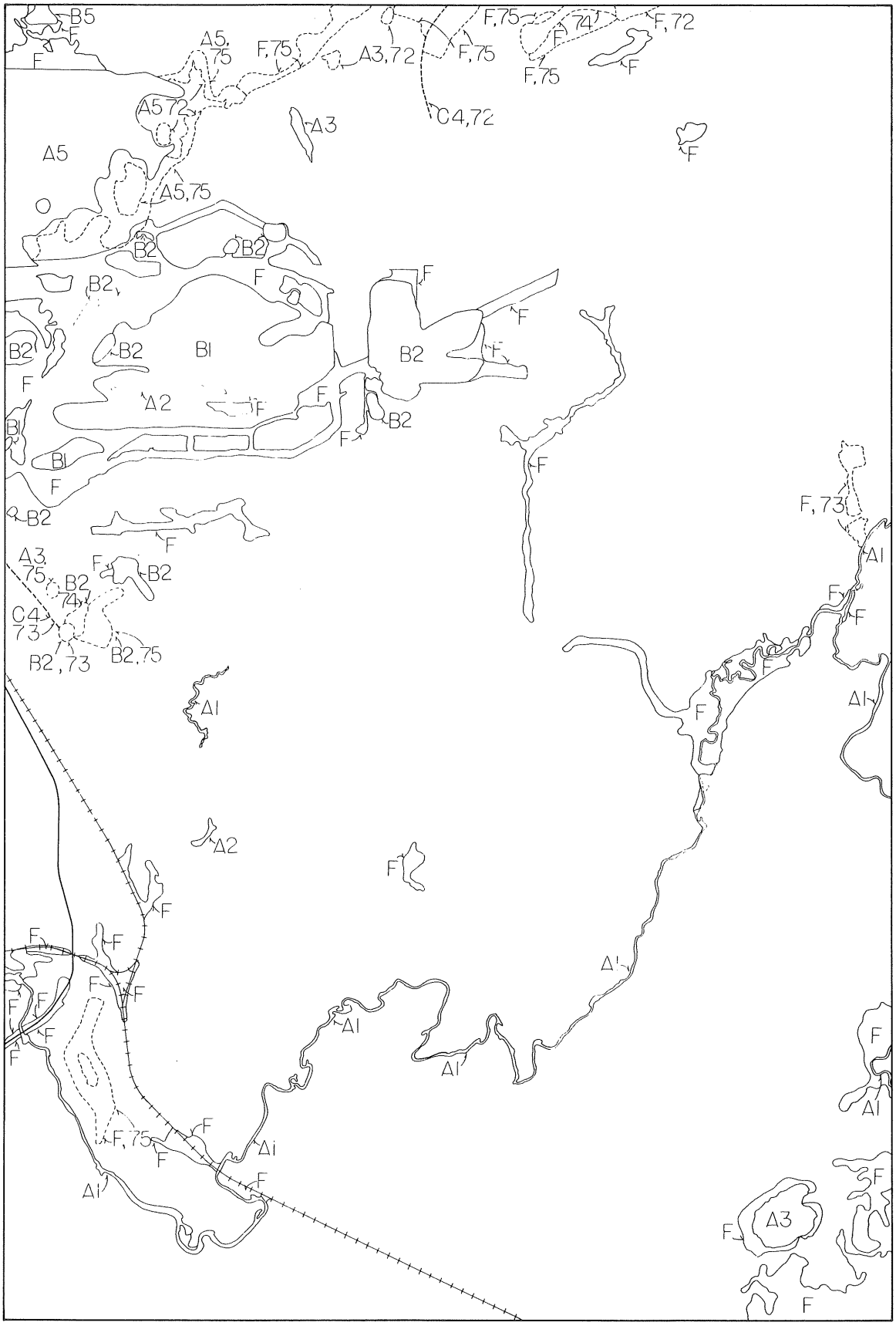
Area Feature Symbol	Class Description
A1	Stream or river
A2	Reservoir or water filled mine pit
A3	Natural lake
A5	Tailings basin usually contains water but water area highly dynamic
B1	Iron mine pit
B2	Iron mine dump (includes tailings piles, overburden piles, stockpiles, and mine plant locations)
B5	Gravel and stone quarries
C5	Urbanized area (outlined from U.S.G.S quadrangles)
F	Fields, clearings, and other open land
No Symbol	Indicates area is forest covered

Linear Feature Symbol	
C4	Major new road or rail line (does not include those in actual mining area)
	Major road (taken from quadrangle)
	Railroad (excludes lines within mining area)
	Solid line delimits areal extent of feature on 1969 photo revised quadrangles. Dashed line indicates areal extent of feature detected on LANDSAT images from 1972-1975.

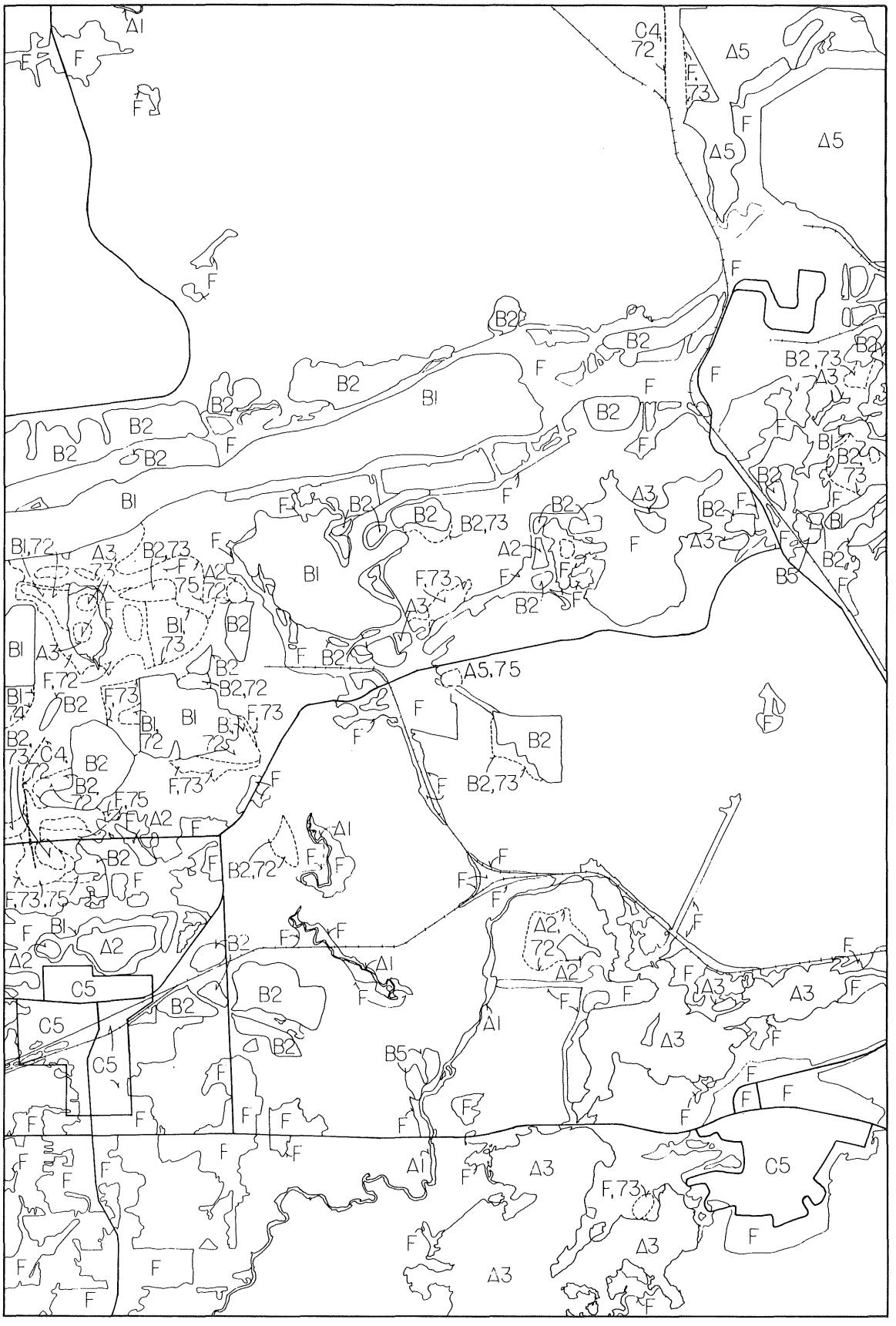
Dates of Change	
72, 73, 74, 75	Indicates year change was detected (1972-1975)

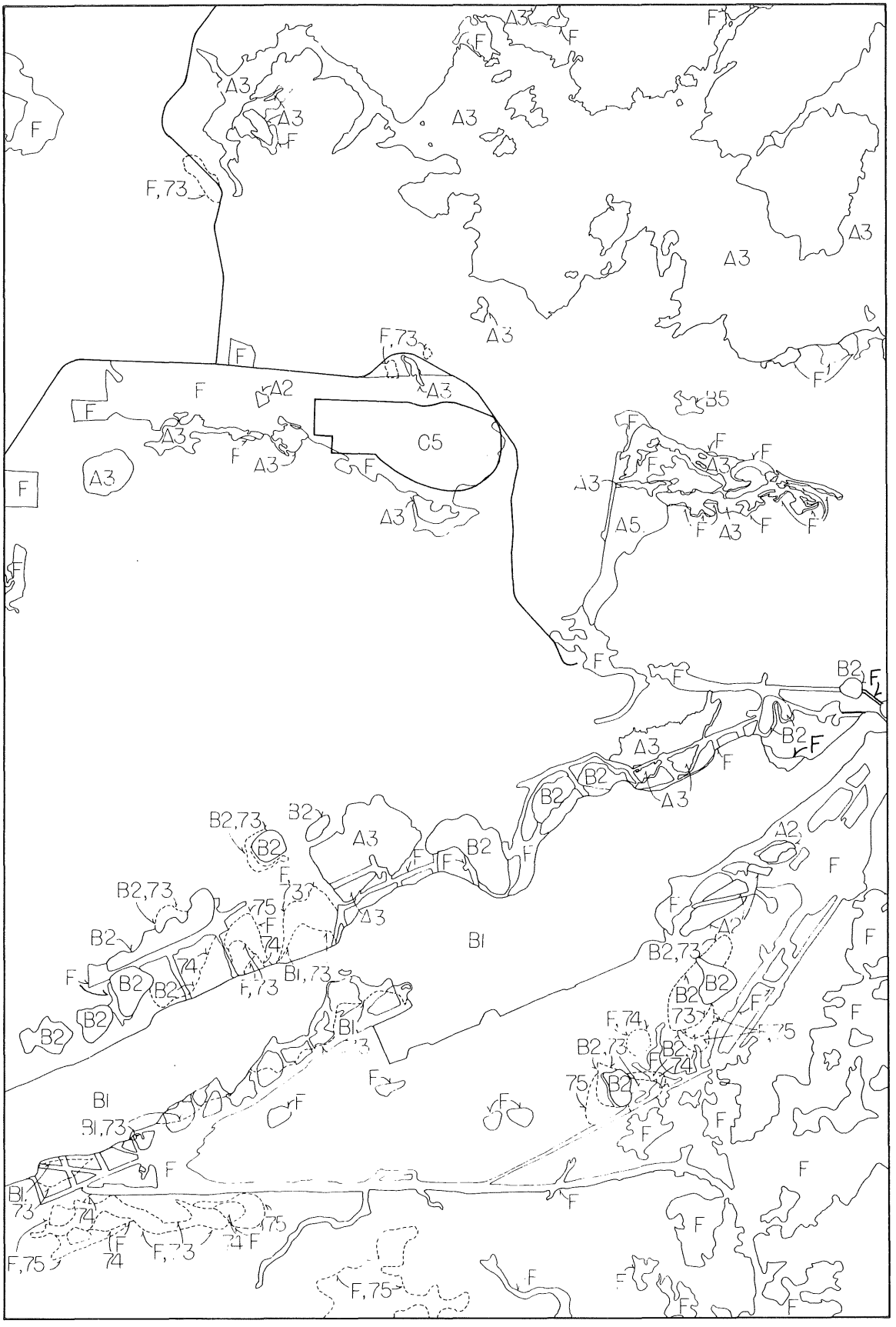
Map Scale = 1:62,500

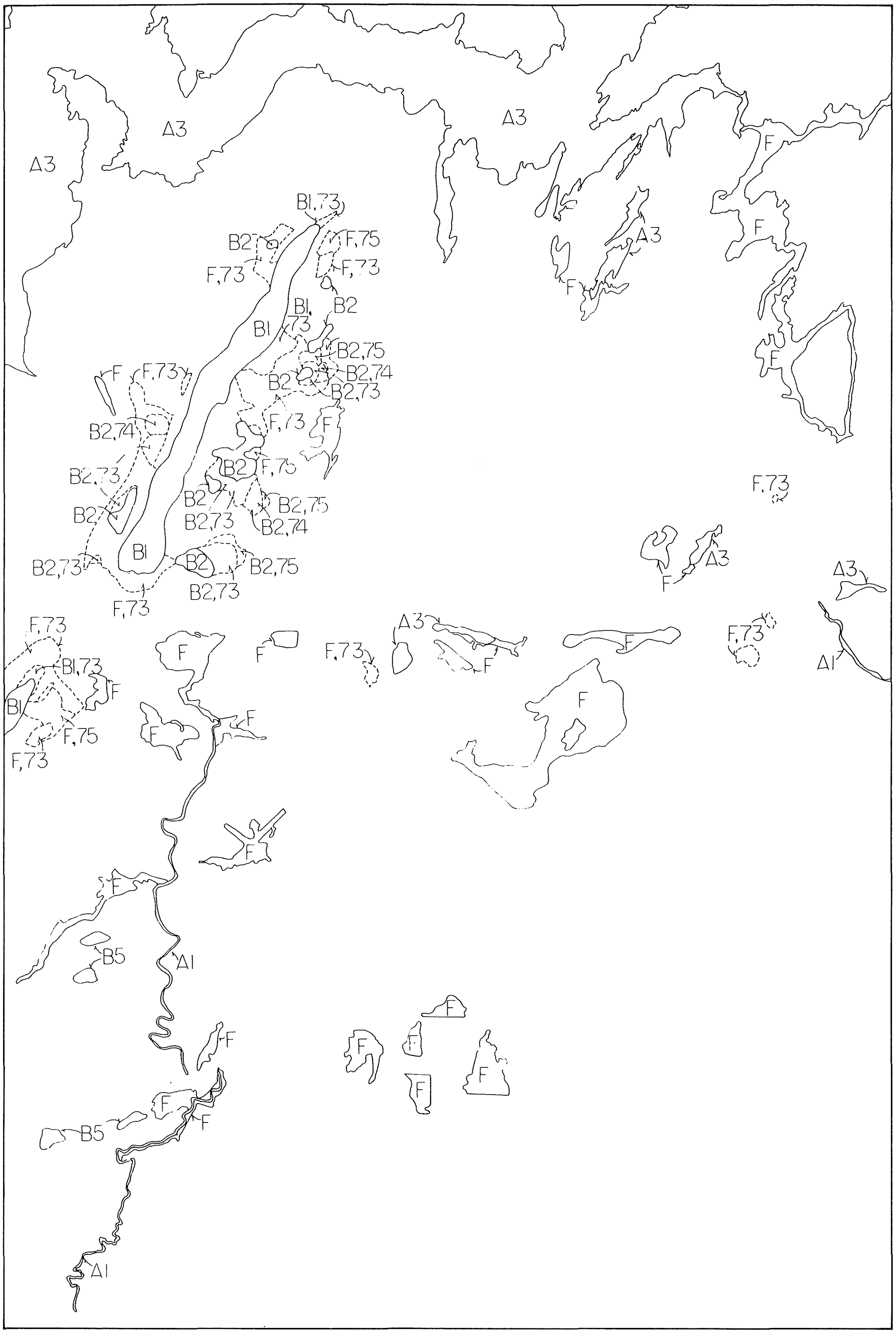
See Figure 1 and 2 in text for location of the quadrangles.



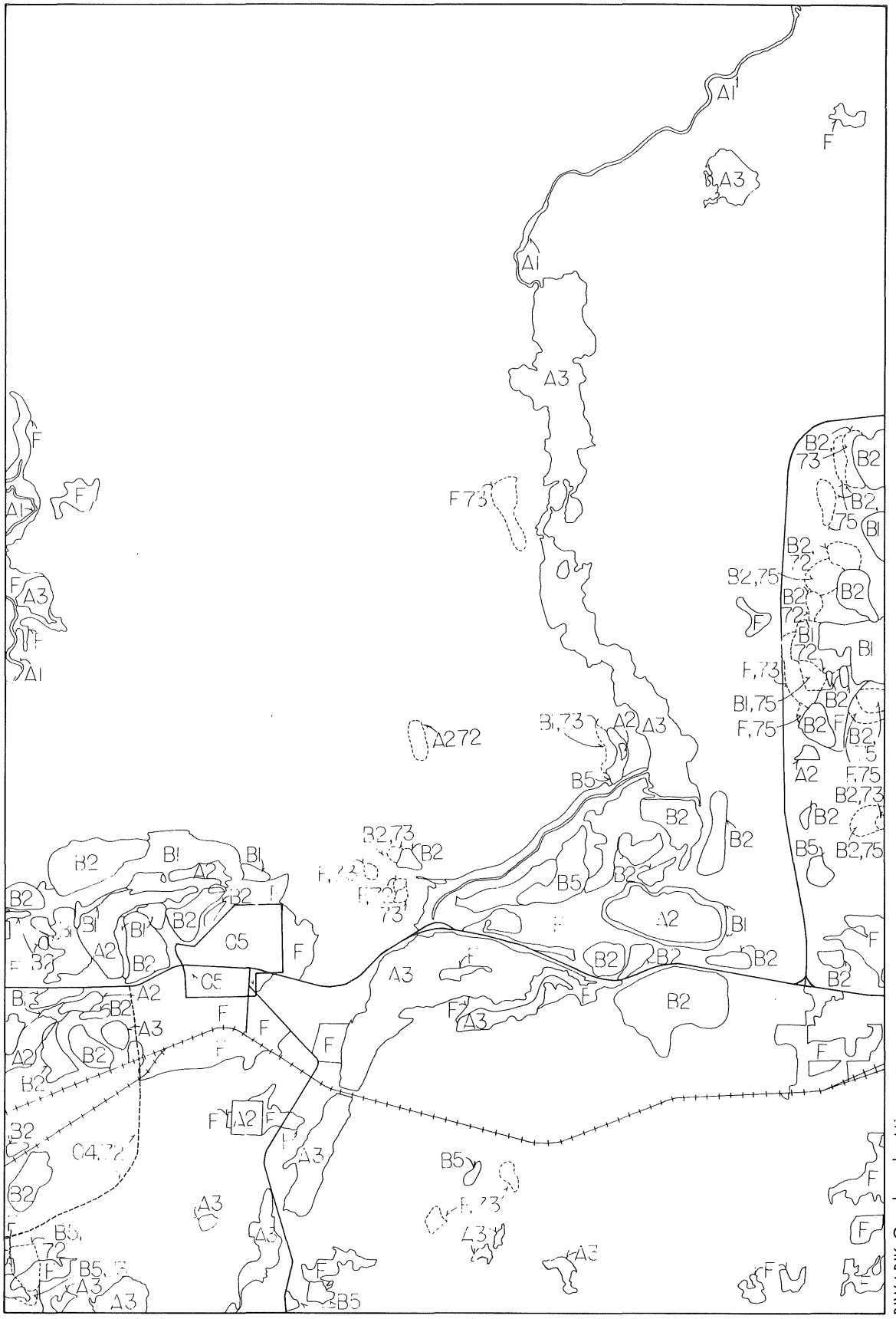
ALLEN Quadrangle, Minnesota

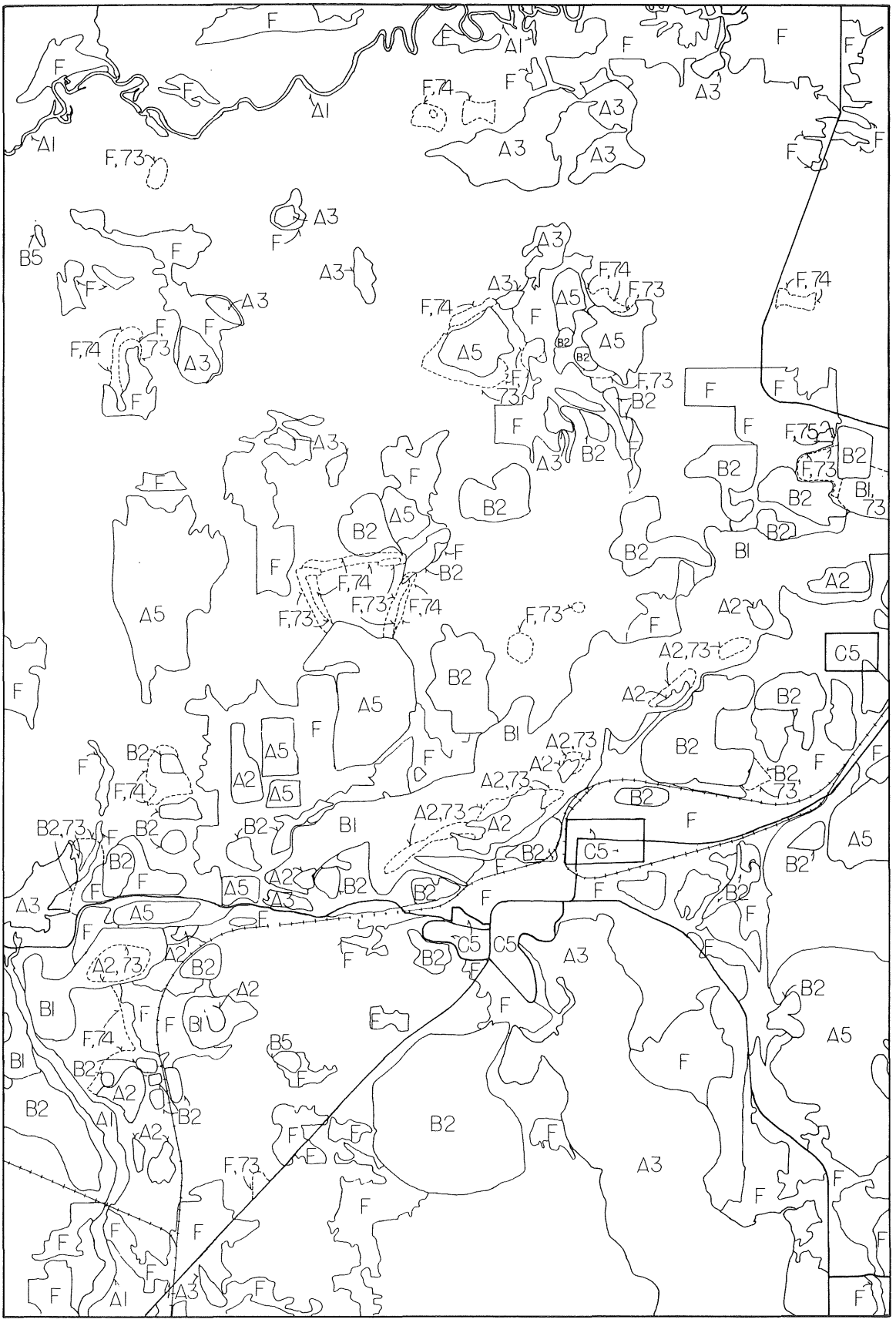

AURORA Quadrangle, Minnesota

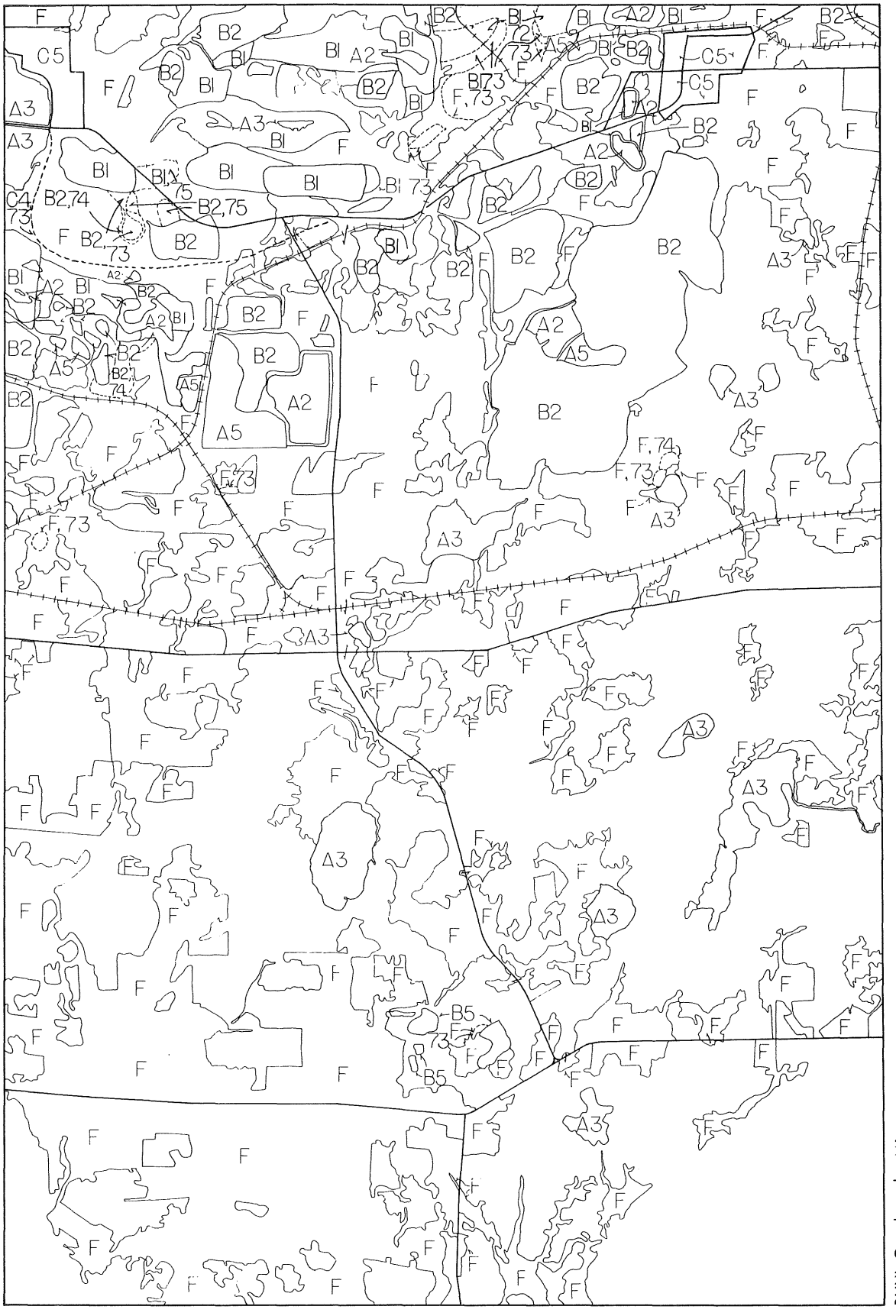

BABBITT Quadrangle, Minnesota



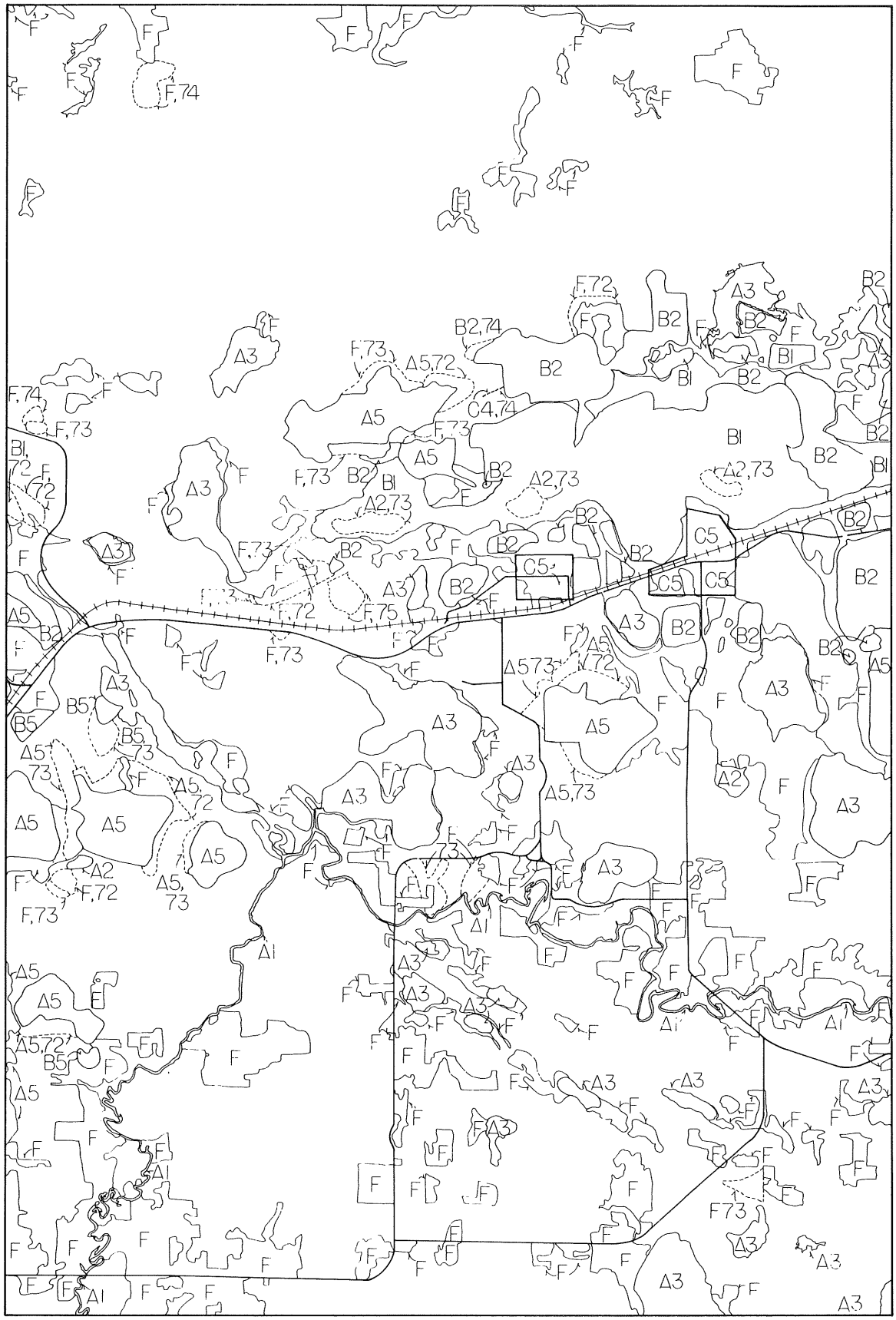
BABBITT N.E., Quadrangle, Minnesota


BIWABIK Quadrangle, Minnesota

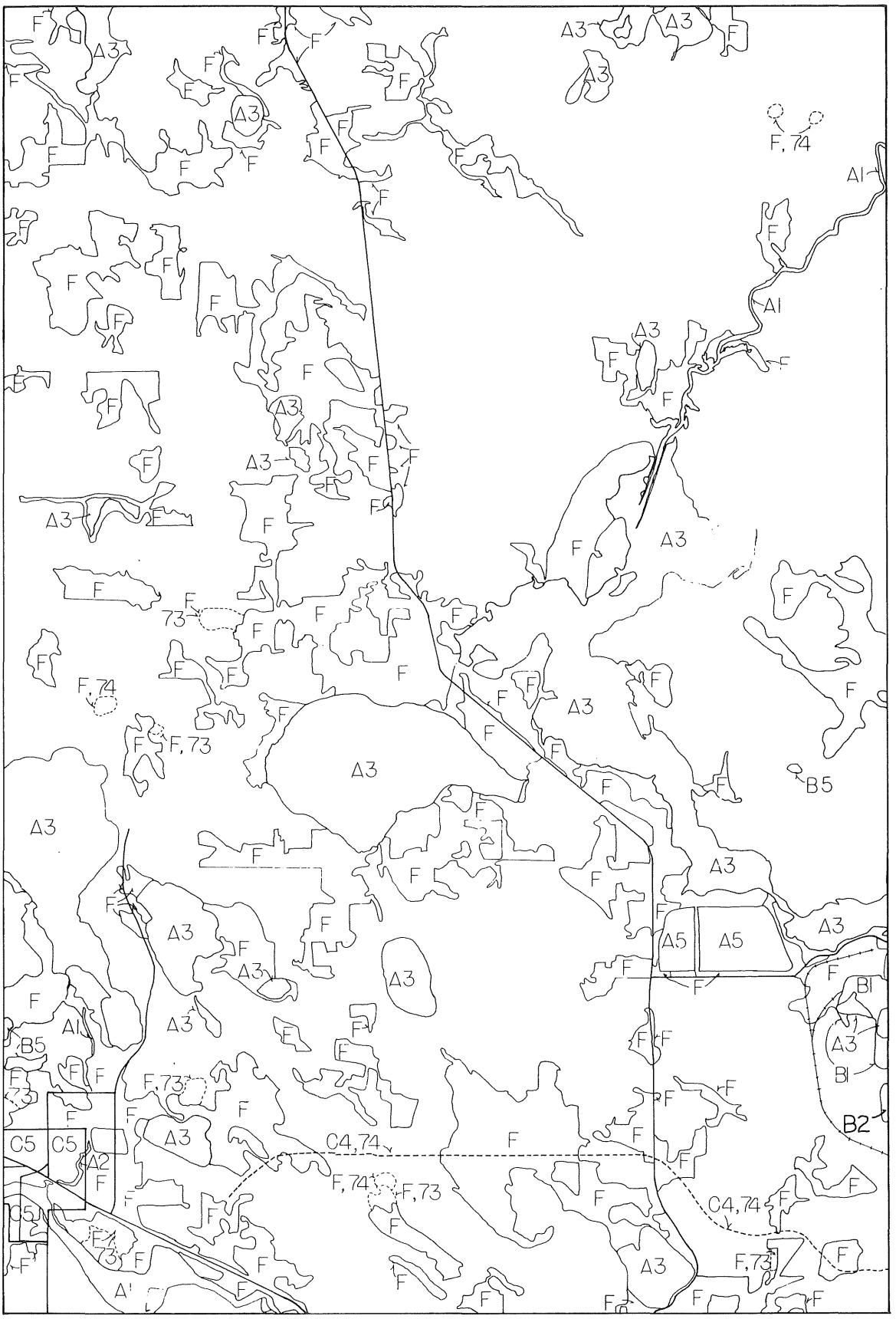

BOVEY Quadrangle, Minnesota

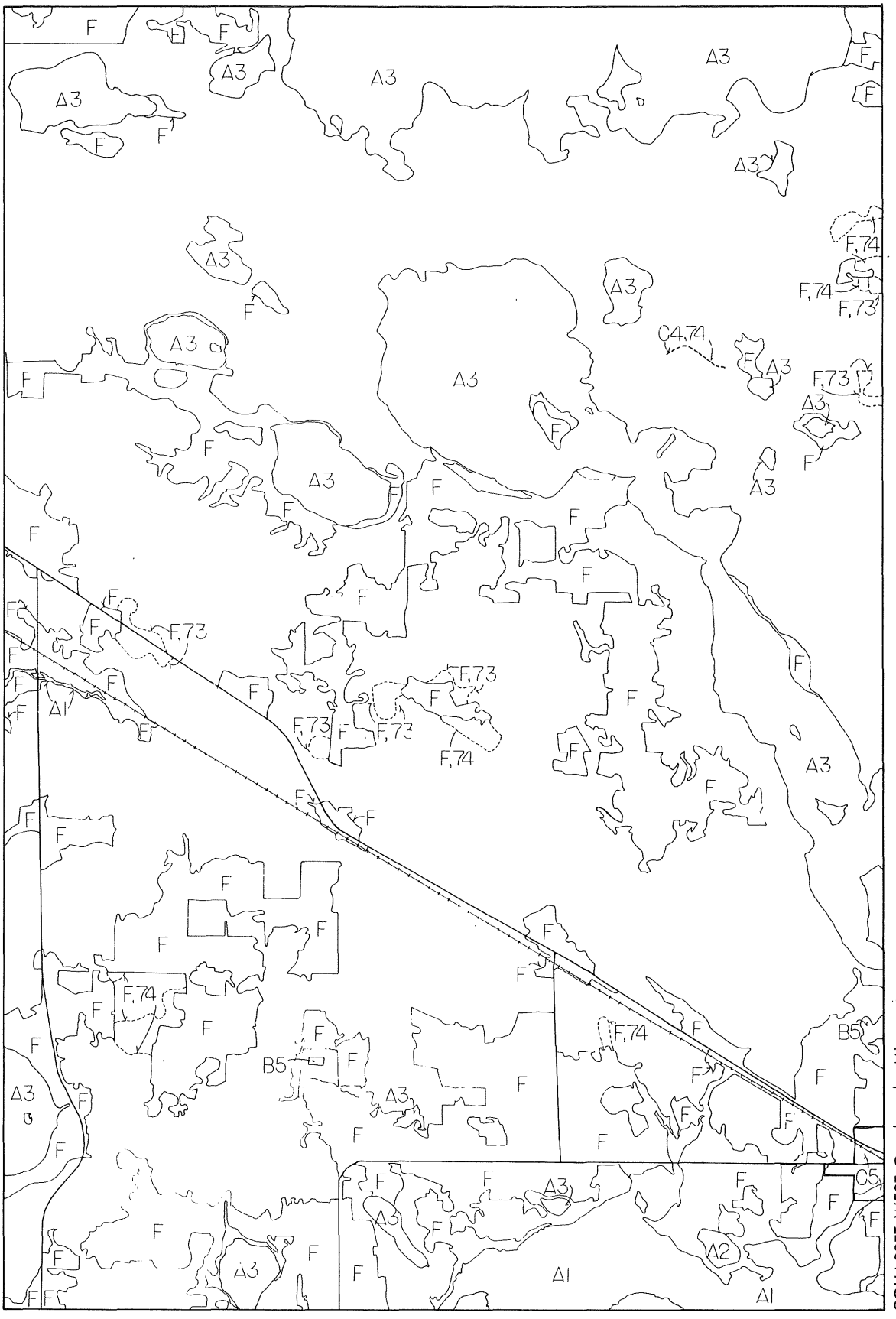


BUHL Quadrangle, Minnesota



CALUMET Quadrangle, Minnesota


COHASSET EAST Quadrangle, Minnesota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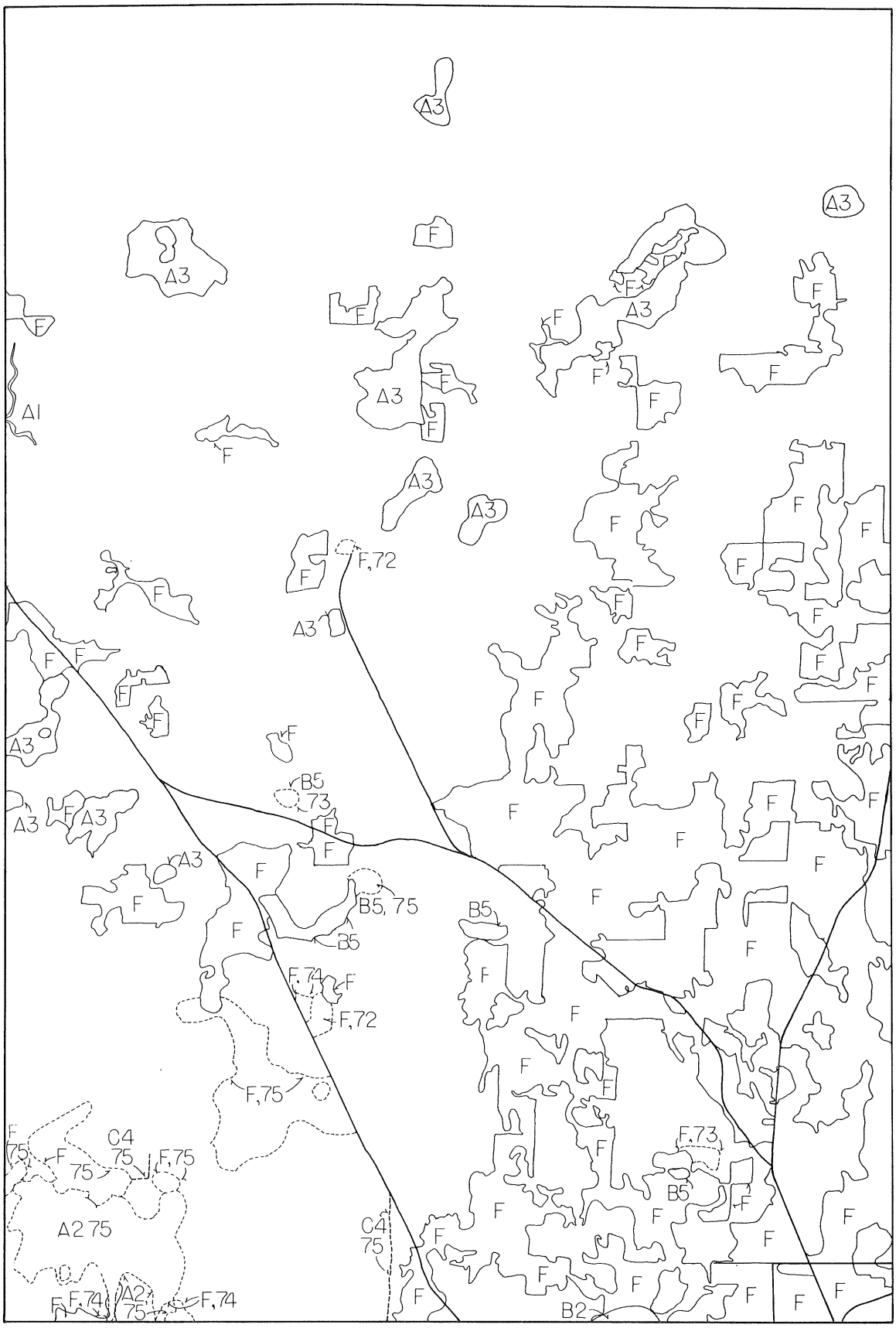
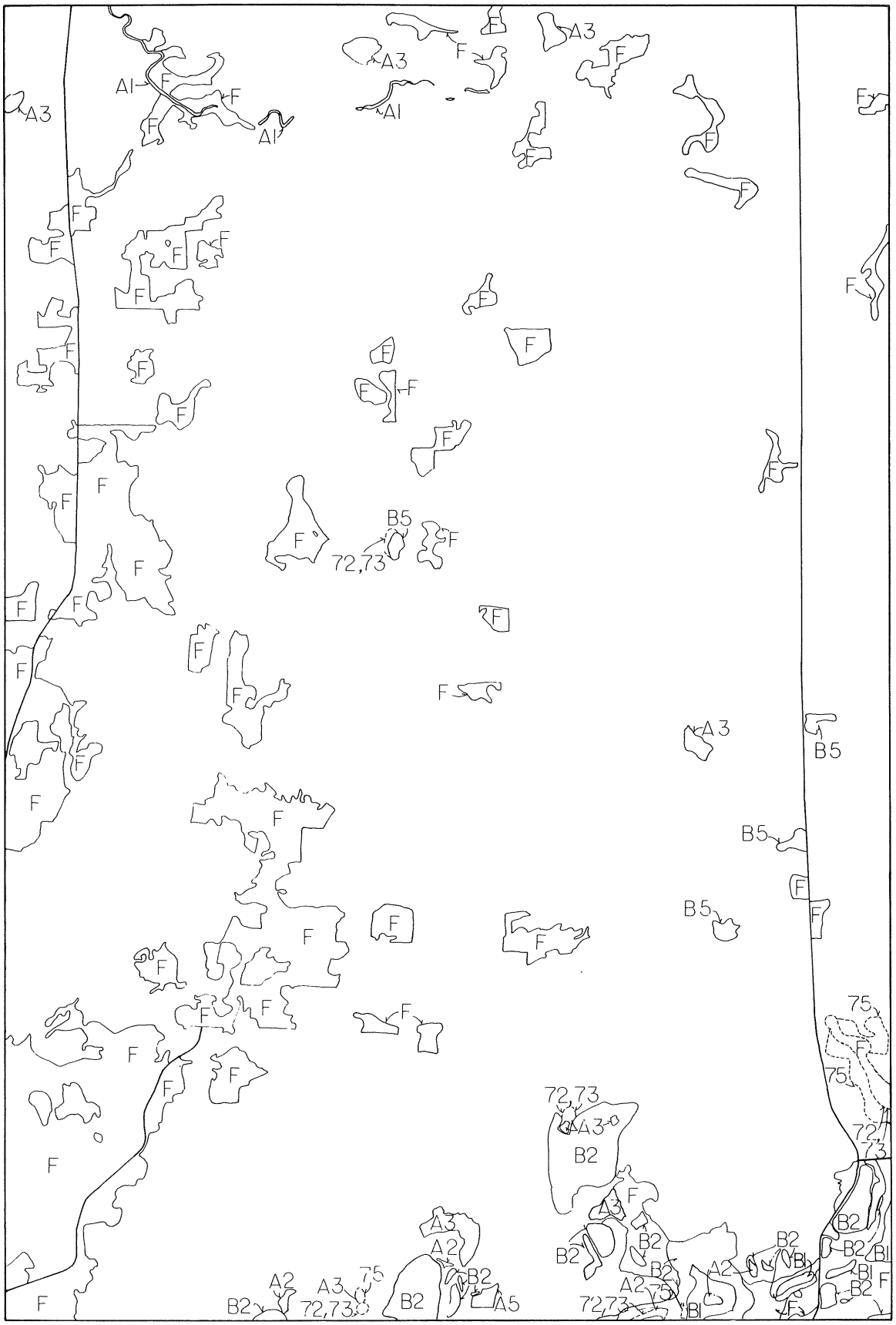
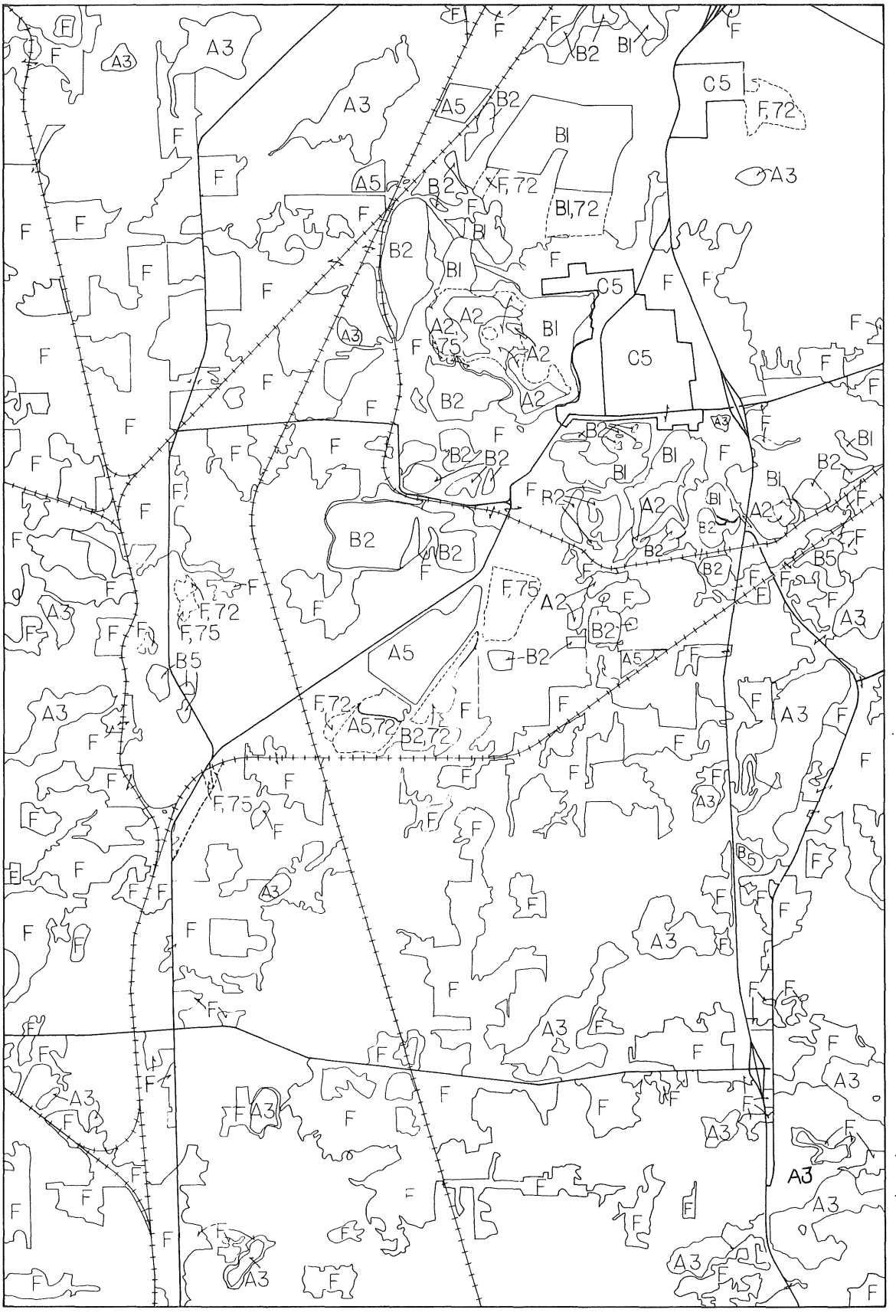


DEWEY LAKE Quadrangle, Minnesota



DEWEY LAKE S.E. Quadrangle, Minnesota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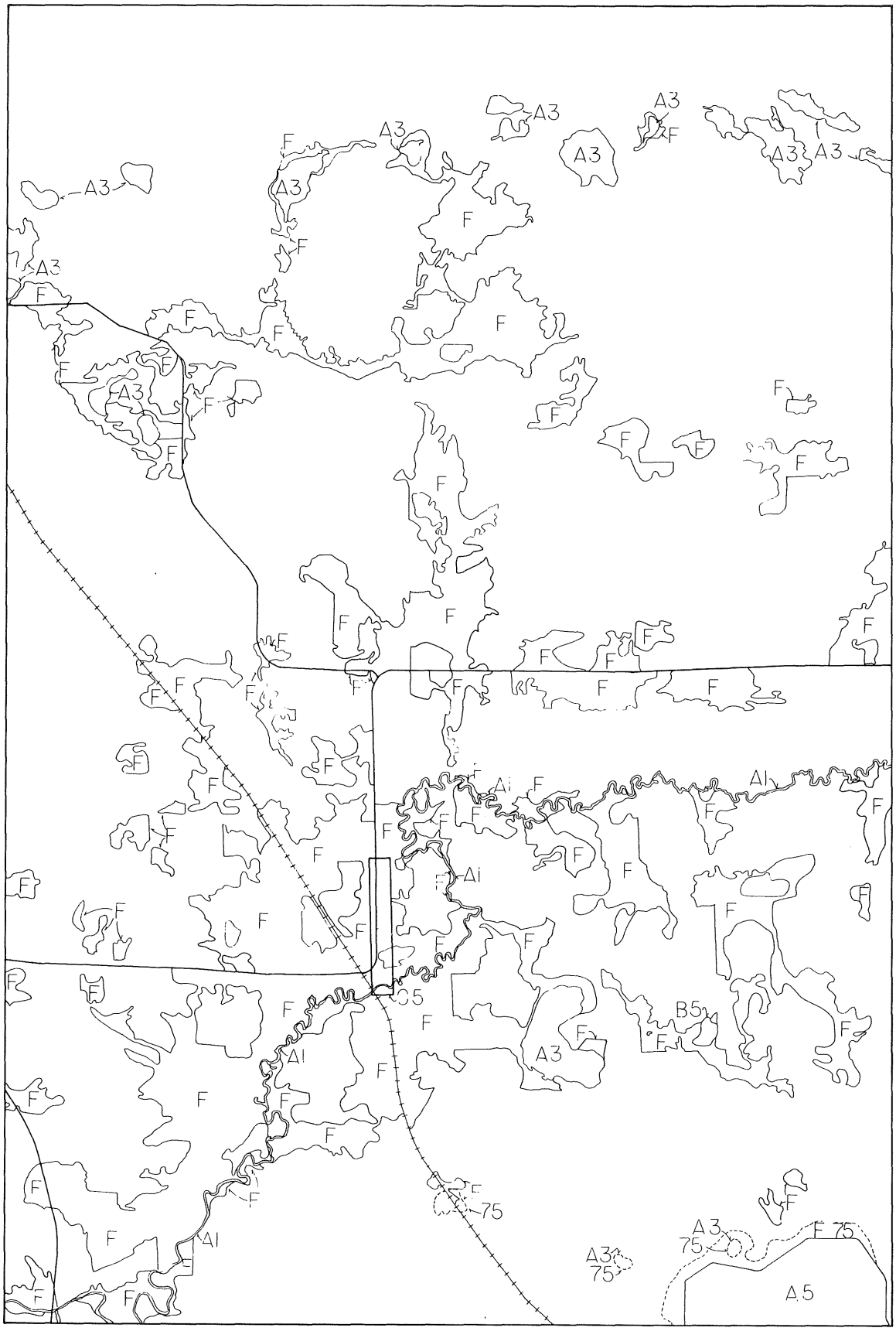
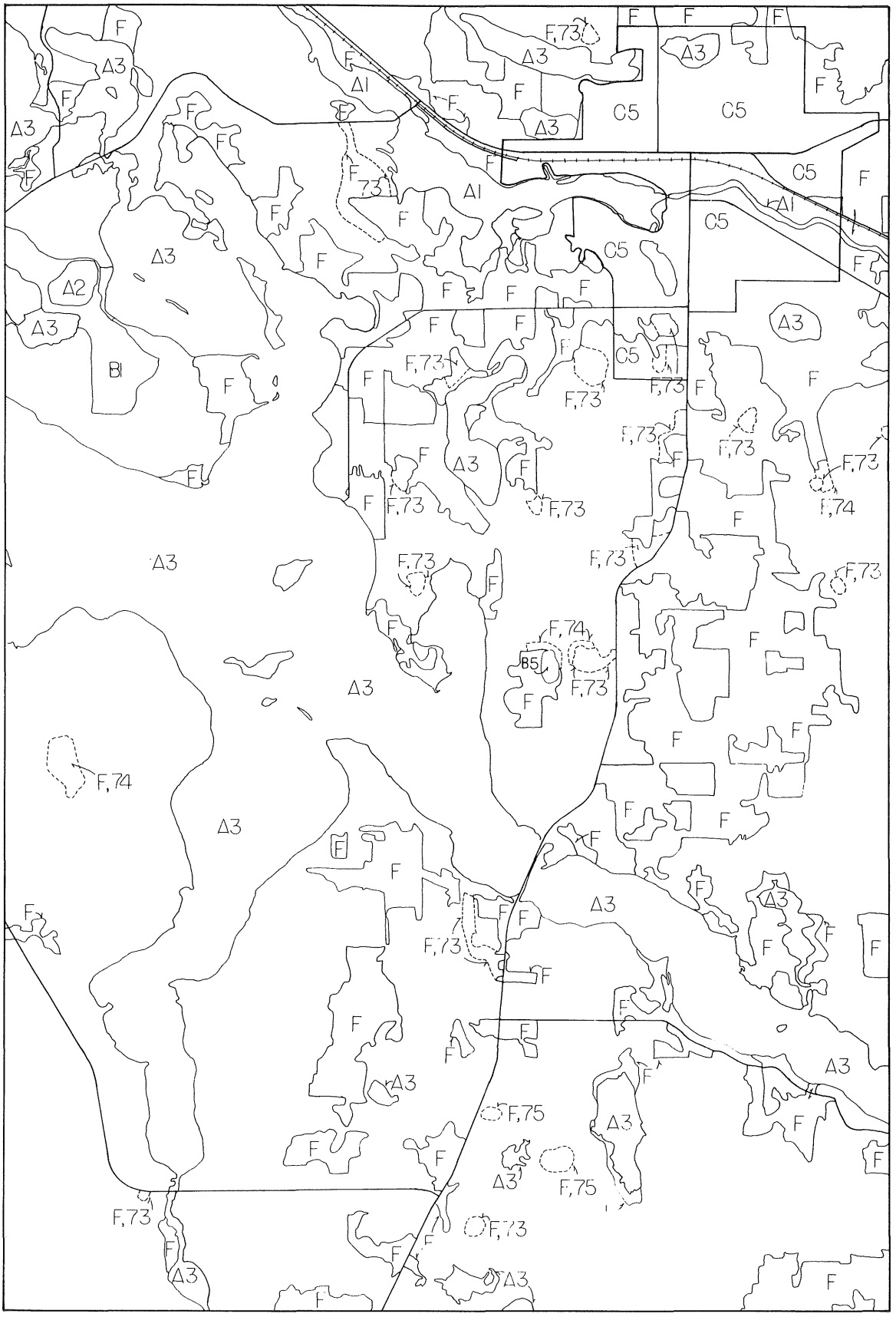
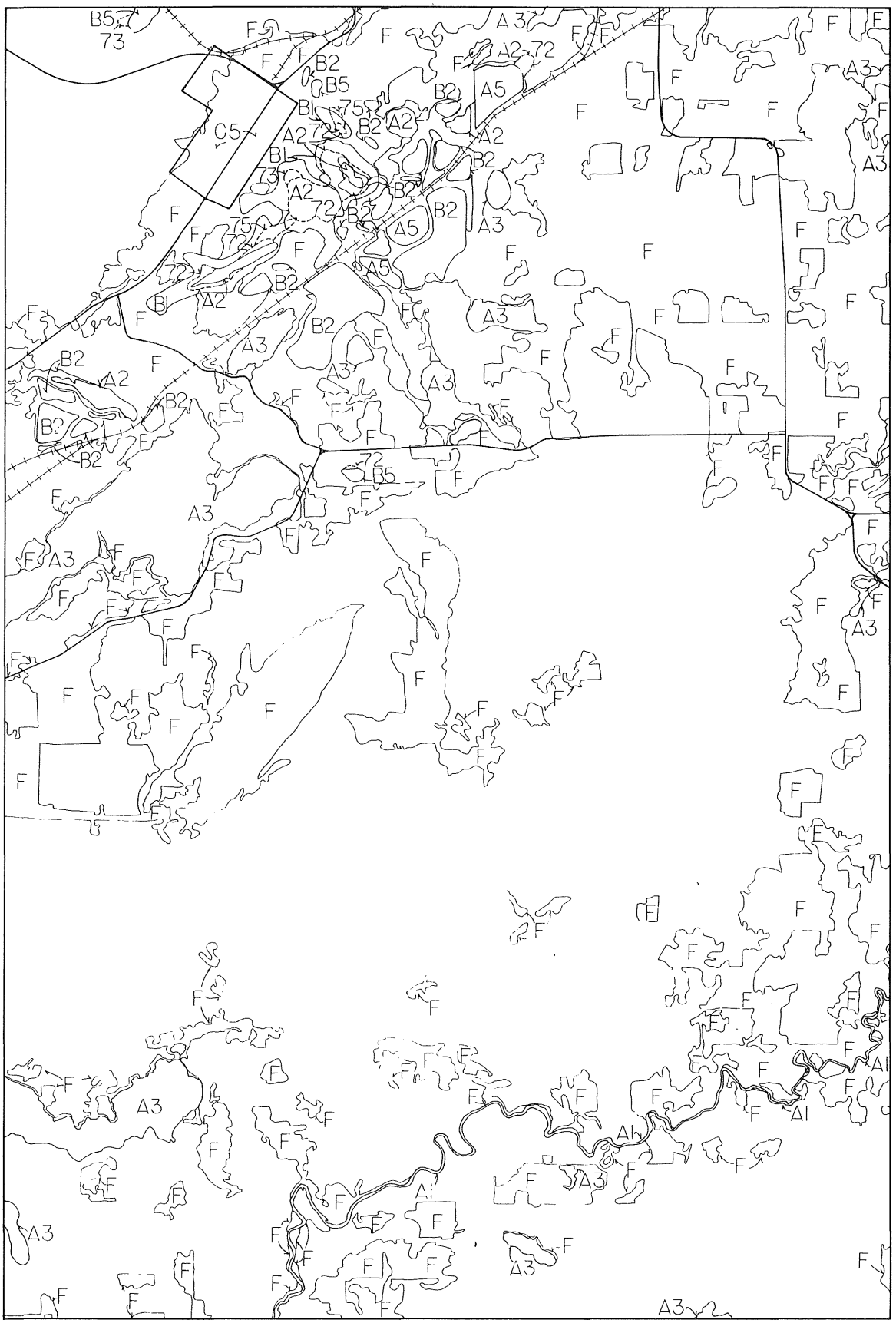
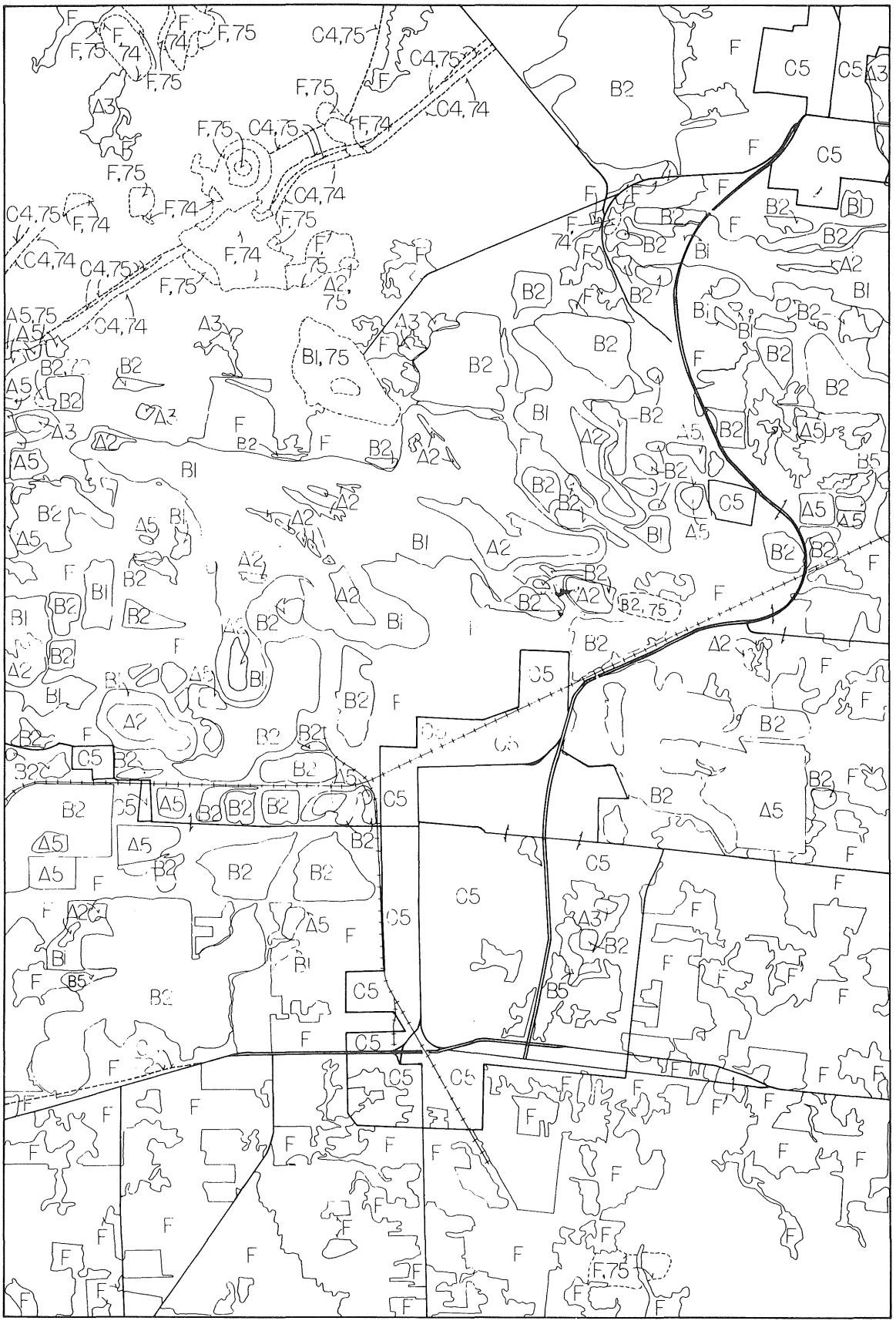

EMBARRASS Quadrangle, Minnesota



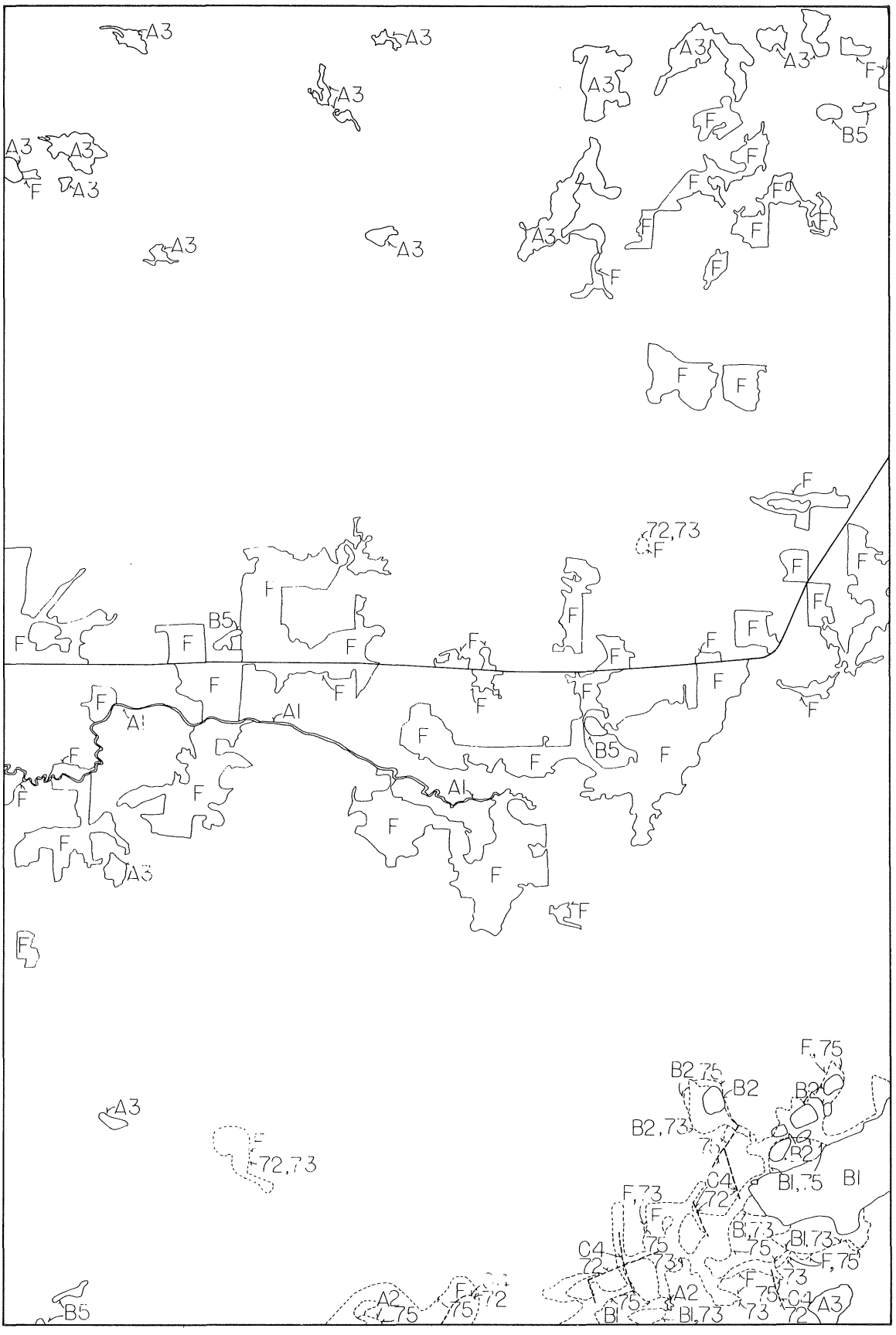
GRAND RAPIDS Quadrangle, Minnesota

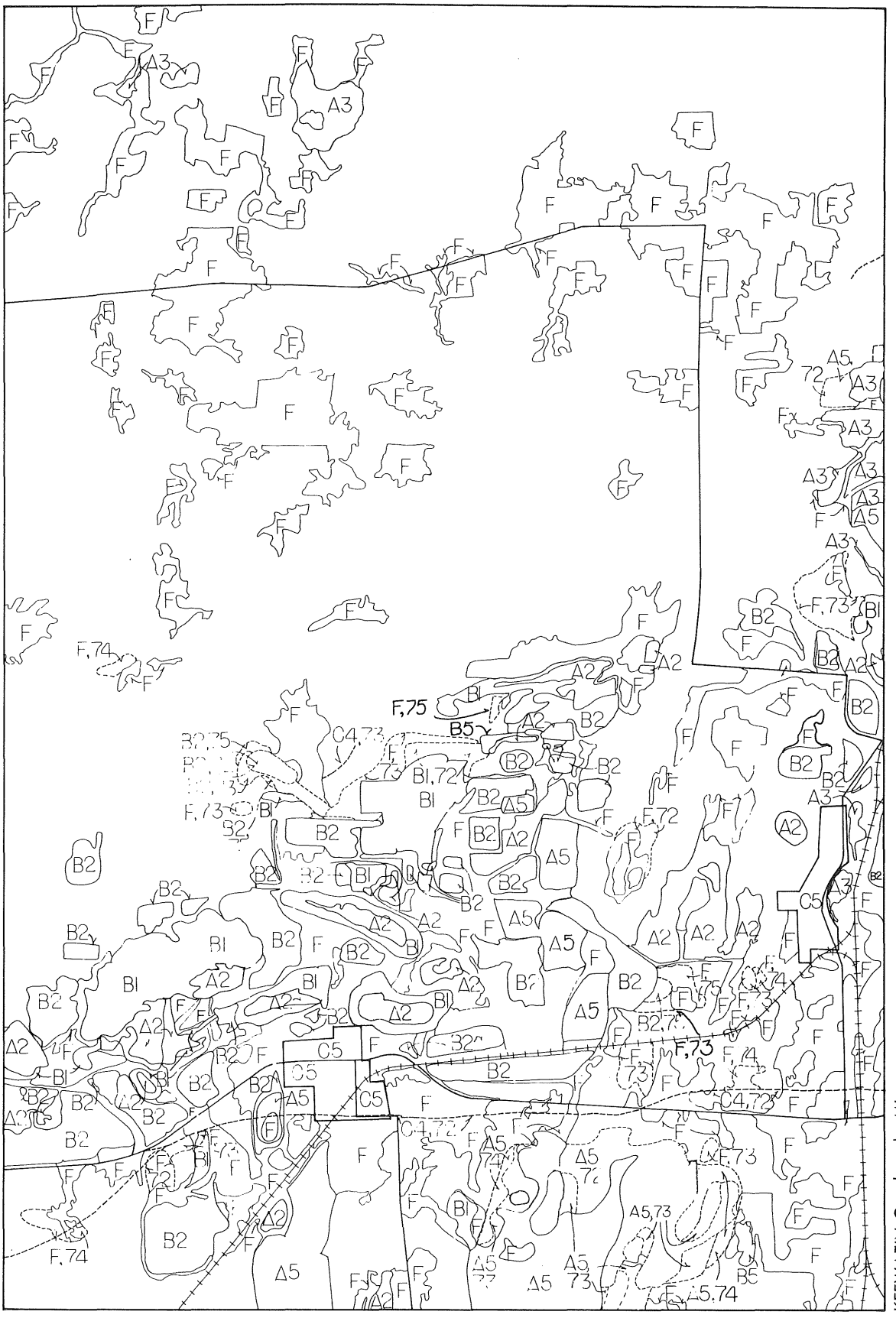


GILBERT Quadrangle, Minnesota

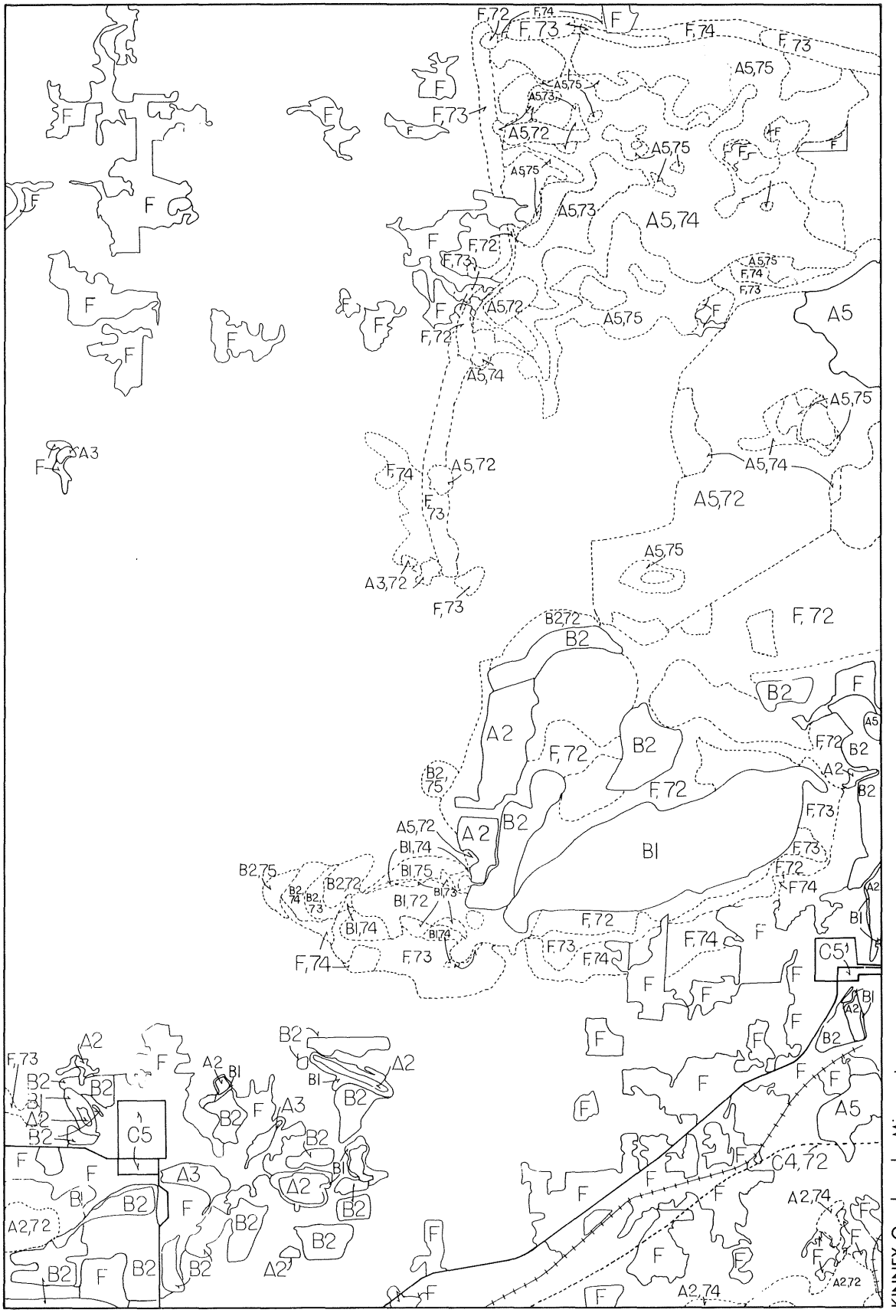


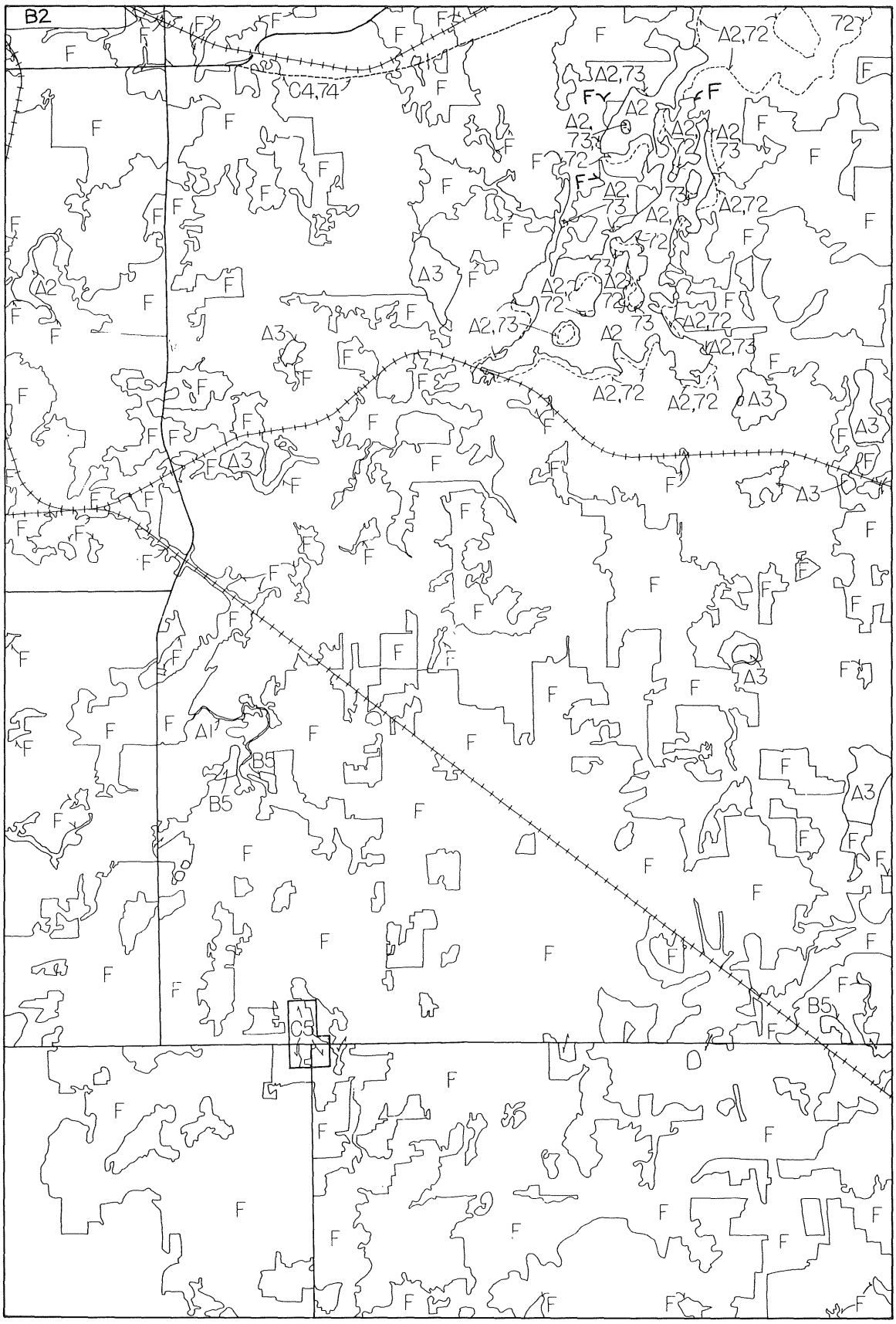
HIBBING Quadrangle, Minnesota


A3
F
B5
A1
72,73
B2,73
B2
B1,75
B1
C4
72
A2
75
ISAAC LAKE Quadrangle, Minnesota

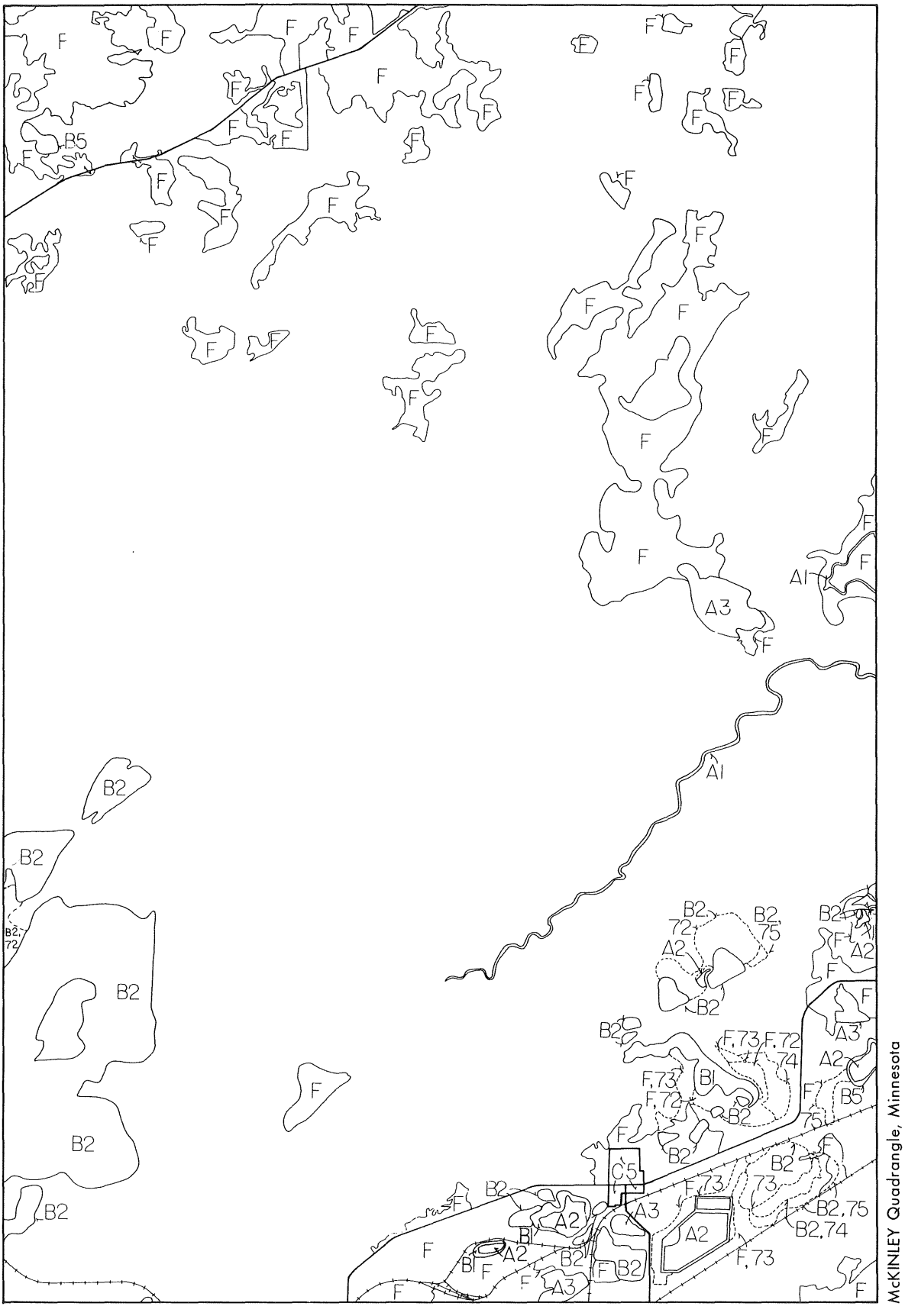


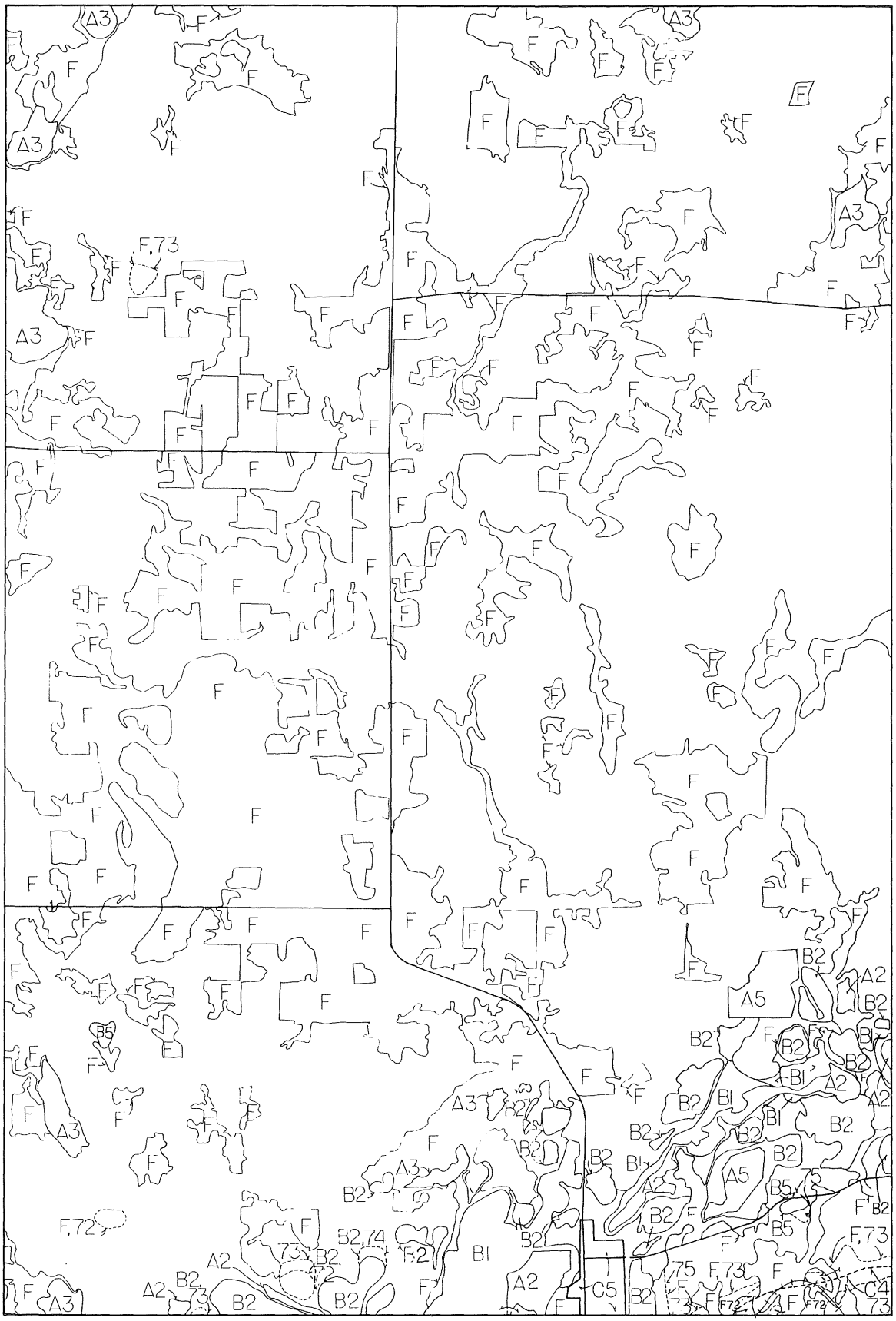
KEEWATIN Quadrangle, Minnesota


KINNEY Quadrangle, Minnesota

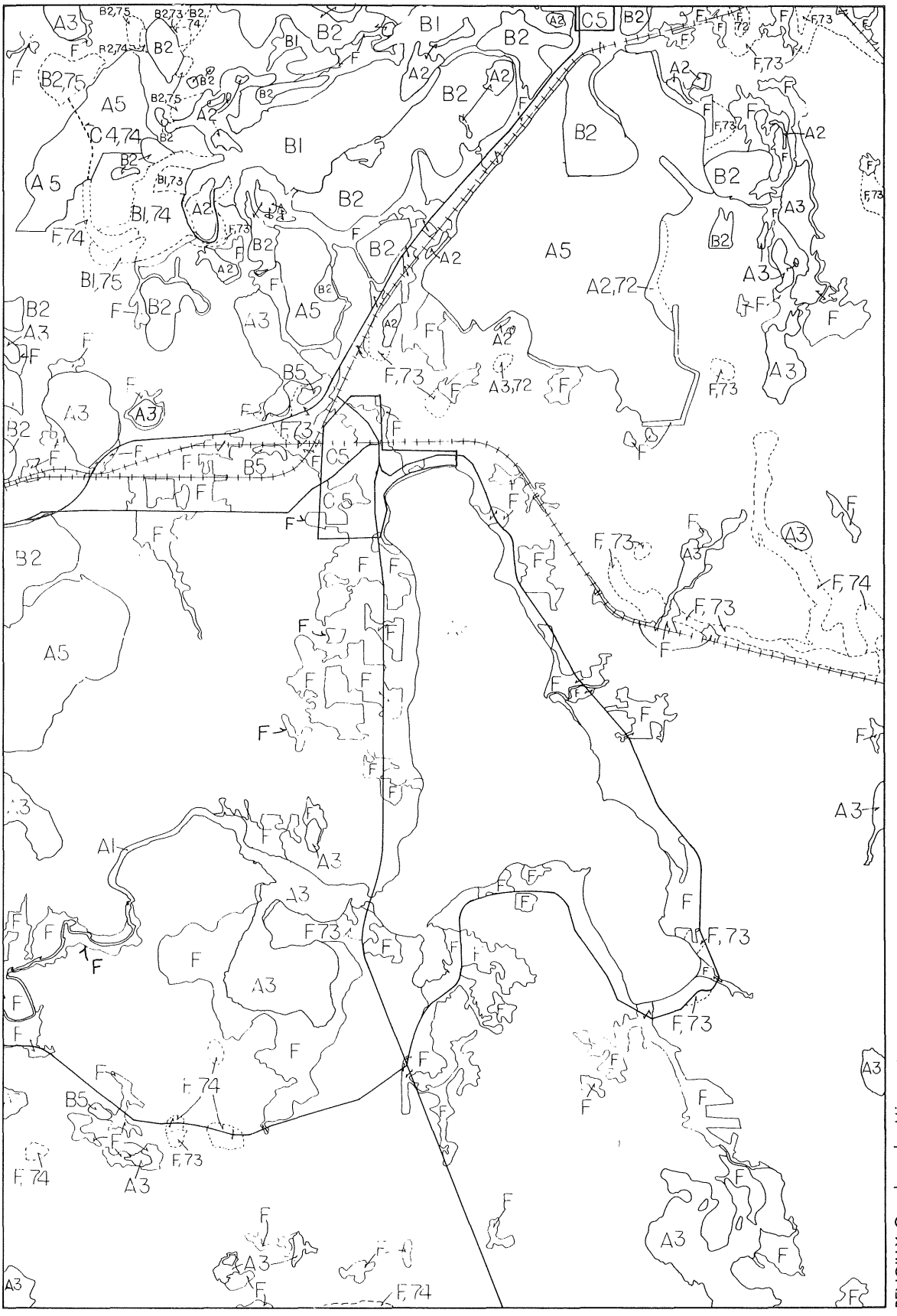


KIRK Quadrangle, Minnesota

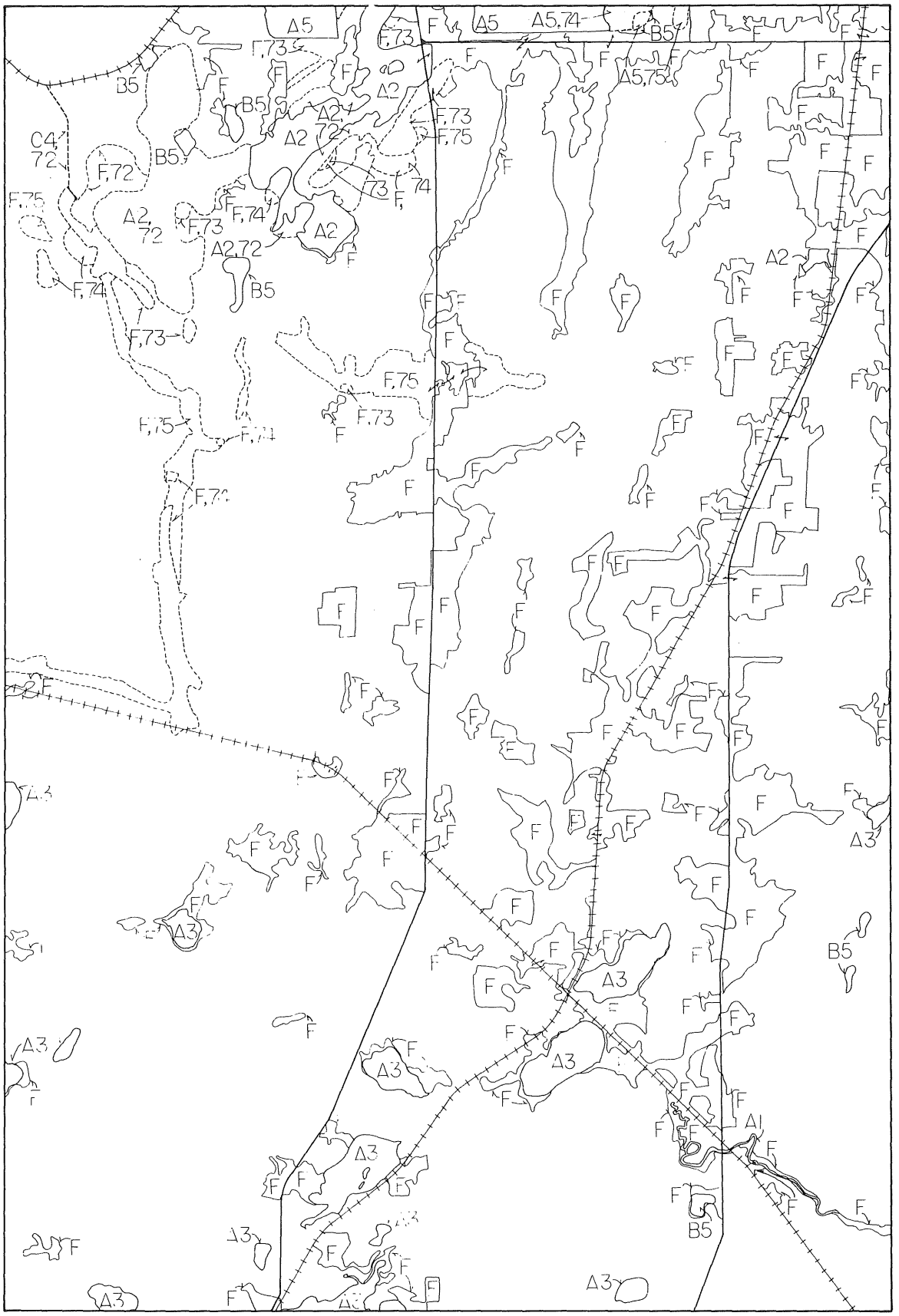

McKINLEY Quadrangle, Minnesota

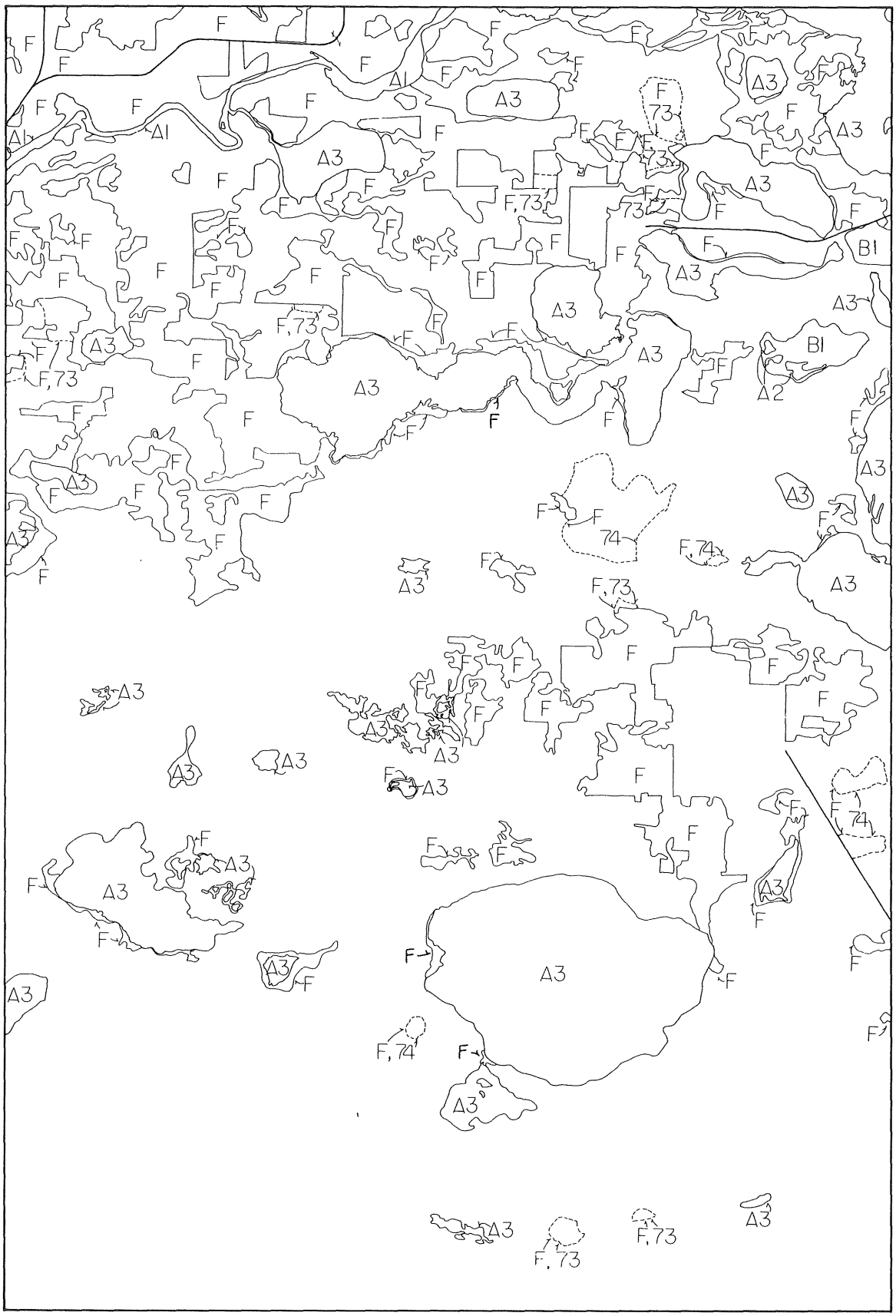


NASHWAUK Quadrangle, Minnesota

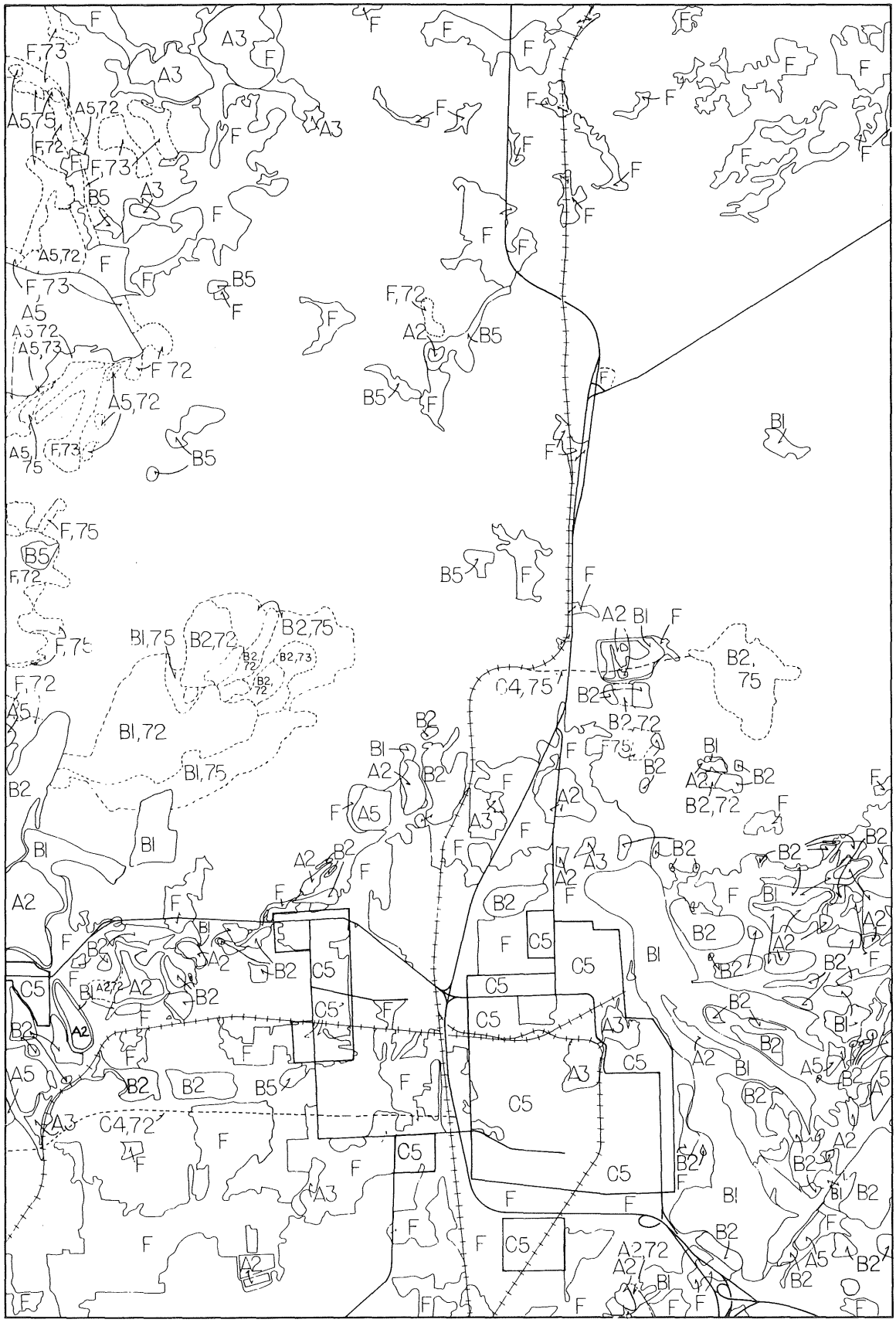


PENGILLY Quadrangle, Minnesota

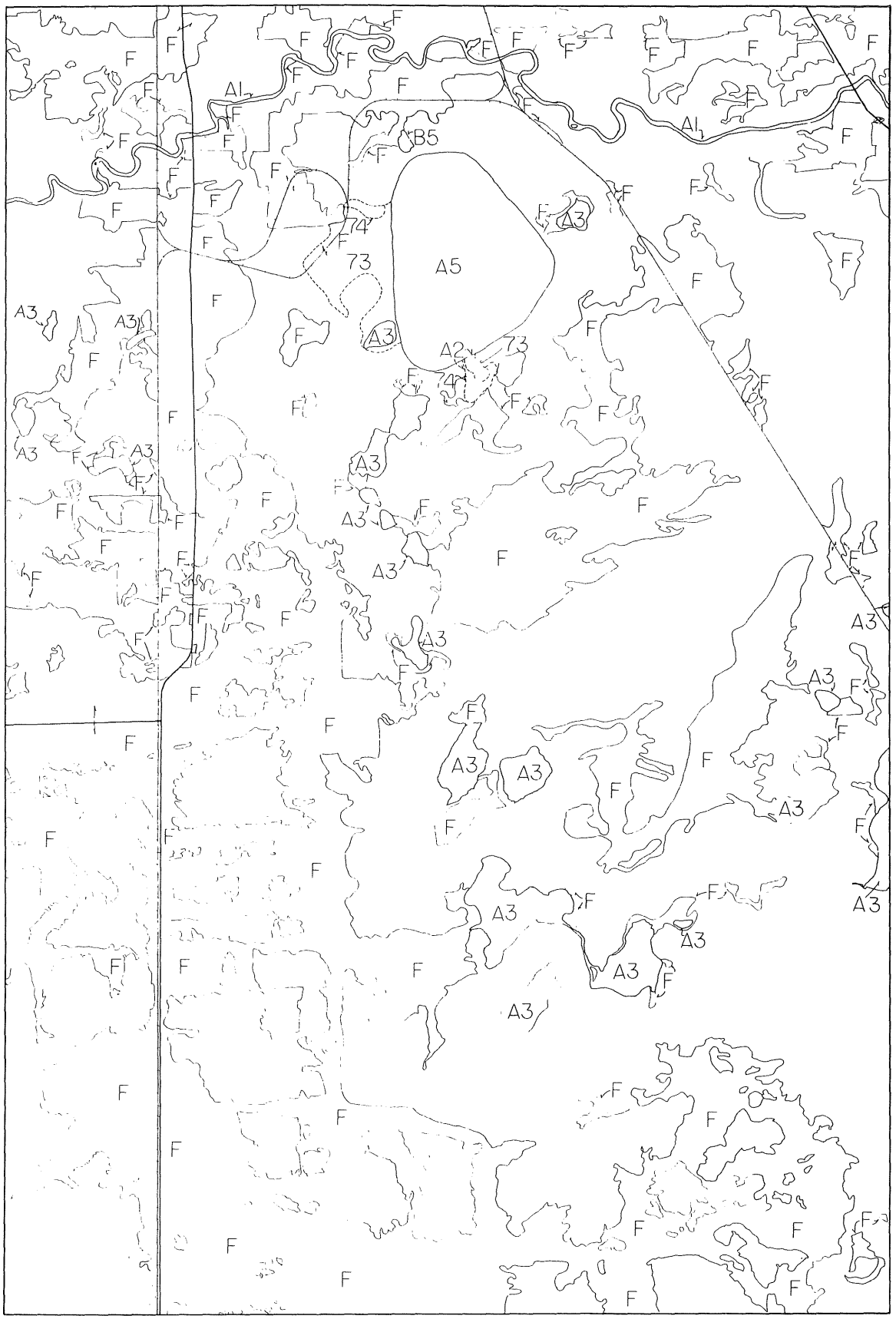

SILICA Quadrangle, Minnesota



SISEEBAKWET LAKE Quadrangle, Minnesota



VIRGINIA Quadrangle, Minnesota



ZIM Quadrangle, Minnesota

APPENDIX II

TIME AND CLASS OF LAND COVER CHANGE
BY QUADRANGLE FOR MESABI RANGE
1969 - 1975

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE

1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Allen

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River					
A_2 Reservoir & Pits					
A_3 Natural Lake	8			4	12
A_5 Tailings Basin (Water Area Highly Dynamic)	*		*	*	224
Extractive Features					
B_1 Iron Ore Mine Pits					
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)		6	11	32	49
B_5 Gravel & Rock Quarries					
Other Features					
F Fields & Other Open Areas	10	31	34	230	305
TOTAL CHANGE	18	37	45	266	590

* Change present but total not differentiated by year.

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE

1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Aurora

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River					
A_2 Reservoir & Pits			6		6
A_3 Natural Lake			15		15
A_5 Tailings Basin (Water Area Highly Dynamic)			31		31
Extractive Features					
B_1 Iron Ore Mine Pits			169		169
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)			173		173
B_5 Gravel & Rock Quarries					
Other Features					
F Fields & Other Open Areas			317	188	505
TOTAL CHANGE			711	188	899

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE
1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Babbitt

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River					
A_2 Reservoir & Pits					
A_3 Natural Lake					
A_5 Tailings Basin (Water Area Highly Dynamic)					
Extractive Features					
B_1 Iron Ore Mine Pits		188			188
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)		133	89	18	240
B_5 Gravel & Rock Quarries					
Other Features					
F Fields & Other Open Areas		163	46	218	427
TOTAL CHANGE		484	135	236	855

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE
1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Babbitt N.E.

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River					
A_2 Reservoir & Pits					
A_3 Natural Lake					
A_5 Tailings Basin (Water Area Highly Dynamic)					
Extractive Features					
B_1 Iron Ore Mine Pits		36			36
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)		73	28	28	129
B_5 Gravel & Rock Quarries					
Other Features					
F Fields & Other Open Areas		36		43	79
TOTAL CHANGE		145	28	71	244

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE
1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Biwabik

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River					
A_2 Reservoir & Pits	17				17
A_3 Natural Lake					
A_5 Tailings Basin (Water Area Highly Dynamic)					
Extractive Features					
B_1 Iron Ore Mine Pits	40	18		13	71
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)	29	17		88	134
B_5 Gravel & Rock Quarries	26	20			46
Other Features					
F Fields & Other Open Areas	3	98		39	140
TOTAL CHANGE	115	153		140	408

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE
1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Bovey

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River					
A_2 Reservoir & Pits		140			140
A_3 Natural Lake					
A_5 Tailings Basin (Water Area Highly Dynamic)					
Extractive Features					
B_1 Iron Ore Mine Pits		55			55
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)		61			61
B_5 Gravel & Rock Quarries					
Other Features					
F Fields & Other Open Areas		83	230	6	319
TOTAL CHANGE		339	230	6	575

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE
1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Buhl

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River					
A_2 Reservoir & Pits					
A_3 Natural Lake					
A_5 Tailings Basin (Water Area Highly Dynamic)					
Extractive Features					
B_1 Iron Ore Mine Pits	95			22	117
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)		15	47	20	82
B_5 Gravel & Rock Quarries					
Other Features					
F Fields & Other Open Areas		64	6	3	73
TOTAL CHANGE	95	79	53	45	272

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE
1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Calumet

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River					
A_2 Reservoir & Pits		67			67
A_3 Natural Lake	5				5
A_5 Tailings Basin (Water Area Highly Dynamic)	152	81			233
Extractive Features					
B_1 Iron Ore Mine Pits	9				9
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)			5		5
B_5 Gravel & Rock Quarries		23			23
Other Features					
F Fields & Other Open Areas	68	110	42	30	250
TOTAL CHANGE	234	281	47	30	592

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE

1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Cohasset East

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River					
A_2 Reservoir & Pits					
A_3 Natural Lake					
A_5 Tailings Basin (Water Area Highly Dynamic)					
Extractive Features					
B_1 Iron Ore Mine Pits					
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)					
B_5 Gravel & Rock Quarries					
Other Features					
F Fields & Other Open Areas		110	22		132
TOTAL CHANGE		110	22		132

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE

1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Cohasset West

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River					
A_2 Reservoir & Pits					
A_3 Natural Lake					
A_5 Tailings Basin (Water Area Highly Dynamic)					
Extractive Features					
B_1 Iron Ore Mine Pits					
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)					
B_5 Gravel & Rock Quarries					
Other Features					
F Fields & Other Open Areas		117	129		236
TOTAL CHANGE		117	129		236

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE
1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Dewey Lake

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River				323	323
A_2 Reservoir & Pits					
A_3 Natural Lake					
A_5 Tailings Basin (Water Area Highly Dynamic)					
Extractive Features					
B_1 Iron Ore Mine Pits					
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)					
B_5 Gravel & Rock Quarries		8		20	28
Other Features					
F Fields & Other Open Areas	32	15	28	444	519
TOTAL CHANGE	32	23	28	787	870

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE
1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Dewey Lake S.E.

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River					
A_2 Reservoir & Pits		50		2	52
A_3 Natural Lake		11		3	14
A_5 Tailings Basin (Water Area Highly Dynamic)					
Extractive Features					
B_1 Iron Ore Mine Pits					
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)					
B_5 Gravel & Rock Quarries		6			6
Other Features					
F Fields & Other Open Areas		35		66	101
TOTAL CHANGE		102		71	173

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE
1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Embarass

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River					
A_2 Reservoir & Pits					
A_3 Natural Lake				10	10
A_5 Tailings Basin (Water Area Highly Dynamic)					
Extractive Features					
B_1 Iron Ore Mine Pits					
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)					
B_5 Gravel & Rock Quarries					
Other Features					
F Fields & Other Open Areas				118	118
TOTAL CHANGE				128	128

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE
1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Eveleth

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River				197	197
A_2 Reservoir & Pits					
A_3 Natural Lake					
A_5 Tailings Basin (Water Area Highly Dynamic)		51			51
Extractive Features					
B_1 Iron Ore Mine Pits		68			68
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)					
B_5 Gravel & Rock Quarries					
Other Features					
F Fields & Other Open Areas		79		130	209
TOTAL CHANGE		198		327	525

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE
1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Gilbert

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River					
A_2 Reservoir & Pits	94	4		14	112
A_3 Natural Lake					
A_5 Tailings Basin (Water Area Highly Dynamic)	5				5
Extractive Features					
B_1 Iron Ore Mine Pits					
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)					
B_5 Gravel & Rock Quarries	2			2	4
Other Features					
F Fields & Other Open Areas					
TOTAL CHANGE	101	4		16	121

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE
1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Grand Rapids

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River					
A_2 Reservoir & Pits					
A_3 Natural Lake					
A_5 Tailings Basin (Water Area Highly Dynamic)					
Extractive Features					
B_1 Iron Ore Mine Pits					
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)					
B_5 Gravel & Rock Quarries					
Other Features					
F Fields & Other Open Areas		279	60	24	363
TOTAL CHANGE		279	60	24	363

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE
1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Hibbing

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River					
A_2 Reservoir & Pits				6	6
A_3 Natural Lake					
A_5 Tailings Basin (Water Area Highly Dynamic)				7	7
Extractive Features					
B_1 Iron Ore Mine Pits				173	173
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)	5			34	39
B_5 Gravel & Rock Quarries					
Other Features					
F Fields & Other Open Areas			365	285	650
TOTAL CHANGE	5		365	505	875

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE
1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Isaac Lake

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River					
A_2 Reservoir & Pits				4	4
A_3 Natural Lake					
A_5 Tailings Basin (Water Area Highly Dynamic)					
Extractive Features					
B_1 Iron Ore Mine Pits		75		151	226
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)		33		33	66
B_5 Gravel & Rock Quarries					
Other Features					
F Fields & Other Open Areas		226		349	575
TOTAL CHANGE		334		537	871

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE

1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Kewatin

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River					
A_2 Reservoir & Pits					
A_3 Natural Lake					
A_5 Tailings Basin (Water Area Highly Dynamic)	24		1049	13	1086
Extractive Features					
B_1 Iron Ore Mine Pits	37				37
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)	31	35		50	116
B_5 Gravel & Rock Quarries					
Other Features					
F Fields & Other Open Areas	101	222	73	40	436
TOTAL CHANGE	193	257	1122	103	1675

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE

1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Kinney

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River					
A_2 Reservoir & Pits	*	*	*	*	108
A_3 Natural Lake					
A_5 Tailings Basin (Water Area Highly Dynamic)	*	*	*	*	2904
Extractive Features					
B_1 Iron Ore Mine Pits	173		73	40	285
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)	95	29	32	51	207
B_5 Gravel & Rock Quarries					
Other Features					
F Fields & Other Open Areas	1084	863	445		2392
TOTAL CHANGE	1352	892	550	91	5897

* Change present but total area not differentiated by year.

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE

1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Kirk

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River					
A_2 Reservoir & Pits	*	*		*	441
A_3 Natural Lake					
A_5 Tailings Basin (Water Area Highly Dynamic)					
Extractive Features					
B_1 Iron Ore Mine Pits					
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)					
B_5 Gravel & Rock Quarries					
Other Features					
F Fields & Other Open Areas					
TOTAL CHANGE					441

* Change present but total area not differentiated by year.

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE

1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME McKinley

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River					
A_2 Reservoir & Pits					
A_3 Natural Lake					
A_5 Tailings Basin (Water Area Highly Dynamic)					
Extractive Features					
B_1 Iron Ore Mine Pits					
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)	58	98	27	39	222
B_5 Gravel & Rock Quarries					
Other Features					
F Fields & Other Open Areas	53	69	30	20	172
TOTAL CHANGE	111	167	57	59	394

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE
1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Nashwauk

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River					
A_2 Reservoir & Pits					
A_3 Natural Lake					
A_5 Tailings Basin (Water Area Highly Dynamic)					
Extractive Features					
B_1 Iron Ore Mine Pits					
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)	22	15	9		46
B_5 Gravel & Rock Quarries				7	7
Other Features					
F Fields & Other Open Areas	29	171		14	214
TOTAL CHANGE	51	186	9	21	267

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE
1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Pengilly

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River					
A_2 Reservoir & Pits	8	41			49
A_3 Natural Lake					
A_5 Tailings Basin (Water Area Highly Dynamic)	28				28
Extractive Features					
B_1 Iron Ore Mine Pits		20	163	25	208
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)		6	19	79	104
B_5 Gravel & Rock Quarries					
Other Features					
F Fields & Other Open Areas	16	312	222		550
TOTAL CHANGE	52	379	404	104	939

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE

1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Silica

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River					
A_2 Reservoir & Pits	*	*	*		663
A_3 Natural Lake					
A_5 Tailings Basin (Water Area Highly Dynamic)			20	14	34
Extractive Features					
B_1 Iron Ore Mine Pits					
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)					
B_5 Gravel & Rock Quarries					
Other Features					
F Fields & Other Open Areas	87	181	223	387	878
TOTAL CHANGE	87	181	243	401	1575

* Change present but total not differentiated by year.

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE

1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Siseebakwet Lake

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River					
A_2 Reservoir & Pits					
A_3 Natural Lake					
A_5 Tailings Basin (Water Area Highly Dynamic)					
Extractive Features					
B_1 Iron Ore Mine Pits					
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)					
B_5 Gravel & Rock Quarries					
Other Features					
F Fields & Other Open Areas		165	256		421
TOTAL CHANGE		165	256		421

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE

1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Virginia

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River					
A_2 Reservoir & Pits	*	*		*	12
A_3 Natural Lake					
A_5 Tailings Basin (Water Area Highly Dynamic)	*	*		*	219
Extractive Features					
B_1 Iron Ore Mine Pits	325	45		198	568
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)	156			163	319
B_5 Gravel & Rock Quarries					
Other Features					
F Fields & Other Open Areas	136	219		252	607
TOTAL CHANGE	617	264		613	1725

* Change present but total area not differentiated by year.

LAND COVER CHANGE ON MINNESOTA'S MESABI RANGE

1:24,000 SCALE, QUADRANGLES IN ACRES

QUADRANGLE NAME Zim

TYPE OF CHANGE	69-72	72-73	73-74	74-75	TOTAL
Water Features					
A_1 Stream or River					
A_2 Reservoir & Pits		10	17		27
A_3 Natural Lake					
A_5 Tailings Basin (Water Area Highly Dynamic)					
Extractive Features					
B_1 Iron Ore Mine Pits					
B_2 Iron Ore Dumps & Stockpiles (Includes Mine Plant Location)					
B_5 Gravel & Rock Quarries					
Other Features					
F Fields & Other Open Areas		163	9		172
TOTAL CHANGE		173	26		199