A GEOGRAPHY OF LEPROSY AND TUBERCULOSIS IN AFRICA AND LAND USE ASSOCIATED WITH SAND AND GRAVEL EXTRACTION ON A PORTION OF THE MASON ESKER

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A GEOGRAPHY OF LEPROSY AND TUBERCULOSIS IN AFRICA

By

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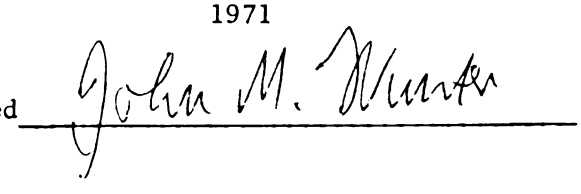
Approved 

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INTRODUCTION

Disease has had a major impact upon the African continent, presently and in the distant past (Hughes and Hunter, 1970, pp. 445). In Africa as in other parts of the world, diseases are part of an intricate system of interacting forces. A particular health problem is contingent upon a host of social, economic, and climatic factors. The principal ingredients of health problems are always the same throughout the world-men and diseases interacting (Bryant, 1969, p. 19).

The purpose of this research is to peruse the literature that pertains to leprosy and tuberculosis in Africa and to discern patterns, trends, and impacts of leprosy and tuberculosis.

It has been estimated by the World Health Organization (WHO) that 35.8% of the world's leprosy cases are in Africa, a continent which contains 10% of the world's population (Bulletin World Health Organization, 1966, p. 811). In Zambia tuberculosis ranks second to pneumonia as the most serious health problem (Gove, 1967, pp. 52-54). During 1961, WHO conducted a tuberculosis survey in Kenya. The results indicated 110,000 cases in a population of 6,000,000 (Roelsgaard and Nyboe, 1961, p. 868).

Leprosy and tuberculosis offer an opportunity to study two diseases in which there appears to be cross-immunization.[1] The exact mechanism of

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[1]Leprosy and tuberculosis both are caused by acid-fast bacteria (Mycobacterium) which have some morphologic resemblance.

the immunological relationship is not known, but it is thought that populations with a high prevalence of tuberculosis may have increased resistance to and hence lower prevalence of leprosy (Grounds, 1964, p. 13). This may be due to the fact that both diseases are chronic and infectious. Tuberculosis is more infectious and spreads more rapidly in non-immune populations than does leprosy (Chaussinaud, 1953, p. 90). Populations heavily infected with tuberculosis are said to be afforded some protection from leprosy which has a longer incubation period and slower spread. Tuberculosis tends to spread faster in the densely populated areas and has ousted leprosy except in the less populated regions where it eventually died out (Grounds, 1964, p. 13). This phenomenon of cross-immunization also takes place with respect to yaws and syphillis (Taneja, 1967, p. 215). Both leprosy and tuberculosis are on the verge of becoming "tropical diseases" in that infection rates are significantly lower in extratropical regions.[2]

The transmission of an infectious disease requires three factors: (1) a susceptible human population, (2) a bacterium or other disease agent, and (3) close contact between infected and non-infected humans, with perhaps a vector. In order for a disease to occur in endemic proportions, all three factors must be present in close proximity of each other. Each portion of the transmission cycle can be expressed geographically. Each factor in the cycle has a particular ecology to which it is best suited. By attempting such an investigation perhaps the nagging problem of why and how some people become infected, while others do not, can be understood.

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[2]The author is not making the assumption that "tropical" carries only a climatic designation.

Chapter 1

LEPROSY

Leprosy is a chronic, infectious, and communicable disease caused by infection with Mycobacterium leprai. The tissues principally affected are those of the skin and peripheral nerves. The leprosy bacillus is the acid-fast type which closely resembles the organism which causes tuberculosis, mycobacterium tuberculosis (Arnold, 1967, p. 296).

There are two principal types of leprosy as recognized by the Sixth International Congress of Leprosy at Madrid, 1953, and reaffirmed in Tokyo in 1963. These are as follows:

A. The Lepromatous type- The patient manifests no resistance to the disease. This type is progressive and found primarily in skin lesions producing swelling. It usually occurs symmetrically in the patient. If untreated it is usually fatal in 10 to 20 years (Arnold, 1967, pp. 297-299).

B. The Tuberculoid type- The patient manifests a vigorous resistance to the disease which usually attacks the nerves and interferes with their function. Sensation and muscular power are diminished. One early sympton is the loss of ability to feel pain or temperature changes in limited patches of the skin. Usually such conditions are not debilitating at first and go unattended (Wilcocks, 1950, p. 90). Unlike the lepromatous type, the occurence is a symetrical and sudden. Spontaneous recovery usually occurs in 1 to 3 years if untreated (Arnold, 1967, p. 299).

Leprosy is transmitted from infected cases to uninfected cases through close, prolonged, and intimate contact with the source of infection (Badger, 1964, p. 70). The exact mode of transmission from man to man is still unknown. The bacilli are commonly believed to enter either

via the nasal mucous membrane or through the skin (Cahill, 1964, p. 141). Other researchers believe the portals of entry are through the respiratory tract and open wounds on the body (Badger, 1964, p. 70).

Treatment of leprosy is based primarily upon chemotherapy utilizing the sulfones. Presently diaminodiphenylsulfone (DDS) is the most widely regarded drug used by leprologists. Dosage of specified amounts continue until skin lesions and nasal mucosa are healed and devoid of the bacilli. The time period involved is at least two or three years and rarely more than eight years. Maintenance therapy to prevent relapse is necessary for most patients. For those who cannot tolerate the sulfones, amizthiozone is a suitable replacement (Arnold, 1967, p. 301).

The general impression is that leprosy is not distributed at random throughout the world, and that it is inefficient in its method of survival. Transmission may be difficult and associated with a massive infecting dose or an intimate method of transfer and/or environmental factors about which there is insufficient information at the present time (Newell, 1966, p. 834). It is in this light that an analysis of the prevalence of leprosy is undertaken. The main thrust of the investigation will be the study of the distribution of the disease among the population in Africa and the search for determining factors of such a distribution.

Pattern of Leprosy Prevalence

The spatial dimensions of leprosy prevalence in African countries offer investigators in the opportunity to define a "leprosy belt." Using sources up to 1952, Nelson depicted the distribution of leprosy in African countries. Rates of 10 per 1000 and above occur in a definite area from Malagasy Republic to Western Nigeria. Another area of high rates occurs in Senegal, Gambia, Portuguese Guinea, and Guinea (Figure 1).

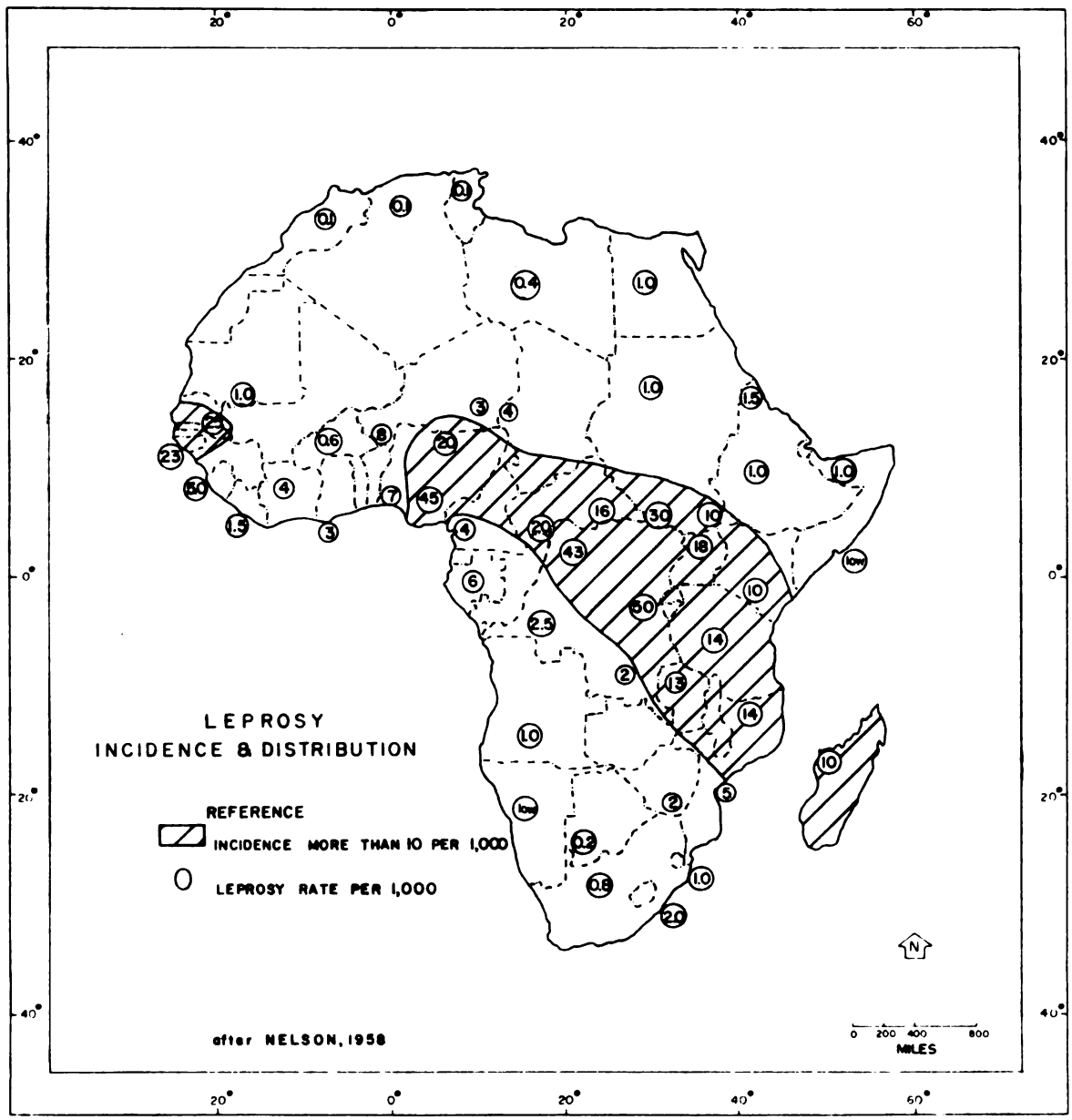
LEPROSY
INCIDENCE & DISTRIBUTION
REFERENCE
INCIDENCE MORE THAN 10 PER 1,000
LEPROSY RATE PER 1,000
after NELSON, 1958
0 200 400 800
MILES
N

Figure 1

The National Academy of Science- National Research Council published a map (Figure 2) of the estimated prevalence of leprosy in 1958. The "leprosy belt" appears to extend nearly uninterrupted from the Mozambique littoral through Senegal on the Atlantic coast. Modifications from Nelson's map include elimination of Madagascar (Malagasy Republic), the northeastern portion of Zambia and the southern portion of Nigeria (lands south of the Niger and Benue Rivers) from the ranking of the most highly endemic areas. Western Nigeria, the Guinea coast, and the Savanna states are included in the hyperendemic zone. Also included are the areas of equatorial Africa (Gabon, Congo (B), Eq. Guinea, and Cameroon). The possible expansion of the "leprosy belt" appears to demonstrate better "hunting techniques" and reporting procedures.

Schaller published a map of estimated leprosy prevalence in African countries (Figure 3)[3]. Schaller's modification of the "leprosy belt" is removing Mozambique and Malawi from the hyperendemic group. A visual constriction of the "leprosy belt" appears from the comparison of Figures 2 and 3. A limitation in comparing the two maps arises because of a lack of quantitative values attached to the legend.

To assess the present pattern of leprosy the most recent prevalence estimates were ranked from highest to lowest (Table 1). The occurence of leprosy shows a disintegration of the "leprosy belt" into two regions with rates greater than 28,700 per million (Figure 4). The Central African Republic and Zaire (Congo, K.) form a region separate from those countries near the headwaters of the Niger River (Mali, Guinea, Portuguese Guinea, Ivory Coast, and Upper Volta).

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[3]No quantitative values were given in the source for the patterns shown in Figure 3.

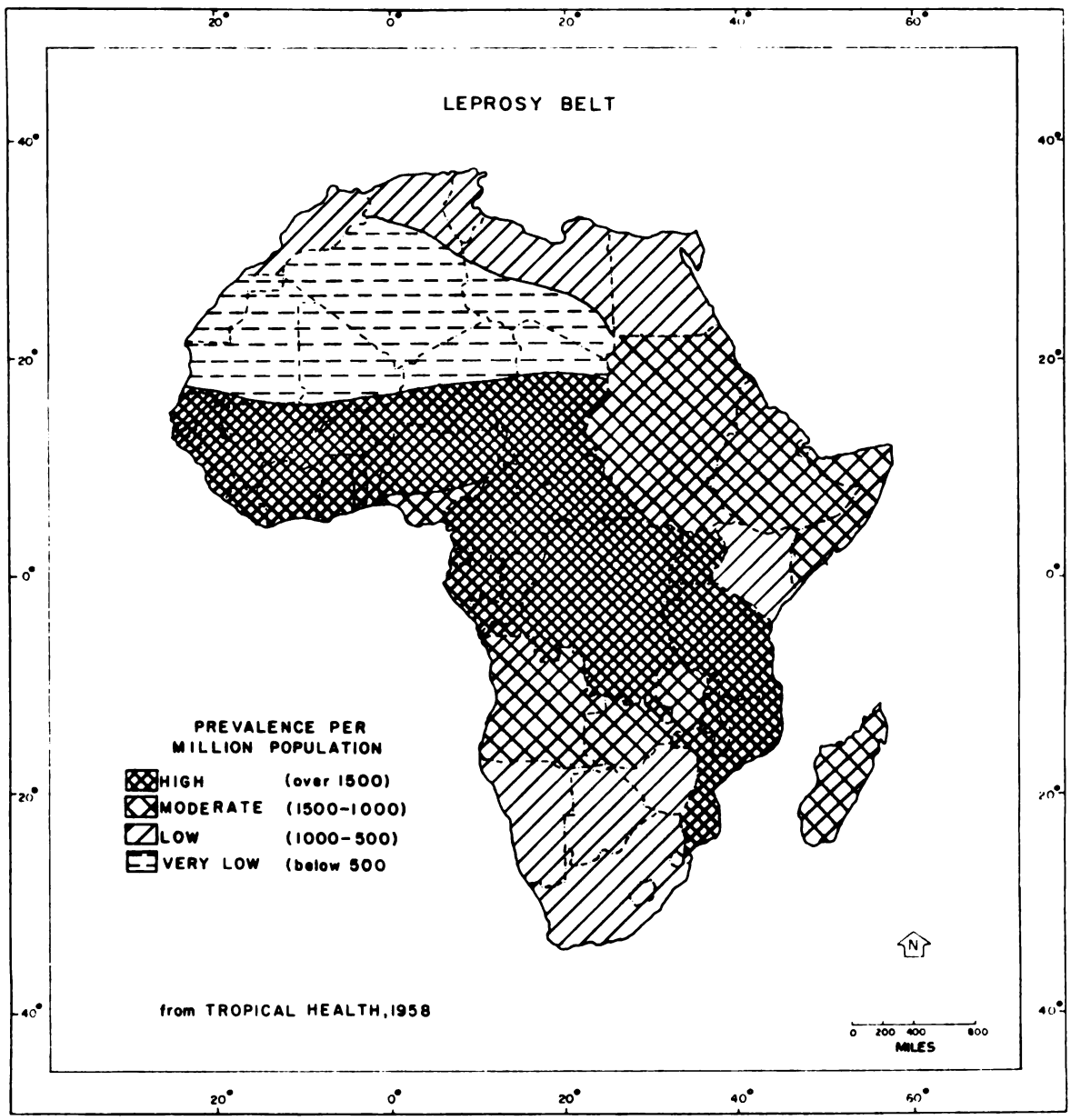

LEPROSY BELT
PREVALENCE PER
MILLION POPULATION
HIGH (over 1500)
MODERATE (1500-1000)
LOW (1000-500)
VERY LOW (below 500
from TROPICAL HEALTH, 1958
0 200 400 800
MILES
N
20° 0° 20° 40° 60°
40° 20° 0° 20° 40°

Figure 2

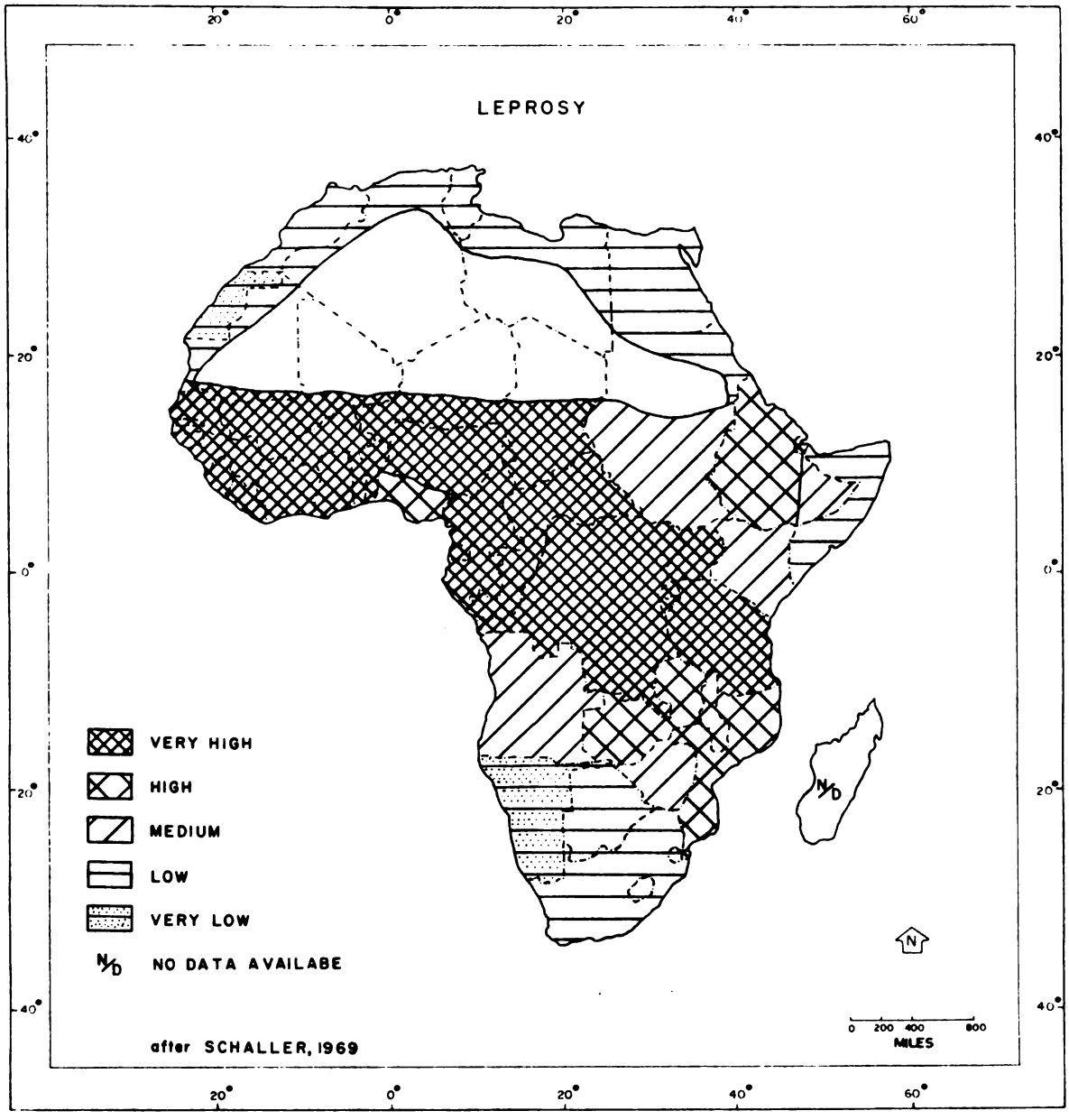

LEPROSY
VERY HIGH
HIGH
MEDIUM
LOW
VERY LOW
N/D NO DATA AVAILABE
after SCHALLER, 1969
N/D
N
0 200 400 800
MILES
20° 0° 20° 40° 60°
40°
20°
0°
20°
40°

Figure 3

Table 1.--Latest Estimates of Leprosy Prevalence in African Countries[a]

Country[b]	Prevalence per million population[c]	Source	Year of Estimate
Central African Republic	93,400	Bechelli et al	1963
Upper Volta	51,000	Bechelli et al	1963
Ivory Coast	49,900	Bechelli et al	1964
Guinea	48,000	Bechelli et al	1964
Eq. Guinea	45,000	Bechelli et al	1959
Sierra Leone	40,000	Bechelli et al	1958
Mali	34,800	Bechelli et al	1963
Zaire (Congo, K)	34,800	Bechelli et al	1959
Togo	34,500	Bechelli et al	1962
Lesotho	33,000	Bechelli et al	1959
Portugese Guinea	30,600	Bechelli et al	1959
Dahomey	28,700	Bechelli et al	1963
Cameroon	25,800	Martinez Dominguez	1966
Gambia	24,000	Bechelli et al	1955
Gabon	22,200	Lechat	1968
French Afars and Issas	22,000	Bechelli et al	1964
Liberia	21,500	Bechelli et al	1963
Zambia	20,000	Bechelli et al	1962
Congo (Brazzaville)	18,000	Lechat	1968
Nigeria	18,000	Bechelli et al	1963
Uganda	17,000	Bechelli et al	1962
Mozambique	16,500	Bechelli et al	1962
Swaziland	16,500	Bechelli et al	1964
Sengal	16,000	Bassett	1964
Chad	15,000	Lechat	1968
Kenya	15,000	Ziedses des Plantes	1968
Malawi	15,000	Molesworth	1967
Ethiopia	15,000	Schaller	1959
Burundi	13,750	Bechelli et al	1960
Niger	13,100	Bechelli et al	1963
Malagasy Republic	12,000	Bechelli et al	1965
Rwanda	11,740	Bechelli et al	1968
Angola	11,500	Bechelli et al	1959
Tanzania	10,000	Wheate	1969
Sudan	10,000	Bechelli et al	1959
Ghana	8,570	Bechelli et al	1964
Mauritania	6,040	Bechelli et al	1963
South Africa	5,260	Schulz & Pentz	1968
Botswana	4,960	Bechelli et al	1963
Zimbabwe (Rhodesia)	4,960	Bechelli et al	1963

Table 1.--(Cont.)[a]

Country[b]	Prevalence per million population[c]	Source	Year of Estimate
Somalia	2,220	Bechelli et al	1959
United Arab Republic	2,220	Bechelli et al	1962
Libya	2,200	Bechelli et al	1964
Spanish Sahara	2,020	Bechelli et al	1964
Algeria	2,000	Bechelli et al	1964
Morocco	2,000	Bechelli et al	1953
Tunisia	2,000	Bechelli et al	1964
Namibia (South West Africa)	1,170	Bechelli et al	1963

[a]Prevalence is defined as the proportion of the population who at some time have had or are affected by the disease.

[b]Names of countries are those used by Organization of African Unity.

[c]Calculations of rates per million were made by author (MOT) to standardize the data.

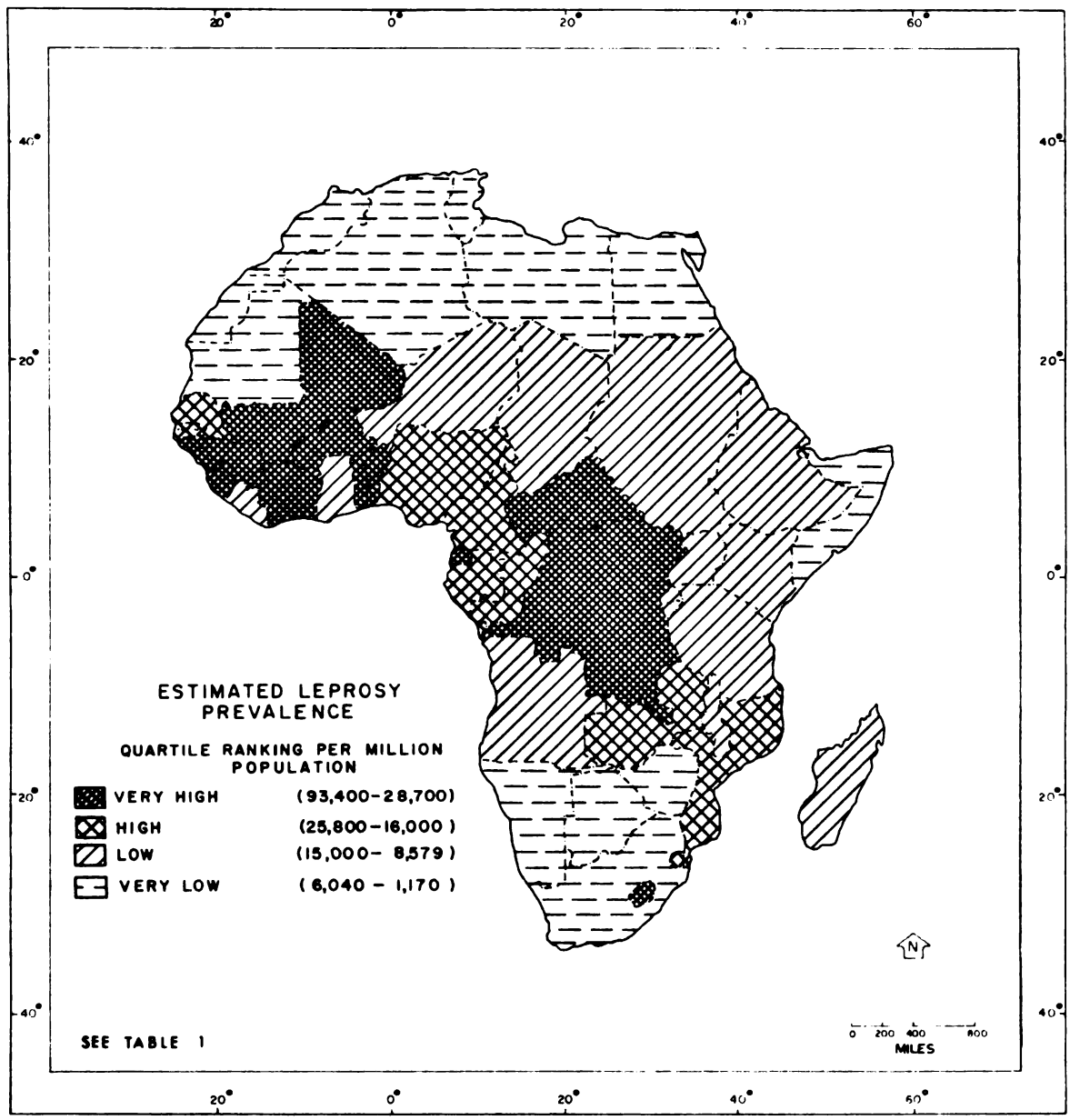

ESTIMATED LEPROSY PREVALENCE
QUARTILE RANKING PER MILLION POPULATION
VERY HIGH (93,400-28,700)
HIGH (25,800-16,000)
LOW (15,000- 8,579)
VERY LOW (6,040 - 1,170)
SEE TABLE 1
N
0 200 400 800
MILES

Figure 4

In order to gain a clear impression of the leprosy problem in Africa, one must go beyond national estimates and analyze the distribution and magnitudes of selected case studies. Case studies offer an opportunity to examine specific aspects of the epidemiology. Table 2 shows the ranking of the case study rates from highest to lowest. The time span covered is from 1953 to 1969. Studies conducted before 1953 were not tabulated on the assumption the data of that age would not contribute to the present analysis.

On the basis of the aforementioned data, upper quartile rankings occur primarily in two distinct regions including Central African Republic, Zaire (Congo, K.), and Zambia in one region. The other region would be one embracing the area from Gambia through Upper Volta (Figure 5). A third area that contains slightly lower prevalence rates can discerned in the highlands of East Africa from Lake Victoria through the Amhor plateau of Ethiopia.

The World Health Organization Technical Report Series No. 459 (1970) states that in areas where the prevalence of leprosy exceeds 500/ million population, the prevalence can be expected to rise even higher. Upon this basis it can be postulated that areas indicated by case studies have a severe medical problem. The approximately 3,868,000 cases found in Africa in 1965 are the reservoir upon which this increase is expected to be manifested (Bechelli, et. al., 1966, p. 821).

Dynamics of Spreading

Leprosy can be contracted at any age, but infants and children appear more susceptible than adults (Manson-Bahr, 1964, p. 478). Some investigators state that the great majority of patients become infected

Table 2.--Ranked Case Studies of Leprosy in Africa[a]

Number on Fig. 5	Country	Location of Study	Source	Estimated[b] Rate per million population	Mean[c] annual precipitation
1	Zaire (Congo, K)	Orientale Province	Browne-1960	118,700	67
2	Zambia	Luapula Valley	Griffiths-1965	86,000	57
3	Nigeria	Zaria	Ross-1956	68,400	50
4	Mali	Bamako	Lanquillion-1964	68,000	44
5	Zaire (Congo, K.)	Banalia	VanderMullen & Melen-1957	66,000	71
6	Central African Rep.	Central Area	Cheneveau-1958	51,000	54
7	Senegal	Eastern	Basset-1964	50,000	40
8	Ethiopia	Shoa	Schaller-1959	49,000	49
9	Upper Volta	Southern	Sansarricq-1968	44,000	46
10	Cameroon	Diamare	Bechelli, et. al.-1966	36,910	50
11	Zambia	Barotseland	Griffiths-1964	34,000	37
12	Kenya	Western	Ziedses des Plantes-1968	34,000	41
13	Senegal	Southern	Basset-1964	30,000	35
14	Uganda	Lango	Ellis-1961	28,800	61
15	Nigeria	Katsina	Bechelli, et. al.-1966	28,730	27
16	Tanzania	Kome Island	Wheate-1969	27,200	40
17	Upper Volta	Central	Sansarricq-1969	25,000	40
18	Uganda	Teso	Stone-1969	25,000	46
19	Angola	Huambo	Leite, et. al.-1958	24,340	57
20	Cameroon	Sangmelima	Bechelli, et. al.-1966	24,150	62
21	Gambia	Eastern	McFadzean & McCourt-1960	24,000	51
22	Upper Volta	Central	Sansarricq-1968	22,800	36
23	Gabon	Central	Cheneveau-1958	18,000	75
24	Tanzania	Bukoba	Korn-1966	17,000	80
25	Kenya	Kitui	Ziedses des Plantes-1968	16,600	39

Table 2.-- (Cont.)[a]

Number on Fig. 5	Country	Location of Study	Source	Estimated[b] Rate per million population	Mean[c] annual precipitation
26	Congo (Brazzaville)	Central	Cheneveau-1958	16,000	78
27	Chad	Eastern	Cheneveau-1958	16,000	29
28	Cameroon	Bamoun	Bechelli, et. al.-1966	15,520	64
29	Ethiopia	Central Valley	Schaller-1959	15,000	26
30	Kenya	Yimbo	Chum & Otsyula-1970	13,000	43
31	Kenya	South Nyanza	Ziedses des Plantes-1968	12,000	44
32	Zambia	Upper Zambezi	Worsfold-1958	11,850	38
33	Uganda	West Nile	Williams-1964	10,600	54
34	Zambia	Southern Prov.	Gauntlett-1969	10,300	27
35	Senegal	Northern	Basset-1964	10,000	25
36	Tanzania	Masasi District	Wheatley-1970	10,000	34
37	Upper Volta	Northern	Sansarricq-1968	8,500	25
38	Kenya	Coastal	Ziedses des Plantes-1968	7,000	41
39	Kenya	Central	Ziedses des Plantes-1968	3,000	38
40	Morocco	Fez	Sicault-1953	2,110	21
41	Morocco	Casablanca	Sicault-1953	2,060	16
42	Morocco	Marrakesh	Quazzini-1959	2,000	9
43	Libya	Cyrencia	Dogliotti-1967	2,000	10

[a]Case studies refer to all age groups.

[b]Data were standardized to rates per million population by author (MOT).

[c]Precipitation values were interpolated from Great Britain Meterological Office Tables of Temperature, Relative Humidity, and Precipitation for the World. Part 4, 1958, pp. 1-183.

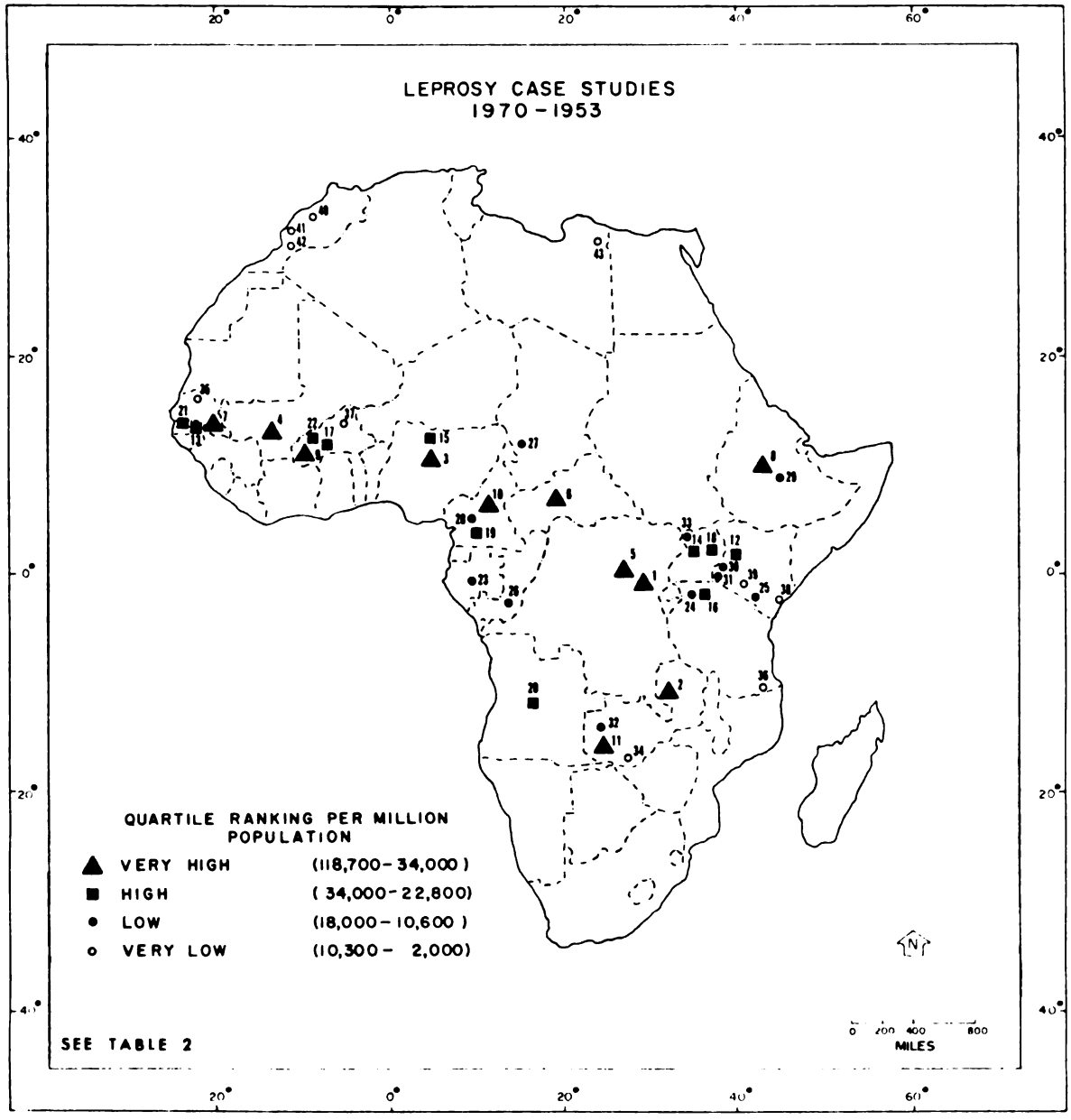

LEPROSY CASE STUDIES
1970 - 1953
QUARTILE RANKING PER MILLION POPULATION
VERY HIGH (118,700 - 34,000)
HIGH (34,000 - 22,800)
LOW (18,000 - 10,600)
VERY LOW (10,300 - 2,000)
SEE TABLE 2
0 200 400 800
MILES
N

Figure 5

in early childhood, and it is rare for an adult to become infected (Badger, 1964, p. 76; Table 3).

The distribution up to 90% of the cases in the 5 to 44 year age bracket is thought to be partly a function of exposure as young children are frequently carried along on their mother's back. Due to the long incubation period (3-5 years), the children exposed early in life do not show signs of leprosy until they become part of the 5-14 age group. Young adults (15-44 years) are generally the most mobile portion of the population; as a result they have a very good chance of being exposed.

Contact

The traditional and perhaps easiest way in which leprosy is spread has been explained by the following statement, "close prolonged contact of a susceptible person with infectious case." If A is the infectious case, capable of infecting the susceptible person B, then just what is the mechanism that causes or allows Mycobacterium lepras to be transmitted between persons?

The pursuit of that mechanism has led Henry L. Arnold Jr. to write the following:

> The transmission of leprosy is mysterious. It is so difficult to acquire that it was believed for many decades to be hereditary rather than contagious. Yet it is so easy to acquire that nearly half the patients with recently acquired disease are unaware of having any contact with another diseased person (Arnold, 1967, p. 297 in Cecil and Loeb).

Not all investigators of leprosy epidemiology are on the side of the "close contact" theory. In particular, work is being urged on the possibility of fleas and lice as possible vectors.

> As leprosy has always been known to spread where squalor and vermin abound but to stop spreading when cleanliness

Table 3.--Age and Leprosy Infection in Northern Nigeria and Cameroon

	Age Group	Population Examined	Cases	Per cent[a] of Cases	Rates per[a] Million Population
Northern Nigeria--					
	0-1	1,110	0	-	-
	1-4	3,801	8	1.2	2,100
	5-14	5,370	175	24.8	32,590
	15-44	12,012	408	57.8	33,660
	45+	2,245	114	16.2	55.780
		24,538	705	100.0	28,700
Cameroons--					
	0-1	425	0	-	-
	1-4	1,809	2	0.5	1,500
	5-14	3,201	24	6.5	7,500
	15-44	6,335	191	51.1	30,100
	45+	2,703	157	41.9	58,780
		14,473	374	100.0	25,840

Source: Martin Dominguez, V., et. al. "W.H.O. Surveys of Disabilities in Leprosy in Northern Nigeria, Cameroon, and Thailand," International Journal of Leprosy. Vol. 34, No. 3, 1966, pp. 244-254.

[a]Rates per million population and percentages of cases were calculated by author (MOT).

> of body and housing are adopted, even where contact is frequent, direct contact seems neglible (Dungal, 1960, p. 31).

The idea that filth and squalor was associated with high prevalence of leprosy is not new. T.F.G. Mayer in 1930 proposed that a poor diet (malnutrition and protein deficiency) along with overcrowding of the population caused perpetuation of leprosy. A further complicating factor in the distribution of leprosy is that in some regions, whole villages have a high rate of incidence and a uniform distribution throughout the village. However, the existence of leprosy in an endemic area may be sporadic with nearby villages having very different rates of leprosy prevalence (Cochrane et. al., 1957, p. 11).

Total Annual Precipitation

Endemic leprosy areas are found primarily in regions of high rainfall and warm temperature. While this relationship has been documented, few researchers believe that climate alone is the causative factor. Historically high leprosy rates have not been confined to the humid tropics and subtropics, since leprosy was considered a major health problem in Medieval Europe (Newell, 1966, p. 838). Researchers in India have noted a significant increase in the number of people who seek first-time medical aid just after the onset of the monsoon rains (Charravarthy, 1966, pp. 99-102).

The author has found from an analysis of case studies in Africa that there is a definite tendency for leprosy prevalence rates to increase as total annual precipitation rates increase (Figure 6). In an attempt to further refine the data, a test of correlation was conducted. The yield of a significantly high correlation value ($r = +0.441$) does offer

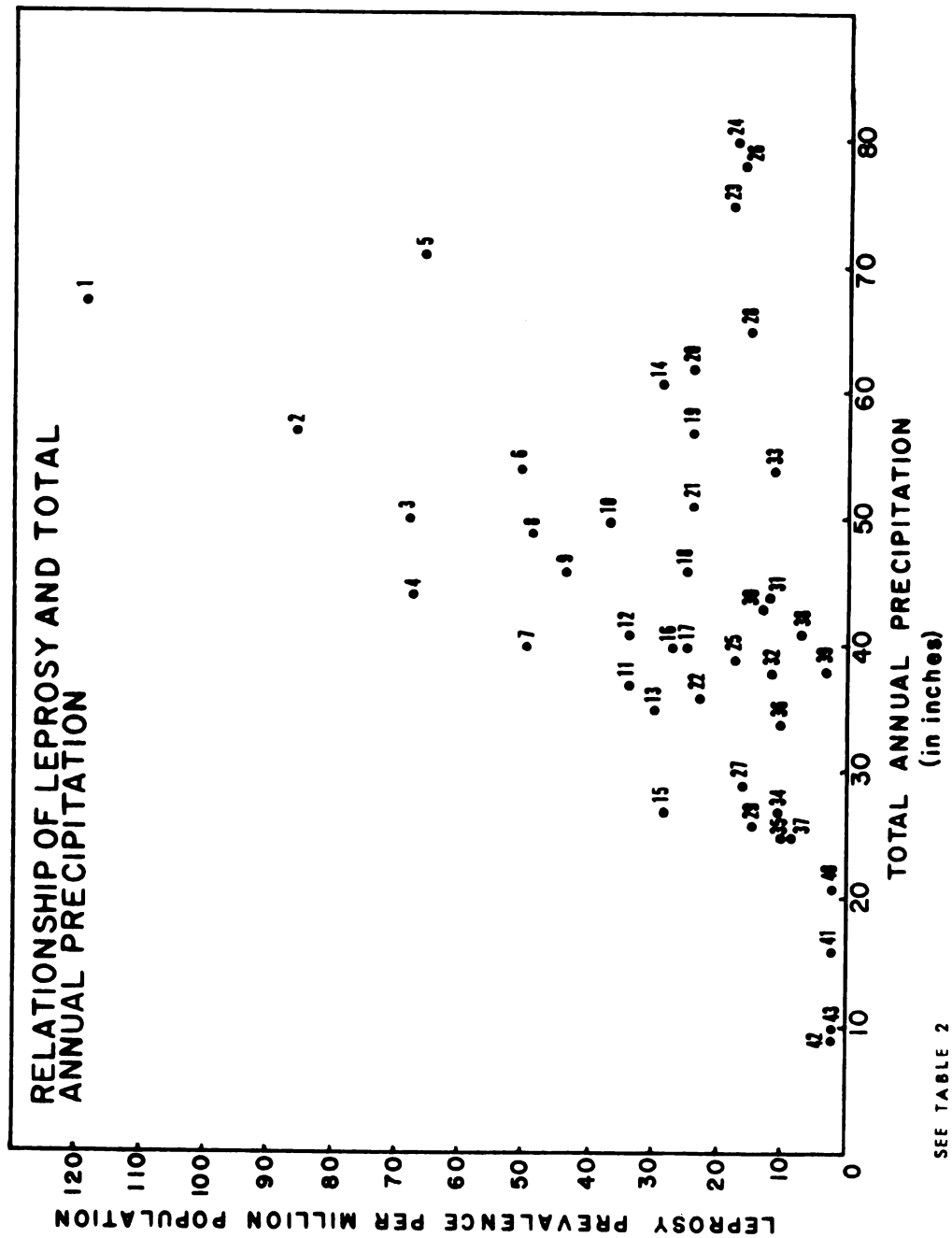

RELATIONSHIP OF LEPROSY AND TOTAL ANNUAL PRECIPITATION
LEPROSY PREVALENCE PER MILLION POPULATION
TOTAL ANNUAL PRECIPITATION (in inches)
SEE TABLE 2

Figure 6

support for the hypothesis that leprosy and high rainfall values are related. A prevalent theory is that leprosy is a filth associated disease, and that once overcrowding, poverty, and unsanitary living conditions are removed, the leprosy rates tend to decline (Doull et. al., 1936, p. 141).

An interesting possibility is the theory that an insect may be the vector that transports Mycobacterium leprai. Such speculation results from two hypotheses:

1. If the portal entry is through the skin, an injury to the skin causing a break is a necessary prerequisite. Insect bites are a common cause of such skin breaks which may help to explain the higher leprosy prevalence rate in hot-moist climates (Doull, 1962, p. 52). Experimental evidence support an optimun growth temperature of M. leprae of 20° C. (68° F.) (Shepard, 1965, p. 1275.)
2. Fleas and lice may be possible vectors as they were reported to be prevalent in endemic areas on a world-wide basis (Dungal, 1960, pp. 25-34).

Chapter II

TUBERCULOSIS

Tuberculosis caused by Mycobacterium tuberculosis is an infectious disease of man and animals and an important cause of death. There are five established varieties of the tubercule bacillus that cause similar manifestations in man and animals. They are the bovine (M. bovis), the avian (M. avium), the human (M. tuberculosis), the murine (M. microti), and the piscine (M. marinum). Tuberculosis in humans is caused by the human and bovine varieties (Muschenheim, 1967, p. 259). The bovine and human varieties are able to infect animals and humans reciprocally, thus the primary reservoirs are cattle and man (May, 1958, p. 109).

Infection occurs due to prolonged contact with infected individuals and consumption of unpasteurized milk. Most commonly infection takes place by entrance into the body of tiny droplets and sputum through the process of inhalation. Bloodstream and congenital infection are rare (Muschenheim, 1967, p. 261). When the tubercule bacillus enter the human body very little reaction is provoked. The bacilli remain extracellular and migrate by lymphatic channels to establish infection in the lymph nodes (Seabury, 1968, p. 183). When a potential human host encounters the bacillus, its natural defense may be adequate. If such is the case, the bacillus may be sealed off by the body's tissues creating a scar in which the bacillus is imprisoned. A chronic benign form will now be present which will react to skin tests. The host that contains the benign

form of tuberculosis may become infected from the bacillus in his own system erupting from the scar tissue (Heaf, 1967, p. 73). Tuberculosis may affect almost any tissue or organ of the body; the most common seats are the lungs and joints.

Fatigue, anorexia, weight loss, malaise, fever, and night sweats are manifestations common to tuberculosis. These symptoms are common to many illnesses and, in the tropics, the people most afflicted are those who have never known really good health. Local symptoms of cough and abundant sputum indicate the pulmonary variety which accounts for 40% of all cases (Seabury, 1966, p. 187). For the above reasons, a combination of methods are used to diagnose tuberculosis. The skin test is common. Examination of sputum by a straining technique isolates the bacillus which are acid-fast. The final method is through the use of X-ray to detect scar tissue (Gordon, 1965, p. 252).

Pattern of Tuberculosis Prevalence

The history of tuberculosis is long and complex. In many parts of the world it has been reduced to very low levels. In other areas it is increasing in prevalence. Tuberculosis appears to be becoming a disease associated with the tropics for socio-economic reasons (Lauchner, 1959, p. 1). It would reason that the level of economic development, social mobility, and urbanization combine to play an important part in the spatial pattern of tuberculosis (Henschen, 1966, p. 101).

Up to the end of the nineteenth century, tuberculosis bacillus was most prevalent along the coast of Africa. The subsequent development of large trading and industrial centers caused tuberculosis to be spread widely. Until the colonial era, the settlement pattern of Africa was

primarily that of small clans and ethnic groups which tended to minimize contacts over wide areas. Even though there were carriers of tuberculosis, widespread diffusion was not taking place. New concentrations of populations occurred and inter-ethnic contact increased after the beginning of colonialism. In 1900, tuberculosis was nonexistent in the former Belgian Congo (Zaire), but in 1921, the number of cases was reported to be rapidly increasing (1900, no cases; 1915, 41 cases; 1921, 103 cases reported). Medical practitioners noted that there was usually an almost total absence of tuberculosis upon penetration. However, the disease attacked the African population at epidemic strength as the European presence increased (Roelsgaard et. al., 1964, pp. 459-463).

Regional foci of tuberculosis in Africa could be hypothesized along the Guinea Coast of West Africa, the mineral rich zone of Central and, Southern Africa, the plateau country of East Africa, and the North African Coast. The West African Coast is a major dispersal point for tuberculosis into the less populated parts of the interior. The mining concerns and industrial development of Central and Southern Africa have attracted workers from a wide area. Recent and past shifts in population in the East African region have caused tuberculosis to become widespread in that part of Africa. Tuberculosis has spread rapidly into some Saharan communities as a result of petroleum exploitation (Meyrney, 1960, p. 139).

Although tuberculosis is a major health problem in Africa, detailed statistics pertaining to nationwide prevalence are lacking. Table 4 shows the latest infection percents in the populations of selected African nations. The high value of youthful infection is an indicator of the severity and the future scope of tuberculosis infection. Most of the high infection rates appear to be associated with the most rapidly developing areas of

Table 4.--Estimated Tuberculosis Infection in African Countries

Country	% Estimated Youth[a] Infection[b]	Sources
Botswana	20	WHO Chronicle-1965
Burundi	39	Geser, et. al.-1966
Dahomey	32	Geser, et. al.-1966
Gambia	11	WHO Chronicle-1965
Ghana	15	WHO Chronicle-1965
Ivory Coast	10	WHO Chronicle-1965
Kenya	10	WHO Chronicle-1965
Lesotho	11	WHO Chronicle-1965
Liberia	9	WHO Chronicle-1965
Libya	8	WHO Chronicle-1965
Malawi	5	WHO Chronicle-1965
Mauritania	16	WHO Chronicle-1965
Mozambique	7	WHO Chronicle-1965
Nigeria	24	WHO Chronicle-1965
Senegal	10	WHO Chronicle-1965
Sierra Leone	23	WHO Chronicle-1965
Somalia	31	WHO Chronicle-1965
Sudan	22	WHO Chronicle-1965
Swaziland	15	WHO Chronicle-1965
Tanzania	10	WHO Chronicle-1965
Tunisia	12	WHO Chronicle-1965
Uganda	9	WHO Chronicle-1965
U.A.R.	22	WHO Chronicle-1965

Sources:

Geser, A., Roy, L. A., and Bløcher, C. "Direct BCG Vaccination in Burundi, Dahomey, and Mauritania. A study of Local Complications," Bulletin of World Health Organization. Vol. 35, No. 4, 1966, pp. 609-632.

"WHO Assisted Activities in Tuberculosis 1959-1964" WHO Chronicle. Vol. 19, No. 8, 1965, pp. 309-325.

[a]Youth is defined as all those in the age group 0-15 years of age.

[b]Infection is defined as those persons with positive tuberculin reactions as a result of vaccination.

settlement (Figure 7) and (Figure 12). The incidence of newly reported cases of tuberculosis offers an opportunity to discern possible hyper-endemic areas. As shown in Figure 8, the areas where economic development (urbanization, industrialization, etc.) is taking place have the high incidence of new cases. As a precaution it should be considered that the nature and sophistication of reporting techniques vary from country to country.

An analysis of the spatial variation of case study rates provides further evidence of the regionalization of tuberculosis. The case study rates shown in Table 7 are ranked from highest to lowest. Upper quartile cases can be shown in Figure 9 as occurring in at least four distinct regions; the North African Coast, the Guinea Coast, the Lake Victoria area, and the Mineral Belt of Central and Southern Africa.

Table 5.--Newly Reported Cases of Tuberculosis in Africa 1966 and 1967[a]

Country	Reported Cases[b]	Rate per million population[c]
Angola	3,298	441
Botswana	1,497	2,524
Burundi	1,985	601
Cameroon	1,164	215
Central African Rep.	601	427
Chad	1,666	485
Congo (Brazzaville)	799	929
Dahomey	396	158
Ethiopia	32,354*	1,367
F. Afars & Issas	958	11,827
Gabon	327	701
Gambia	633	1,861
Ivory Coast	2,337	584
Kenya	5,978	603
Lestho	1,661	1,887
Liberia	430	391
Libya	4,554	2,681
Malagasy Republic	4,028	623
Malawi	6,211	1,498
Mali	1,237	268
Mauritania	1,610*	1,504
Mozambique	1,575	221
Niger	823	222
Nigeria	9,203	149
Portugese Guinea	346	665
Senegal	3,539	983
South Africa	69,261	3,703
Spanish Sahara	310	5,082
Sudan	17,052*	1,681
Swaziland	1,298	3,547
Tanzania	19,413	1,509
Togo	433	260
United Arab Rep.	4,377*	215
Upper Volta	316	625
Zaire (Congo, K)	935*	58
Zambia	3,502	897
Zimbabwe (Rhodesia)	4,093	890

Source: World Health Statistics Annual, Vol. 2, 1966 and Vol. 2, 1967.

[a]Those cases marked with an asterisk (*) are for the year 1966.

[b]Reported cases are those which have been documented or estimated by health officials.

[c]Rates per million were calculated by the author (MOT).

Table 6.--Ranked Tuberculosis Case Studies in Africa

Number in Fig. 9	Location of Study		Source	Estimated rate[a] per million population
1	Senegal	Dakar	Brunel, et. al.-1967	229,000
2	Zambia	Kitwe	Gove-1967	126,000
3	Uganda	Kampala	Lloyd-1969[b]	125,000
4	Zimbabwe (Rhodesia)	Midlands Prov.	Davies-1970	86,500
5	Tunisia	Tunis	Nyboe & Christensen-1966	65,000
6	Zambia	Broken Hill	Buchan-1967[b]	64,000
7	South Africa	Transkei	Shennan-1968	50,000
8	Morocco	Urban	Shennan-1968	50,000
9	Sierra Leone	Urban	Shennan-1968	50,000
10	United Arab Rep.	Urban	Shennan-1968	45,000
11	Botswana	Urban	Shennan-1968	40,000
12	Upper Volta	Rural	Shennan-1968	40,000
13	Ghana	Coastal village	Koch-1960	30,000
14	South Africa	Natal	Shennan-1968	30,000
15	Swaziland	Rural	Shennan-1968	30,000
16	Uganda	Kampala	Kanti & Lwanga-1971	28,700
17	Lestho	Rural	Shennan-1968	20,000
18	Port. Guinea	Rural	Das Neves-1964	15,600
19	Tanzania	Mwanza	Radtke-1968	15,000
20	Zimbabwe (Rhodesia)	Chikore	Donaldson-1971	14,570
21	Zaire (Congo,)	Luluaborg	--1957	10,800
22	Kenya	Central Prov.	Geser & Thorup-1967	10,000
23	Uganda	Rural	Geser & Thorup-1967	9,900
24	Gambia	Urban	Geser & Thorup-1967	8,000
25	Ethiopia	Harar	Blakos-1963	4,300
26	Ghana	Forest Belt	Koch-1960	3,000
27	Liberia	Urban	Geser & Thorup-1967	3,000
28	Zimbabwe (Rhodesia)	Bulawayo	Doy-1970	900
29	Nigeria	Igbo-Ora	Wyatt & Matthew-1968	900
30	Kenya	South Nyanza	Grounds-1962	400

[a]Data were standardized to rates per million by author (MOT).

[b]Case studies are not age specific except where indicated; those so marked are children only.

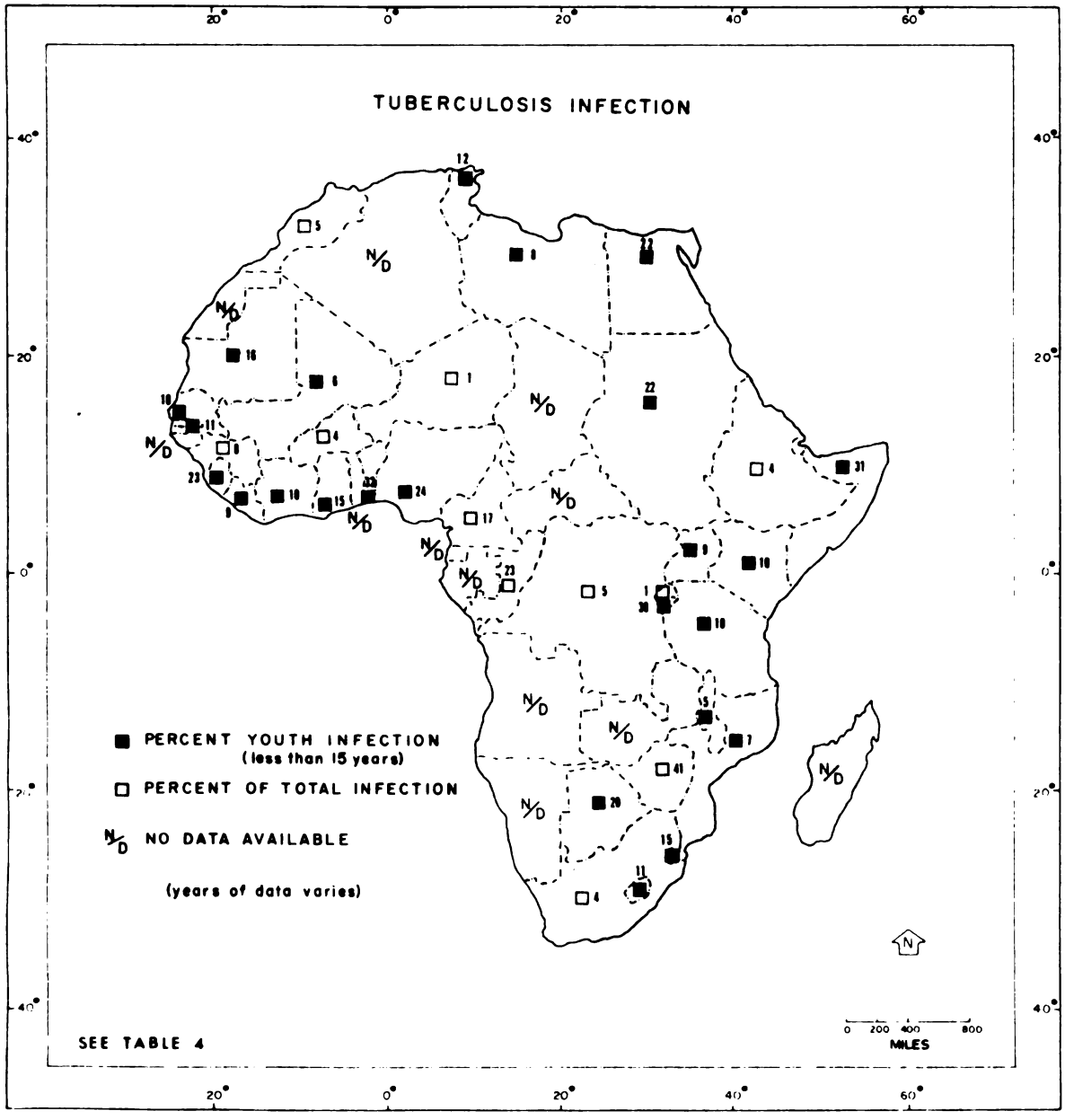

TUBERCULOSIS INFECTION
PERCENT YOUTH INFECTION
(less than 15 years)
PERCENT OF TOTAL INFECTION
N/D NO DATA AVAILABLE
(years of data varies)
SEE TABLE 4
0 200 400 800
MILES
N

Figure 7

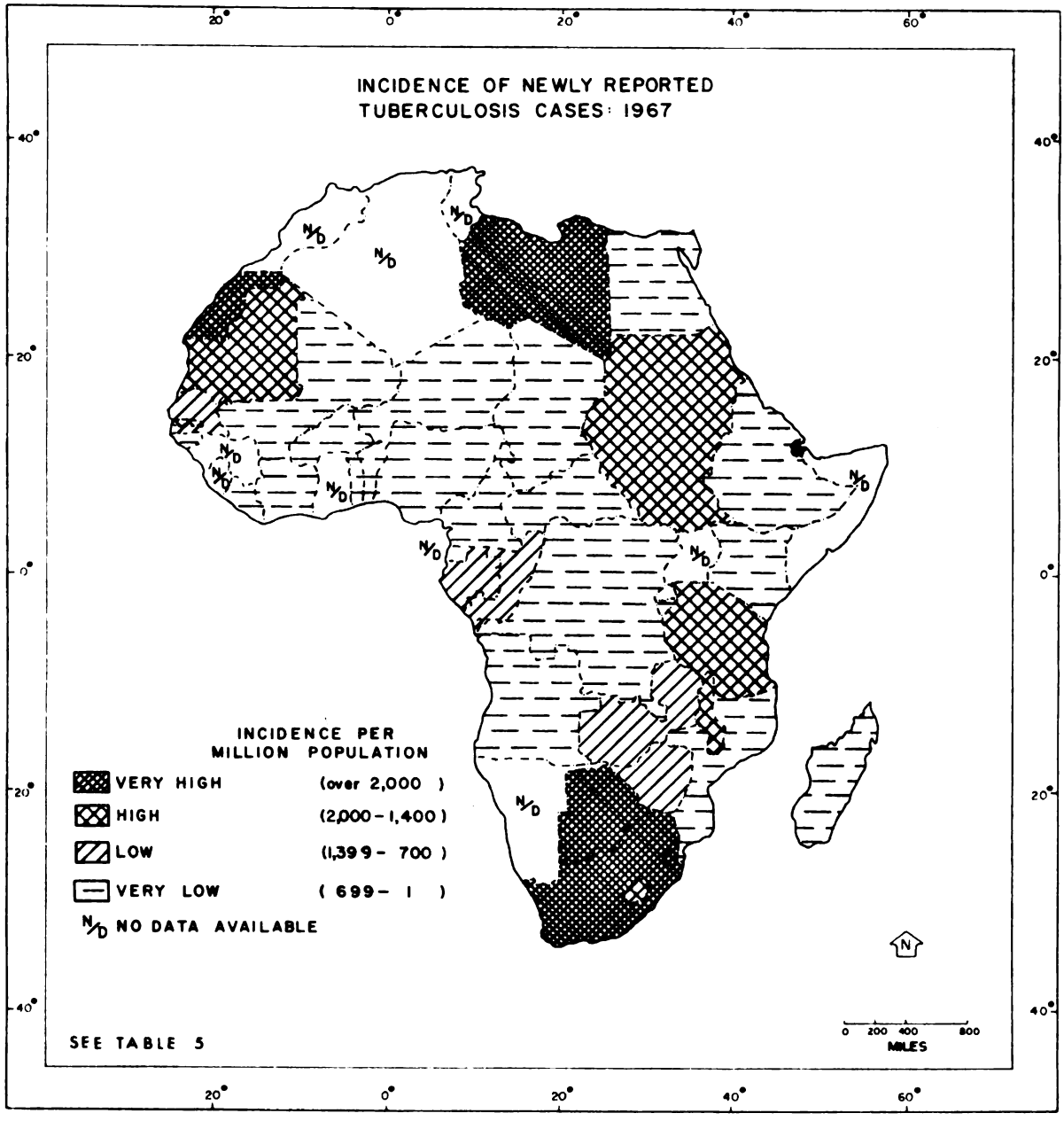

INCIDENCE OF NEWLY REPORTED
TUBERCULOSIS CASES: 1967
INCIDENCE PER
MILLION POPULATION
VERY HIGH (over 2,000)
HIGH (2,000 - 1,400)
LOW (1,399 - 700)
VERY LOW (699 - 1)
N/D NO DATA AVAILABLE
SEE TABLE 5
0 200 400 800
MILES
N
20° 0° 20° 40° 60°
40°
20°
0°
20°
40°

Figure 8

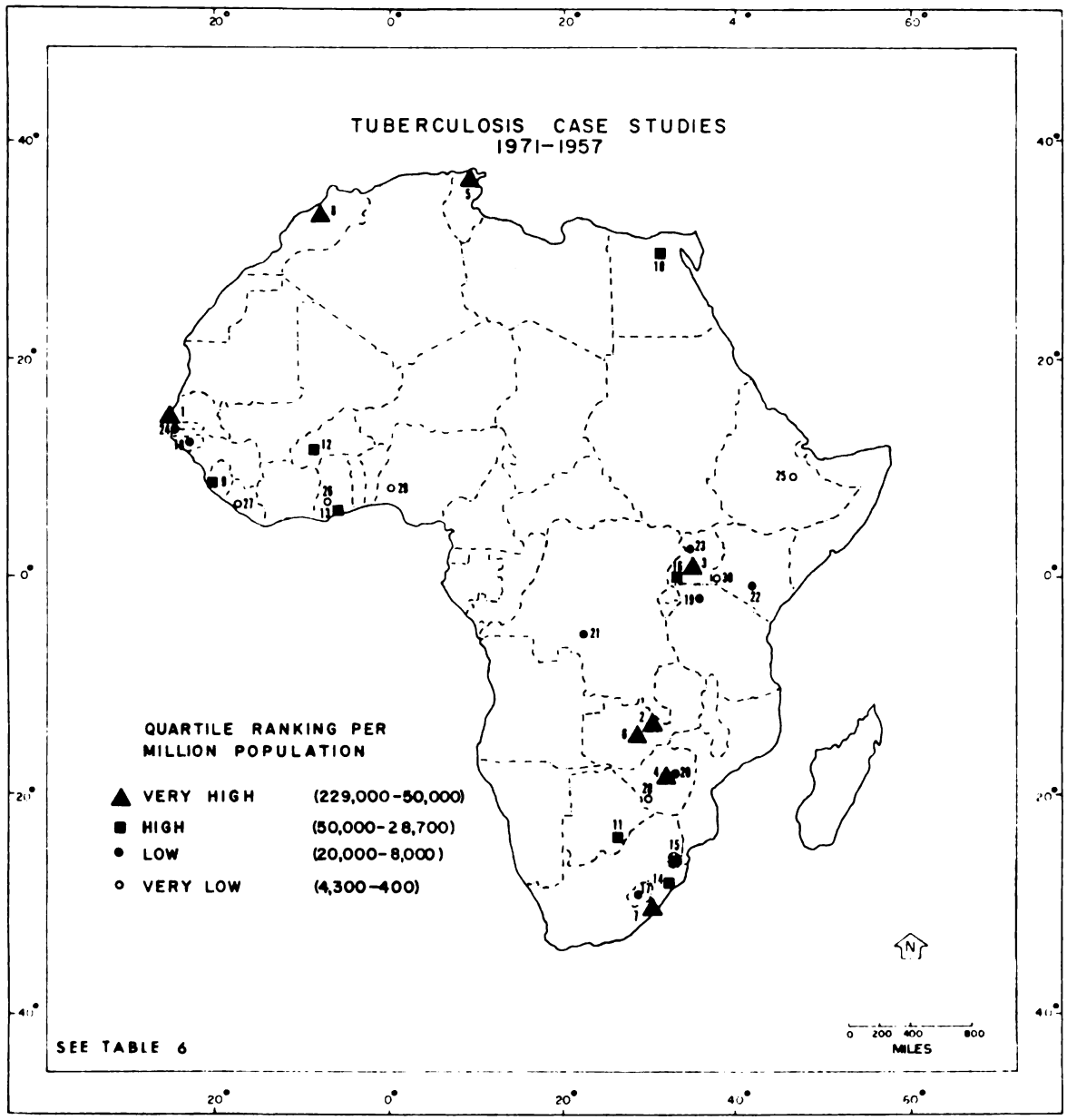

TUBERCULOSIS CASE STUDIES
1971-1957
QUARTILE RANKING PER
MILLION POPULATION
VERY HIGH (229,000-50,000)
HIGH (50,000-28,700)
LOW (20,000-8,000)
VERY LOW (4,300-400)
SEE TABLE 6
N
0 200 400 800
MILES

Figure 9

Dynamics of Spreading

Urbanization

The transmission of tuberculosis is dependent upon man-to-man contact. As the potential host comes into contact with infected host, the transmission of tuberculosis may occur. In every tuberculosis situation the size of an infector pool is of primary concern. However, the reservoir is not just active cases but also includes benign cases which may under situations of undetermined stress become active cases (May, 1958, pp. 110-111).

The world pattern shows three factors which tend to determine in any given area the prevalence of tuberculosis:

- standard of living
- length of time the disease has been present
- population density

In most of the African countries the population is primarily rural. Because of this and due to the length of time since tuberculosis becomes widespread, the amount of infection varies considerably between countries (Shennan, 1968, pp. 12-13).

African cities are usually the centers of modernization. The resulting rapid growth has fostered a host of problems for the African urban community. One problem which has a direct bearing upon tuberculosis infection is overcrowding and unsanitary conditions. Lagos, in Western Nigeria is estimated to have grown from 267,000 in 1950 to 800,000 in 1970 (Davis, 1969, p. 165). An African scholar commented upon this fact:

> Demand for housing remains insatiable owing to a chronic shortage of housing finance. The result is overcrowding

> and a rapid rate of property deterioration in most parts of Lagos. In the older parts of the city this has led to the creation of indescribably squalid slums (Mabogunje, 1969, p. 320).

Due to the lack of refined data, a statistical test of the relationship of tuberculosis prevalence to urbanization cannot be made. Visual examination of the data raises the speculation that some relationship exists. Figure 10 which shows urban centers with populations greater than 100,000 and Figures 7 and 8 which show infection rates and newly reported cases show a strong visual correlation of increasing urbanization with increasing tuberculosis infection. The work of a recent World Health Organization survey shows rural-urban comparisons in six African nations (Figure 11). In nearly all cases urban prevalence rates are higher than the corresponding rural rates (Roelsgaard, 1964, pp. 457-518).

Migration

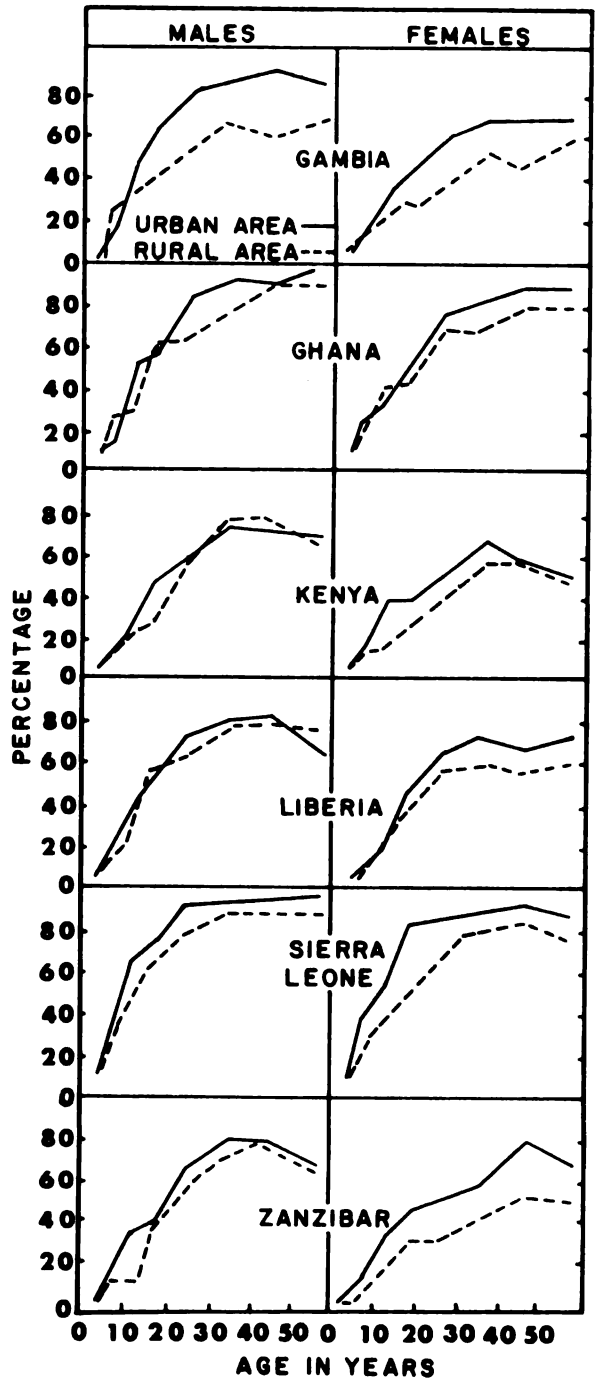
The patterns of movement from the rural areas to the urban areas is shown in Figure 12. This movement is the result of both a poor agricultural base in the rural areas and the lure of a wage earning job in the city.

Migration between rural and urban areas is only one component of the total migration phenomena. The economic development of the African continent along Western lines has had a profound influence upon the distribution of tuberculosis. Increasing industrialization has resulted in increased abandonment of the traditional way of life. The growth of urban centers near mineral-rich zones has provided for increased movements of people to towns. South Africa increased the total urban population by


URBAN CENTERS WITH POPULATION GREATER THAN 100,000
20°
0°
20°
40°
60°
40°
20°
0°
20°
40°
N
0 200 400 800
MILES
FROM: DAVIS, 1969

Figure 10

ESTIMATED PREVALENCE OF TUBERCULOSIS INFECTION IN URBAN AND RURAL AREAS OF SIX COUNTRIES



SOURCE: ROELSGAARD et al, 1964

Figure 11

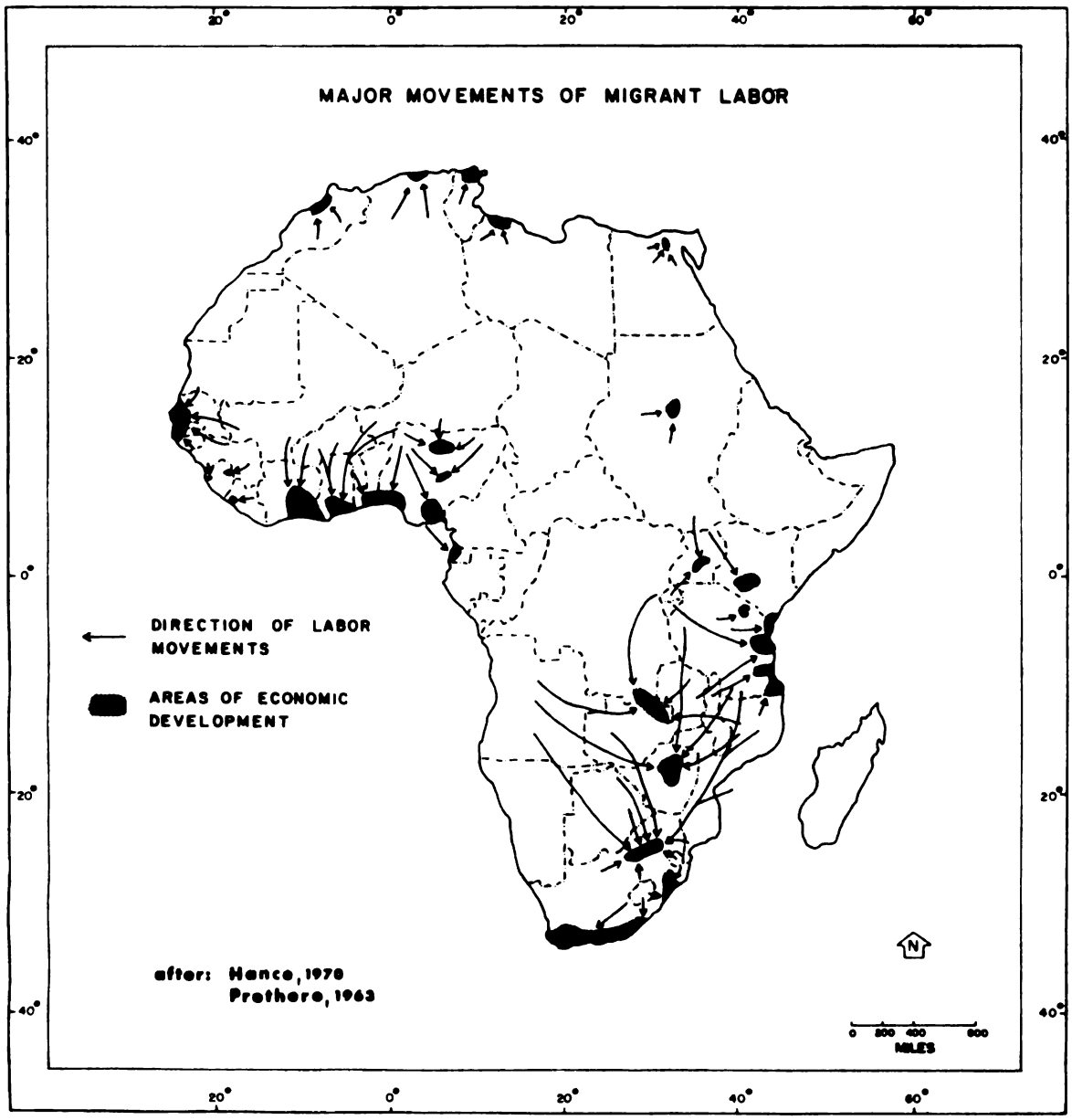

MAJOR MOVEMENTS OF MIGRANT LABOR
DIRECTION OF LABOR MOVEMENTS
AREAS OF ECONOMIC DEVELOPMENT
after: Hance, 1970
Prothero, 1963
N
0 200 400 600
MILES

Figure 12

80% between 1936 and 1951. In Zimbabwe (Rhodesia) the African population of seven municipal areas increased from 248,000 to 324,700 during the years 1951 to 1956 (Oram, 1965, p. 12).

The primary reason for this increase is migration of either a permanent or a temporary type. In Malawi, 27% of the grown men at any one time are estimated to be away working in Rhodesia and South Africa (Oram, 1965, p. 13). Two aspects of this migration to urban areas warrant attention. The temporary migrant has one main objective: to work and save as much as possible in order to bring a lump sum of money home or to send regular remittances. Invariably they live at their place of work or nearby in unsanitary and crowded conditions. As most of these men are unmarried or without their wives, they develop poor nutritional habits. Thus, they make themselves susceptible to disease infections (Roelsgaard, et. al., 1964, p. 462). The second aspect is that the individual who becomes unable to work usually returns home. Tuberculosis then is transferred from the urban foci to the rural foci (Dormer, 1956, p. 52). The repatriated migrant worker represents a grave problem in all of Africa. Tuberculosis has been spread from the coastal cities inland to rural areas (Delamoras, 1960, p. 281). Investigations have shown that tuberculosis reached into the most remote areas of Zaire (Congo, K), brought by sick workers returning home. In Kenya, it was found that although the rate of infection was highest in Nairobi, the rate of active cases was much higher in the rural areas due to movements from the city at the onset of infection (Roelsgaard and Nyboe, 1961, p. 862). This fact is supported by the work of Haynes (1951, p. 67) who found in Kenya that high reactor rates and high disease rates indicate new introductions of the disease.

In 1955, a new source of infection into Malawi resulted from African workers returning home from South Africa and Rhodesia (Goodall, 1955, p. 48). A virtual epidemic of tuberculosis occurred in the upper part of the Zambezi from 1950 to 1960. It was thought that the development of new roads and the accompanying migration between northwestern Zambia and urban centers were to blame (Grave, 1962, p. 217). At El Golea, an oasis community in the Algerian Sahara, 70.1% of 12,000 inhabitants reacted positively to tubercular tests. These high rates were attributed to the influx of oil prospectors (Meyrney, 1960, p. 139).

The diffusion of tuberculosis is contingent upon three factors:

(1) The Mycobacterium must be capable of persisting in a reservoir. In the poor living conditions of the urban centers this condition is easily met because of the continual migration to the city.

(2) A carrier is needed to move the mycobacterium about. The repatriated worker acts a carrier of the disease to infect the rural areas.

(3) The environment must be favorable to increasing the virulence of the disease. The underexposed rural areas represent an excellent medium upon which tuberculosis can manifest itself (Siegfried, 1965, pp. 21-23).

The urban center is seen as the primary dispersion point for tuberculosis. The households of the infected migrant and his family function as secondary foci (Gordon, 1962, p. 43). It would appear that in the future the major tuberculosis problem in Africa will be a rural one (Figure 13).

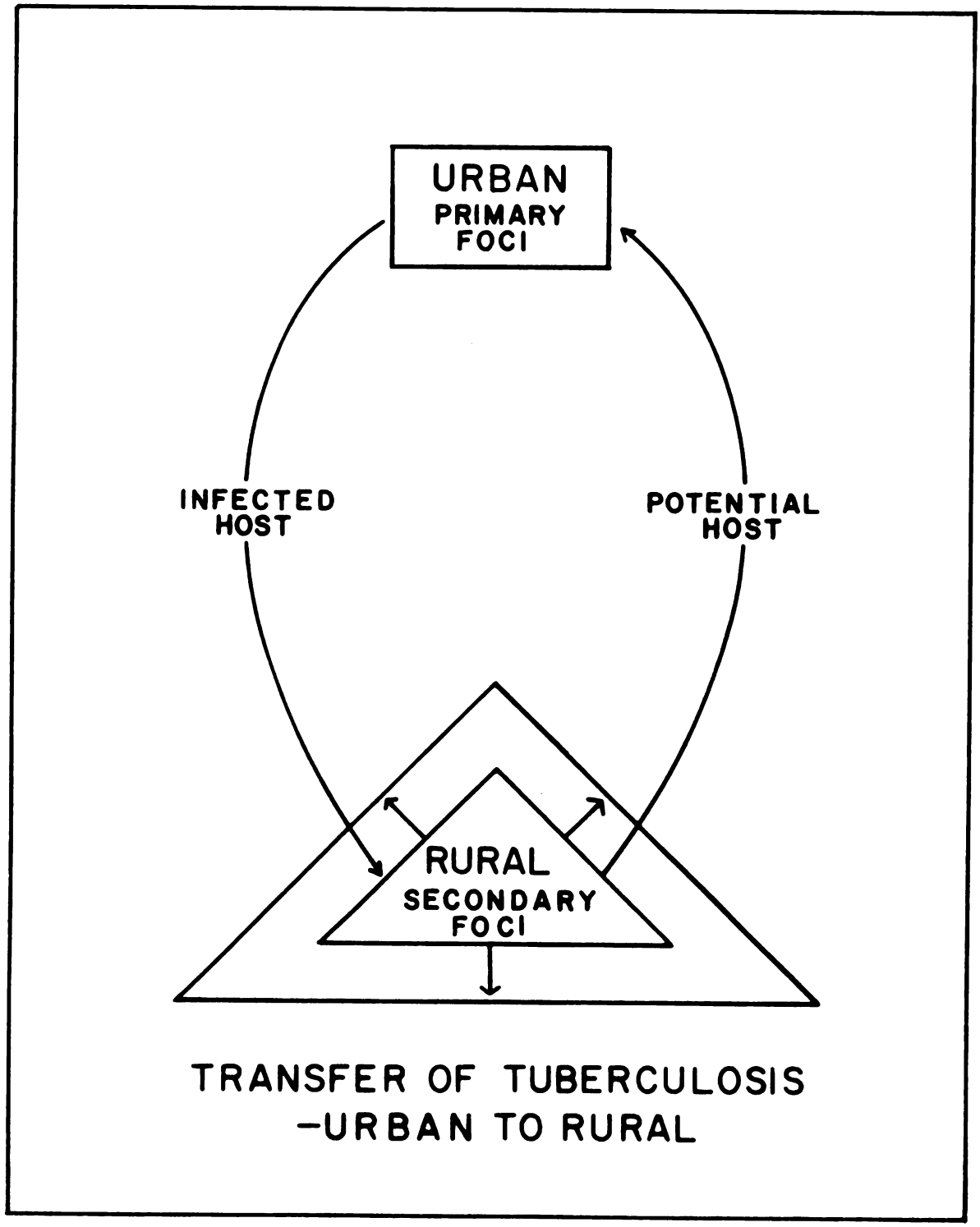

URBAN
PRIMARY
FOCI
INFECTED
HOST
POTENTIAL
HOST
RURAL
SECONDARY
FOCI
TRANSFER OF TUBERCULOSIS
-URBAN TO RURAL

Figure 13

Chapter III

INTERRELATIONSHIPS OF LEPROSY AND TUBERCULOSIS

Cross-Immunology

It is usually accepted that a close relationship exists between leprosy and tuberculosis. The exact mechanism of the immunological relationship is not known, but it is thought that populations with a high prevalence of tuberculosis may have increased resistance to and hence a lower prevalence of leprosy (Grounds, 1964, p. 13). This may be due to the fact that both diseases are chronic and infectious. Tuberculosis is more infectious and spreads more rapidly in non-immune populations than does leprosy (Chaussinaud, 1953, p. 90). Thus, populations heavily infected with tuberculosis are said to be afforded some protection from leprosy which has a longer incubation period and slower spread. It seems probable from historical sources that leprosy preceded tuberculosis in most countries, and when introduced, tuberculosis spread initially in more densely populated areas. Thus, leprosy was ousted from all areas except the less populated regions where it eventually may die out (Grounds, 1964, p. 13).

Chaussinaud suggests that in Europe where tuberculosis was increasing leprosy was declining. The basis for this statement is that there are low rural tuberculosis rates and high rural leprosy rates. He states that in West and Central Africa, tuberculosis is rare, while leprosy shows active

foci. "Civilization"[4] by its development tends to spread tuberculosis while leprosy is caused to disappear (Chaussinaud, 1953, pp. 90-95). The foregoing conclusion needs clarification in that Chaussinaud does not distinguish between specific regions of West and Central Africa. In West and Central Africa, the active leprosy foci are located away from urbanized areas.

The relative para-immunity can be studied in relation to BCG vaccinations in newborns where leprosy is highly endemic and where tuberculosis spreads only slightly. If the theory of antagonism between the two diseases is valid, subjects negative to tuberculosis and not vaccinated with BCG should furnish a relatively elevated proportion of leprosy cases, particularly of the lepromatus type. Cases of leprosy in turn should appear more rarely and tend to be more of the tuberculoid type after a period of three years following revaccination. Further evidence of abortion of leprosy by tuberculosis can be shown by regions where leprosy has been spread only recently and where leprosy has declined. The tuberculosis index will be found to be low in countries where leprosy appeared recently or is very marked (Chaussinaud, 1964, pp. 82-84).

The following is a study of the relationship between leprosy and tuberculosis in South Nyanza, Kenya conducted by Grounds.

South Nyanza, is a rural district in the southwestern part of Kenya where leprosy and tuberculosis are common. The Luo inhabit the warm, dry lower lying part of the district and the Gusii live in the cooler, wetter, highlands. The Watende-Kuria who are Bantu pastoralists live on a grassy plateau in the south part of the district at an altitude and climate

---

[4]Chaussinaud is implying westernization.

midway between the other two areas. Most of the Kissii in the highlands live fairly close together in areas where the average family holdings are 2 to 3 acres. The lower lying country is less populated with the average holdings about 8 to 24 acres. The Kuria have large areas of grazing land and live in isolated homesteads.

During 1955-59, work in the district showed that in the fairly densely populated Kissii highlands where leprosy was very rare, the prevalence rate of tuberculosis was nearly twice that of the less populated areas among the Luo and Kuria where leprosy was common. Where leprosy did occur it could be seen that the numbers of tuberculosis patients were high and those of leprosy patients were low and vice versa.

Table 7 shows the results of the survey. When the figures from columns 6 and 7 are plotted by log/log transformation, a linear relationship results as shown by Figure 13.

The situation in the Kissii highlands is that leprosy is virtually non-existent. The clinics concerned are numbers 1 to 9. They are bracketed as A in Figure 13. Clinic 22 drew its population from the border of Kissii and Luo country where the incidence of leprosy was very low (10 cases in 895 people examined). Clinics 14, 22, and 29 were included in section B of Figure 14 where adequate data collection was known to show a low register of tuberculosis due to staffing problems. If A and B sections are excluded, section C represents tuberculosis and leprosy from locations where both diseases exist and as far as possible have had equal attention by health officials.

The coefficient of correlation for section C with 17 observations is -0.675 which is significant at about the .01 level. The conclusion is that in areas where leprosy occurs not infrequently, a percentage increase

Table 7.--The Prevalence of Known Cases of Leprosy and Tuberculosis in Proportion to the Population Served in Various Clinics in South Nyanza-November, 1959

Serial No.	Clinic	Population Served	Tuberculosis on Live Register	Leprosy on Register	Known Tuberculosis /1000 Served	Known Leprosy /1000 Served
1	Kisii	112,000	186	0	1.65	0
2	Keroka	28,000	40	1	1.43	0.04
3	Nyamache	29,000	9	0	0.31	0
4	Ogembe	34,000	52	0	1.53	0
5	Nduru	26,000	34	1	1.30	0.04
6	Tinga	24,000	25	0	1.04	0
7	Nyamira	14,000	18	0	1.28	0
8	Nyamia	24,000	26	0	1.08	0
9	Matongo	10,000	5	0	0.50	0
10	Kabondo	29,000	11	262	0.37	8.34
11	Oyugis	52,000	35	257	0.67	4.94
12	Wagwe	20,000	13	119	0.65	5.95
13	Homa Lime	20,000	19	106	0.95	5.30
14	Ndiru	29,000	4	287	0.14	9.89
15	Homa Bay	20,000	6	245	0.03	12.25
16	Mbita	21,000	3	341	0.14	16.23
17	Gwassi	14,000	13	57	0.93	4.01
18	Ndiwa	34,000	39	266	1.14	7.82
19	Marindi	21,000	11	164	0.52	7.81
20	Pala	11,000	7	65	0.63	5.91
21	Sare	31,000	31	236	1.00	7.61
22	Kamgambo	25,000	17	14	0.68	0.56
23	Kehanca	14,000	12	20	0.85	1.43
24	Taranganya	14,000	44	21	3.15	1.50
25	Butende	10,000	23	34	2.30	3.04
26	Migori	22,000	32	54	1.45	2.45
27	Muhoru	4,000	1	65	0.25	16.25
28	Kadem	10,000	10	72	1.00	7.02
29	Karungu	19,000	4	27	0.21	1.42

Source: Grounds, J. G., "Leprosy and Tuberculosis, A Statistical Relationship in South Nyanza, Kenya," Journal of Tropical Medicine and Hygiene. Vol. 67, No. 1, 1964, pp. 13-15.

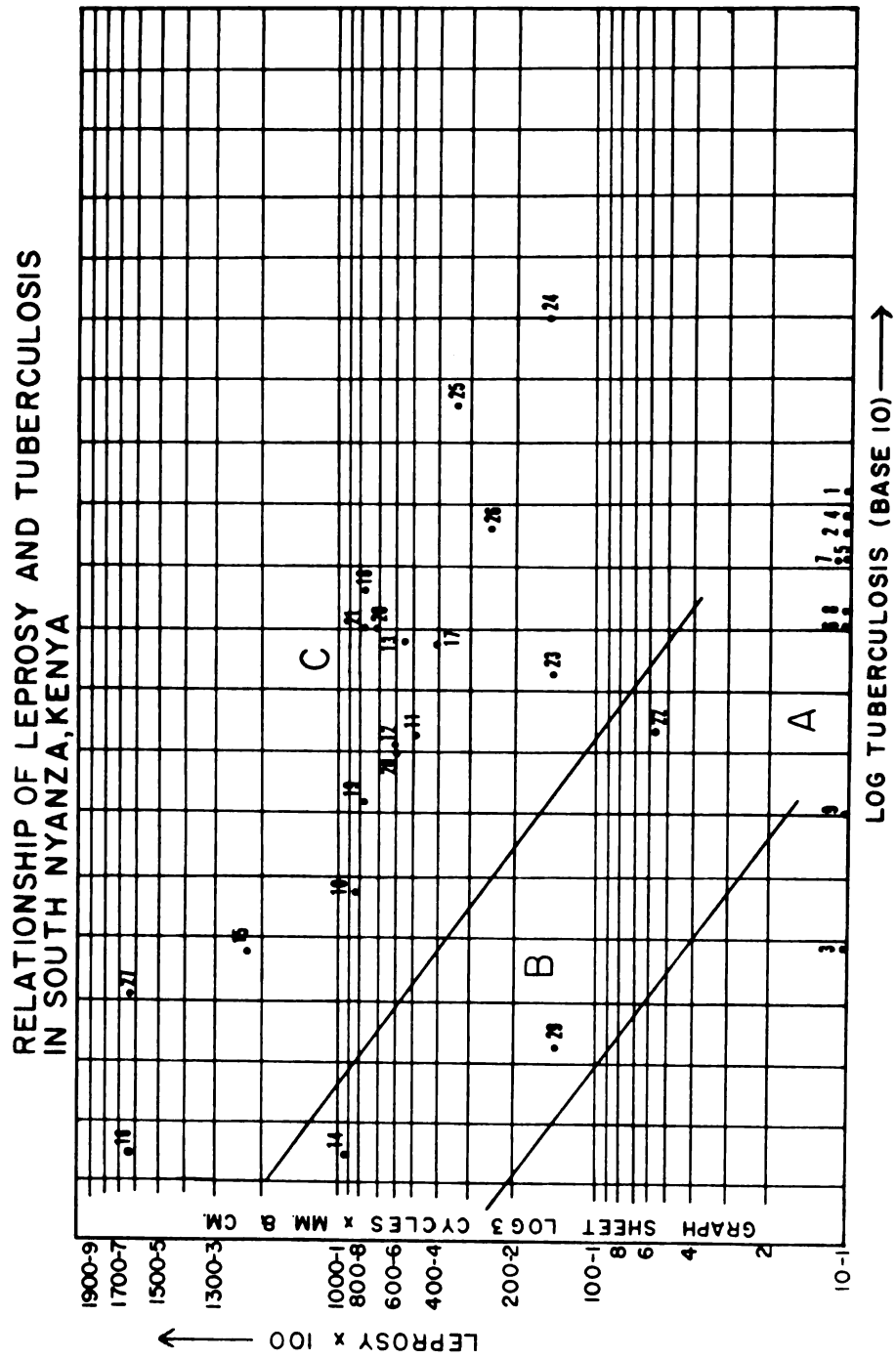

RELATIONSHIP OF LEPROSY AND TUBERCULOSIS
IN SOUTH NYANZA, KENYA
LEPROSY x 100 ⟵
1900-9
1700-7
1500-5
1300-3
1000-1
800-8
600-6
400-4
200-2
100-1
8
6
4
2
10-1
GRAPH SHEET LOG 3 CYCLES x MM. & CM.
A
B
C
LOG TUBERCULOSIS (BASE 10) ⟶
SOURCE: GROUNDS, 1964

Figure 14

in the tuberculosis rate is associated with a percentage of proportional decrease in the leprosy rate, and that probability of obtaining such a correlation by chance is about 1 in 1000 which is normally accepted as highly significant (Grounds, 1964, pp. 13-15).

Another study in West Kenya utilizing registered patients shows a prevalence rate of tuberculosis that varies from 3.0% to 0.1%. The conclusion is that the distribution of tuberculosis alone does not offer a satisfactory explanation for the distribution of leprosy. No correlation was made between the two indices (Leiker et. al., 1968, pp. 79-83).

Work by Lowe and McNulty gives no evidence to support the hypothesis that previous infection of tuberculosis renders the leprosy rate nil by producing some kind of immunity. There is no evidence that in the absence of tuberculosis or previous infection, leprosy tended to be severe (Lowe and McNulty, 1953, pp. 61-89).

The observation that many leprosy patients at post-mortem show evidence of tuberculosis and that tuberculosis is stated as the main cause of death encouraged the belief that the two diseases are related or antagonistic (Newell, 1966, p. 838).

The relationship between leprosy and tuberculosis was again examined in Kenya; the results were published in 1968. It was concluded that in West Kenya the distribution of tuberculosis alone does not offer a satisfactory explanation for the distribution of leprosy. In three sample populations in West Kenya the incidence of leprosy and tuberculosis did not vary inversely enough to show a clear correlation (Leiker et. al., 1968, p. 80).

There is little direct evidence to support either view. Although the causative organisms of both diseases are classified as mycobacteria,

no other relationship has been demonstrated. If tuberculosis is found to be a frequent cause of death in leprosy patients, it could well be used as evidence against the antagonism hypothesis (Newell, 1966, p. 839). The suggestion that infection with Mycobacteria tuberculosis endured a tissue resistance which also covered Myco. leprae offers a simple explanation for some observed facts, but it proved to be too superficial to contain the whole truth (Davey, 1959, p. 317).

Social Implications

Tuberculosis and leprosy can be examined from a socio-economic point of view. In most areas of Africa, leprosy patients have been shunted away from urban areas and villages. Among the Lunda people of Zambia leprosy has been known for a long time. There is a tremendous amount of folklore about leprosy: e.g. "Hunger is like leprosy it doesn't kill quickly." The disease was believed to be a punishment for theft, adultery, and foolish behavior. Believing that leprosy was extremely contagious, isolation of severe cases was practiced. The diseased person had to leave the village and live downwind or to the West. Usually these people died of hunger because of taboos against receiving food or the physical inability to perform work (Giffiths, 1965, pp. 59-67).

As previously stated leprosy has a long incubation and manifests itself slowly. It is probable that isolation comes too late to prevent infection of the family.

Tuberculosis usually ranks second to pneumonia as a major health problem in Africa. Both have coughing or a symptom which is greatly tolerated in many areas. As a result isolation such as practiced in the case of leprosy does not exist. Transmission by tiny droplets through the air is easily accomplished.

Poverty

Both diseases seem to be greatly influenced by living conditions. They show direct relationships with poor diets and crowded living conditions. As previously noted, the exact mechanism which makes one person susceptible and another resistant is not known. Rural poverty with its monotonous poorly balanced diet contributes to leprosy infection. Rural population pressure is causing changes in traditional diets which in many cases were protein rich. Following famines in the West Nile District of Uganda, laws were passed to require families to plant a specific amount of cassava. Although cassava generated on the average twice as many calories per land unit, its protein content is very low (Jelliffe, 1962, pp. 33-50). On the basis of apparent visual correlations between high leprosy rate areas and low protein intake, poverty is viewed as a precipitating factor to leprosy infection. Impirical data along these lines is scant or very dated.

Urban poverty with its resulting poor nutritional intake predisposes one to tuberculosis infection. Protein-calorie malnutrition is becoming a distinct problem in urban areas of Africa. Urban diets tend to be low in vitamins, minerals, and protein because of cost, lack of knowledge, and processing techniques, e.g. milling of grains (Hughes and Hunter, 1970, p. 471). It would be presumptuous to attach infection of leprosy and tuberculosis solely to poor nutrition until more research is conducted. However, it cannot be denied that infection by leprosy and tuberculosis are essentially problems of developing countries where protein-calorie malnutrition is also a problem.

Infection Levels

The ability of any infectious disease to spread is directly related to its prevalence in the general population. Some investigators believe that it is better to try and locate the geographical distribution of absolute cases rather than work with rates per unit of population. The belief is that in a given area, the population increase will obscure the increase in the disease (Shennan, 1968, p. 61).

It has been estimated that 10 to 20 million people in the world are suffering from infectious tuberculosis and that they have the ability to infect 50 to 100 million (Mahler, 1970, p. 20). Fendall estimates that in East Africa alone 60,000 new cases will occur each year unless the reservoir of infected hosts is reduced (Fendall, 1967, p. 1417). There appears to be no critical prevalence rate which will generate an epidemic. The crux of the problem lies in the fact that the infected persons are scattered throughout the general population. This is the rationale for investigating the absolute number of cases more critically.

The World Health Organization estimates that in 1965, 3,868,000 (35.8%) of the leprosy cases in the world were in Africa (Bulletin of the World Health Organization, 1966, p. 811). Due to the slower spread of leprosy compared to tuberculosis, critical infection values have been cited. Investigators working in India established a rate of 20,000/million as being critical enough to warrant a house to house survey of an area (Browne, 1963, p. 195). The World Health Organization indicates that in areas where the rates are greater than 500/million the prevalence can be expected to rise (Bechelli, et. al., 1966, p. 811).

Chapter IV

PREVENTION, CONTROL, AND ERADICATION: THE CHALLENGE TO HEALTH PLANNING IN AFRICA

The World Health Organization is in the forefront in seeking to control disease in Africa. Such an organization is needed in order to supercede national interests. For in all of Africa and the world the infection of people knows no national boundaries. Political instability results in frequent change in priorities which poses great threats to immediate eradication of disease in Africa. In many countries, there is only one doctor for 25,000 to 50,000 people. In few cases is more than $2.00 per person per annum spent on health needs by the government (World Health Chronicle, 1968, pp. 398-402). Surveys have shown that tuberculosis cannot be controlled by giving attention only to the high risk groups, e.g. urban areas. Tuberculosis may lie dormant in an already infected population; therefore, long range plans for mass testing are needed to find where potential endemic areas occur. To decrease the reservoir pool it has been suggested that B.C.G. vaccination become a routine procedure for all children under one year of age. However, such an approach poses the knotty problem of who is most important--society or the individual (Fendall, 1967, p. 417).

In Zimbabwe (Rhodesia) an ambitious scheme was developed in Midlands Province where the infection rate was seen to decline from 1750/million to 865/million. This decline is attributed to a mass program of

B.C.G. vaccination of 10% of the population each year. After 20 years tuberculosis infection is expected to be 1/3 of the initial rate (Davies, 1970, pp. 149-158).

The control of leprosy presents another difficult task to African health officials. The reputation that leprosy has present problems in just finding infected persons. Health officials have found instances that persons thought to have leprosy were hidden; in that way the family would not lose status in the village. In the world, 2,097 million people (1966) live in areas with leprosy prevalence rates estimated to be greater than 500/million. These infected persons are expected to generate one million new cases in the next five years. The problem is critical in Africa since an estimated 3,868,000 of the 10,786,000 cases are on the African continent. The seriousness of the problem of leprosy should be thought of in terms of the human and social consequences (Bechelli, et. al., 1966, p. 823). The following description of leprosy probably typifies the attitude toward leprosy:

> In all of history there has been no more tortorous pestilence than leprosy. It cripples, disfigures, and blinds. It is chronic, contagious and until recently nearly always impossible to treat or cure. It anesthetizes sense of touch; victims burn and mutilate themselves accidently for they no longer feel pain. It seldom kills by itself; it saps the body and opens the way for other diseases to enter and do the killing (Gallagher, 1969, p. 57).

The problems of controlling leprosy and tuberculosis in Africa are manifold. Both require improvement of living conditions which means improved diets and sanitation. Chemotherapy in both cases requires massive inputs of money from the individual countries. On an international basis cooperation is needed particularly in dealing with the eradication of tuberculosis. Control, prevention, and eradication of disease hazards

in Africa will continue to be a major problem unless a well-rounded holistic approach incorporating all segments of the African society is instituted.

CONCLUSIONS

The processes of urbanization and population migration between rural and urban areas are considered critical factors in assessing the spatial pattern of tuberculosis in Africa. Unless preventive measures are taken to control tuberculosis infection the distribution of the disease can be expected to expand from the major urban centers into the rural areas in the near future.

The distribution of high leprosy rates was found to correlate positively with high humidity. It is further suggested that regions not undergoing rapid transformation via economic development in the form of manufacturing, mining, etc. will remain as strongholds of high leprosy infection.

Tuberculosis in nearly all instances spreads faster in a population than does leprosy. If leprosy and tuberculosis are mutually antagonistic then the predicted patterns regarding the geography of these two diseases in Africa would be that leprosy will probably decline due to the expansion of tuberculosis.

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LAND USE ASSOCIATED WITH SAND AND GRAVEL EXTRACTION ON A PORTION OF THE MASON ESKER

BY

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INTRODUCTION

Statement of Problem and Objectives

The purpose of this research paper is to describe, analyze, and develop some generalizations regarding land-use patterns upon sand and gravel resources, partially situated in an urban area. The general problems under investigation are these: What is the nature of subsequent or sequential land use that has evolved in an area of sand and gravel removal? Second, what are the factors that most strongly influence evolving land-use patterns, and what might be expected in terms of future use of land formerly associated with sand and gravel extraction in and near an urban area?

The Mason Esker with its sand and gravel deposits provides a distinct geomorphic feature that is located partially within a long-established and expanding urban setting. The location of the esker offers an opportunity to investigate a case study of a most common situation. The impact of land-use change in such a situation is shown by the following description.

> The greatest change in land use since 1920 has been doubling of areas in special purpose uses, including highways, parks, and urban residential areas. During the 1950's, these uses absorbed 2,000,000 acres per year. Cropland, grassland, and pasture were the source of 40%, forests 40%, and idle land 20%. Expansion of requirements for land for non-agricultural uses has affected agricultural land; in some areas agricultural land has shifted totally to special purpose uses (Regan and Wooten, 1963, p. 60).

The pressure for additional residential, recreational, commercial, and industrial facilities raises questions as to the site of the Mason

Esker, which represents an extensive tract within the Lansing area. This study will attempt to discern evolving land-use patterns and relate them to the economic and environmental situations with the idea that some light will be shed upon the future usage.

Review of Pertinent Literature

Theories on the origin of eskers are numerous. Those who believe that eskers develop under stagnant glacial ice include Davis (1893, pp. 477-499), Strahler (1960, p. 401), Putnam (1964, pp. 347-348), and Leavitt and Perkins (1935, p. 71). Proponents of the esker forming on top of the glacial ice are Crosby (1902, pp. 375-411) and Sproule (1939, pp. 101-109). Another hypothesis suggests that eskers form within the glacier and gradually let down to the ground (Alden, 1924, p. 54). Still another suggestion is that eskers are actually crevasse fillings (Flint, 1928, pp. 410-416). Flint was later to change his idea and now supports the hypothesis that eskers develop under the glacier, particularly those of great length (Flint, 1970, p. 218).

The Mason Esker was among the first to be described in North America when C. C. Douglas wrote about it in 1839 in the Second Annual Report of the First Michigan Geological Society (1839, p. 67). A brief description was later produced by L. C. Wooster in 1884. Probably the best known description of the feature was published in 1915 (Leverett and Taylor, 1915, p. 206).

Petrographic studies of the Mason Esker indicate that it is the result of stream-bed deposits built up in subsequent layers in a streamlike channel (Erickson, 1948, and McCallum, 1949, unpublished theses, Michigan State University).

Interpretations of the dimensions of the Mason Esker have varied since early reports. In 1859, the esker was reported to be 10-11 miles in length (Topographic Map of Ingham and Livingston Counties, 1859). Leverett and Taylor in their classic work propose that the esker is not less than 20 miles in length (Leverett and Taylor, 1915, p. 209). A geologic map of Michigan published in 1955 shows the length as approximately 25 miles (Martin, 1955). Most recent interpretations of the length of the Mason Esker propose it to exceed 30 miles (Yarger and Cranson, 1970, p. 13).

The amount of published material relating to the land-use patterns associated with eskers is small and does not specifically focus on the esker. An example of this type of work is the Comprehensive Development Plan for Delhi Charter Township, 1967. Land-use studies relating to urban fringe areas are numerous. An example is one which deals with land-use change in Macomb County (Sinclair, Shipton, and Willis, 1971, pp. 161-181). The economic impact of sand and gravel extraction upon a local community was examined in Finland (Grano, 1959, pp. 1-33). Barlowe states that the change in land area from one use to another is a natural phenomenon in a dynamic economy, that is, one characterized by a growing population, expanding demands for land products, high per capita incomes, and the ability of the individual to make most decisions regarding the ownership and use of the land without a great amount of interference (Barlowe, 1958, p. 1339).

Methods of Research

The primary method of investigation was field study. Preliminary work was conducted during July, 1968, and subsequent intensive field

research was carried on during the months of September through December, 1971. Supplementing the field study were the use of air photos to examine past land uses and personal interviews with land owners, realtors, and county and township officials. This paper is basically the result of field investigation though library research comprised a significant but minor portion of the research methods.

General Discussion of Study Area

The study area is located in south-central Michigan in Ingham County and presents an excellent opportunity to observe eskers and associated land-use problems. In this area eskerine forms are found in close proximity to and within an expanding urban setting (Figure 1). These eskers are the result of deposition during disintegration of the Wisconsinan Stage of the Pleistocene. The Saginaw glacial lobe that had traversed the area eventually, at least in part, stagnated and as a result eskers were deposited (Leverett and Taylor, 1915, p. 206). Eskers are long, narrow ice-contact ridges most commonly sinuous and composed primarily of stratified drift. The most common origin is by deposition in a tunnel at the base of the glacier, but they may have also been formed englacially or supraglacially. Many eskers are associated with troughs or valleys and often appear related in some meaningful way to the adjacent terrain (Flint, 1970, p. 218).

The Mason Esker (Figure 2) is the largest one found in Michigan and is believed to extend from near DeWitt (Section 3, T5N, R2W) through the eastern part of Lansing to terminate south of Mason. In its northern-most portion (T5N) the esker is situated in a trough and is nearly indistinct above the ground surface, particularly where it intersects

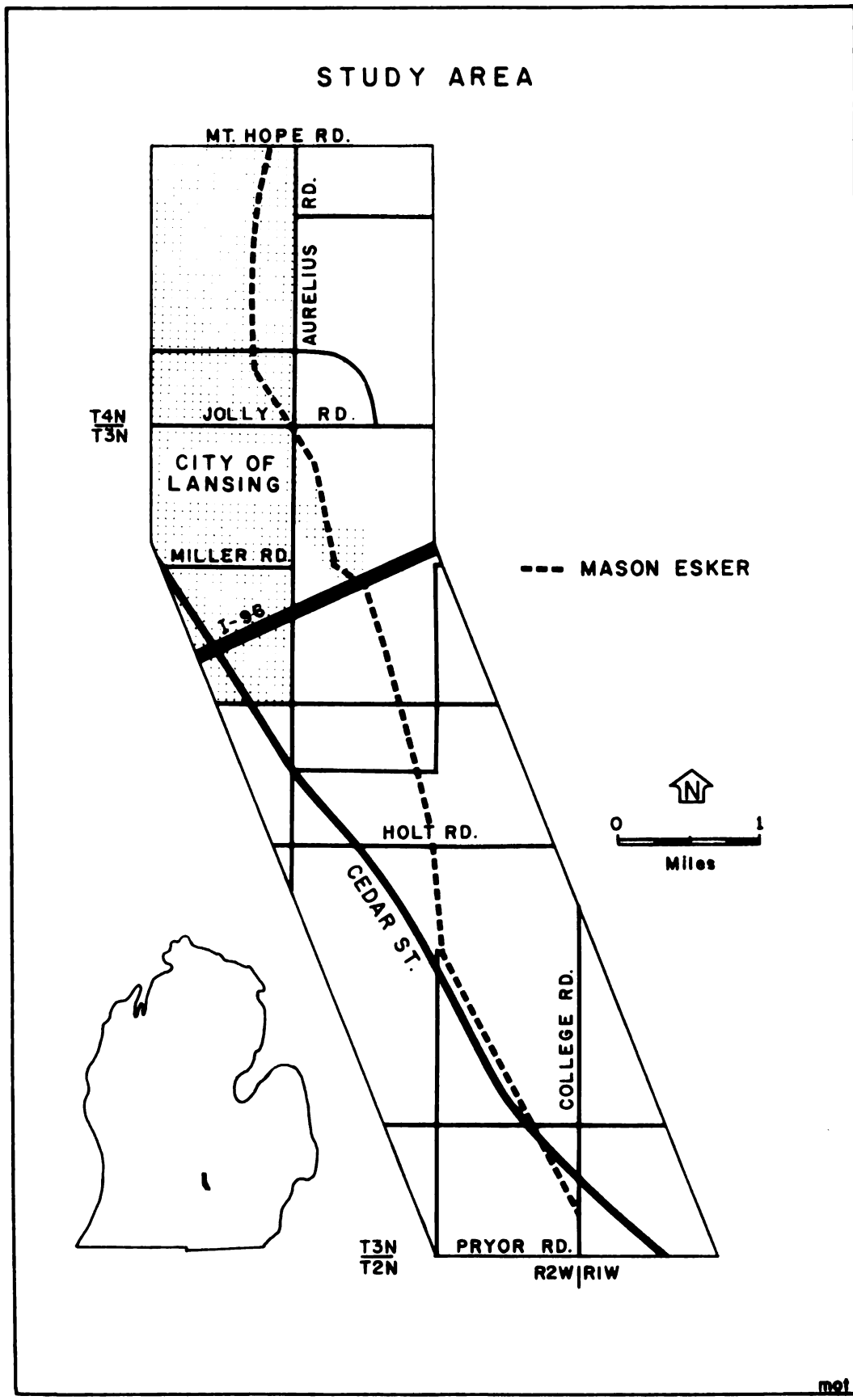
STUDY AREA
MT. HOPE RD.
AURELIUS RD.
JOLLY RD.
T4N
T3N
CITY OF LANSING
MILLER RD.
I-96
MASON ESKER
HOLT RD.
CEDAR ST.
COLLEGE RD.
N
0
1
Miles
T3N
T2N
PRYOR RD.
R2W
R1W
mgi

Figure 1

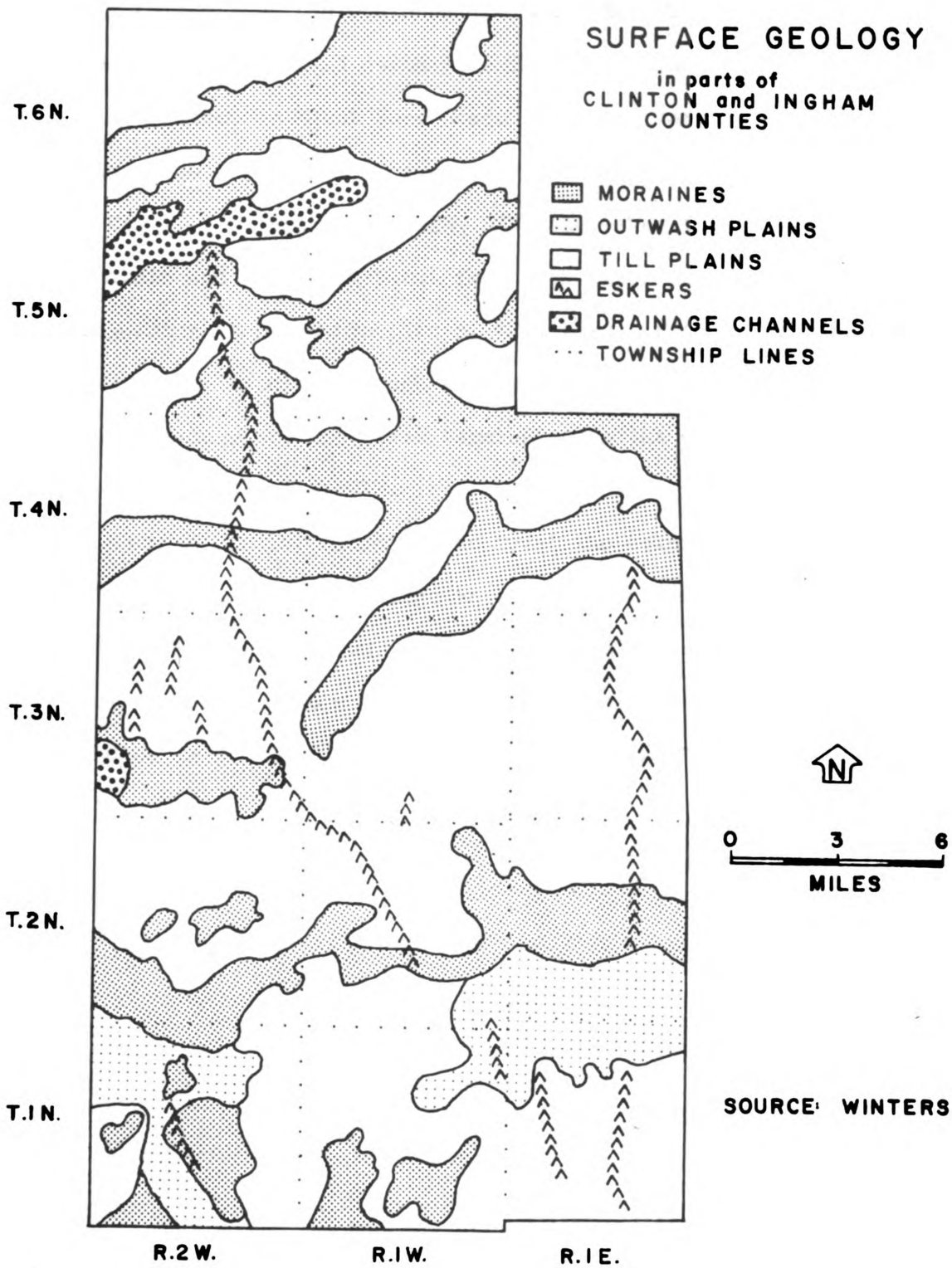
SURFACE GEOLOGY
in parts of
CLINTON and INGHAM
COUNTIES
MORAINES
OUTWASH PLAINS
TILL PLAINS
ESKERS
DRAINAGE CHANNELS
TOWNSHIP LINES
T.6N.
T.5N.
T.4N.
T.3N.
T.2N.
T.1N.
R.2W.
R.1W.
R.1E.
N
0
3
6
MILES
SOURCE: WINTERS

Figure 2

the Portland, Ionia, and Grand Ledge moraines (Yarger and Cranson, 1970, p. 7). Immediately to the south of the Red Cedar River the esker is again recognized as a broad delta-like feature in Section 27, T4N, R2W, where it is crossed by Mount Hope Road. From the Lansing moraine south for 3 miles, the esker lies in a clearly defined trough associated with Sycamore Creek. In Section 11, T3N, R2W, the esker trough and Sycamore Creek separate and remain distinct from each other for about 8 miles before rejoining in Mason (Section 5, T2N, R1W). From Mason southeastward for 3 miles the esker trough and Sycamore Creek are together only to separate again where the esker terminates in the Charlotte morainic system in Section 27, T2N, R1W.

The purpose of this study is to treat the esker as an example of a glacial landform undergoing change in and near an urban setting. To satisfy these goals, the study area was limited to a representative portion of the esker within the urban area. For these reasons, the area to be studied is within T4N, R2W (Lansing city) and T3N, R2W (Delhi Charter Township). (See Figure 1.)

DISCUSSION

Development of Sand and Gravel Extraction

Within the Lansing area the impact of man's activities upon the landscape is nowhere more vivid than that shown by the Mason Esker. The esker has been greatly altered primarily by the extraction of gravel and sand. The former position of the esker is generally marked by a series of linear ponds and excavations. The original esker ridge remains only in a few places and most of these appear destined for quarrying.[1]

General extraction on a large scale was initiated about 60 years ago. The Lansing Topographic Quadrangle of 1911 shows areas where quarrying was extensive enough to be mapped. Before this time the esker had minimal economic value to man because of a lack of demand for gravel to be used as aggregate. The initial increased demand for sand and gravel on a large scale resulted primarily from a need for more and better roads which was related to the increasing use of the automobile. By 1925, five of the 13 areas delimited in this study as quarries had been established. By 1940 this figure had increased to seven, and nine of the 13 areas were or had been in production by 1950 (Figure 3).

During the 1910 to 1920 period the alteration of the esker was not one of continuous operation at a site until the materials were depleted. Instead much of the removal was done intermittently by men shoveling directly from the slopes of the esker. When the material was quarried down to ground level, a new section of the esker was excavated. Later the widespread use of the steam shovel allowed many of these abandoned

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[1] "Quarrying" is a term often used for extraction of unconsolidated economic deposits as well as bedrock. It is used to describe removal of generally unconsolidated glacial drift of economic value in this study.

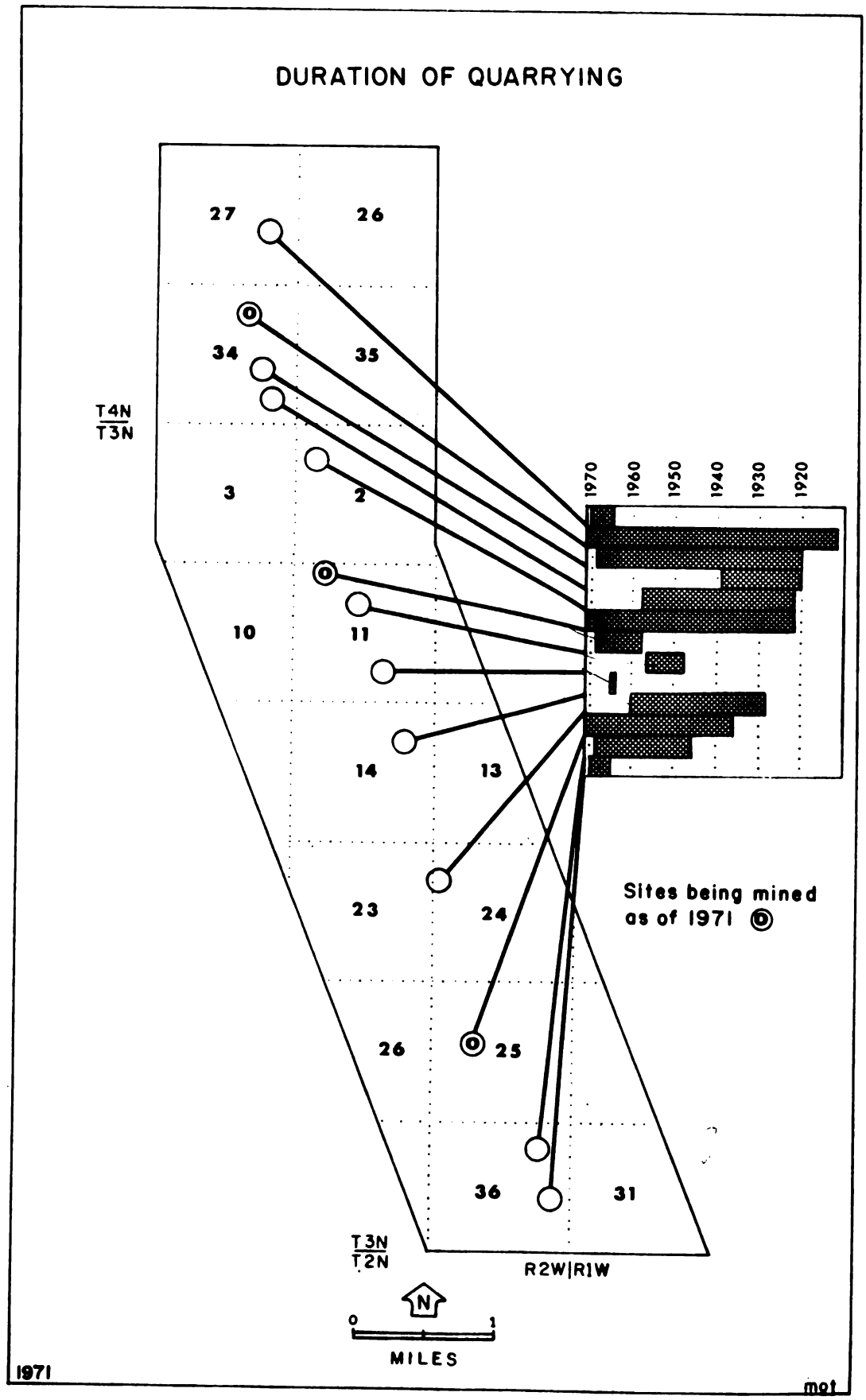
DURATION OF QUARRYING
27
26
34
35
T4N
T3N
3
2
1970
1960
1950
1940
1930
1920
10
11
14
13
Sites being mined as of 1971
23
24
26
25
36
31
T3N
T2N
R2W|R1W
N
0
1
MILES
1971
mot

Figure 3

sites to be quarried to a lower level generally marked by the water table. A final phase of excavation involved the use of drag lines and dredges which made possible the removal of the sand and gravel below the ground water surface (personal communication with O. Solomon of S. D. Solomon and Sons). Figure 4 represents the results of an earth resistivity survey conducted by the Michigan State Highway Department on the esker in the NE $\frac{1}{4}$ of Section 14, T3N, R2W. Investigation of quarrying operations shows that the depth of the esker below ground level is nearly equal to its elevation above the general ground level. As a result of quarrying operations penetrating the water table, ponds now mark the former position of the esker.

Selected Economic Aspects

Analysis of the esker materials for use in highway projects indicate that the materials in the esker are of poor quality. Boring tests show that the composition of materials is primarily coarse sand with occasional local zones of finer texture materials (Figure 4). Negligible amounts of gravel were found at the site (Report of Resistivity and Boring Survey, 1964). Those who are involved in excavating the esker materials generally expect to find at least 70% sand. Most of the sand is used as road fill or general fill (personal communication with M. Miller, retired superintendent, Cheney Block Company, 1971).

The demand for sand which comprises the bulk of the esker deposits has increased. In 1954, fill sand from the esker south of Holt was valued at approximately $0.04 per cubic yard. Presently raw material from the esker is valued at $0.10 to $0.30 per cubic yard. The present variation in price is due to location and quality of the material

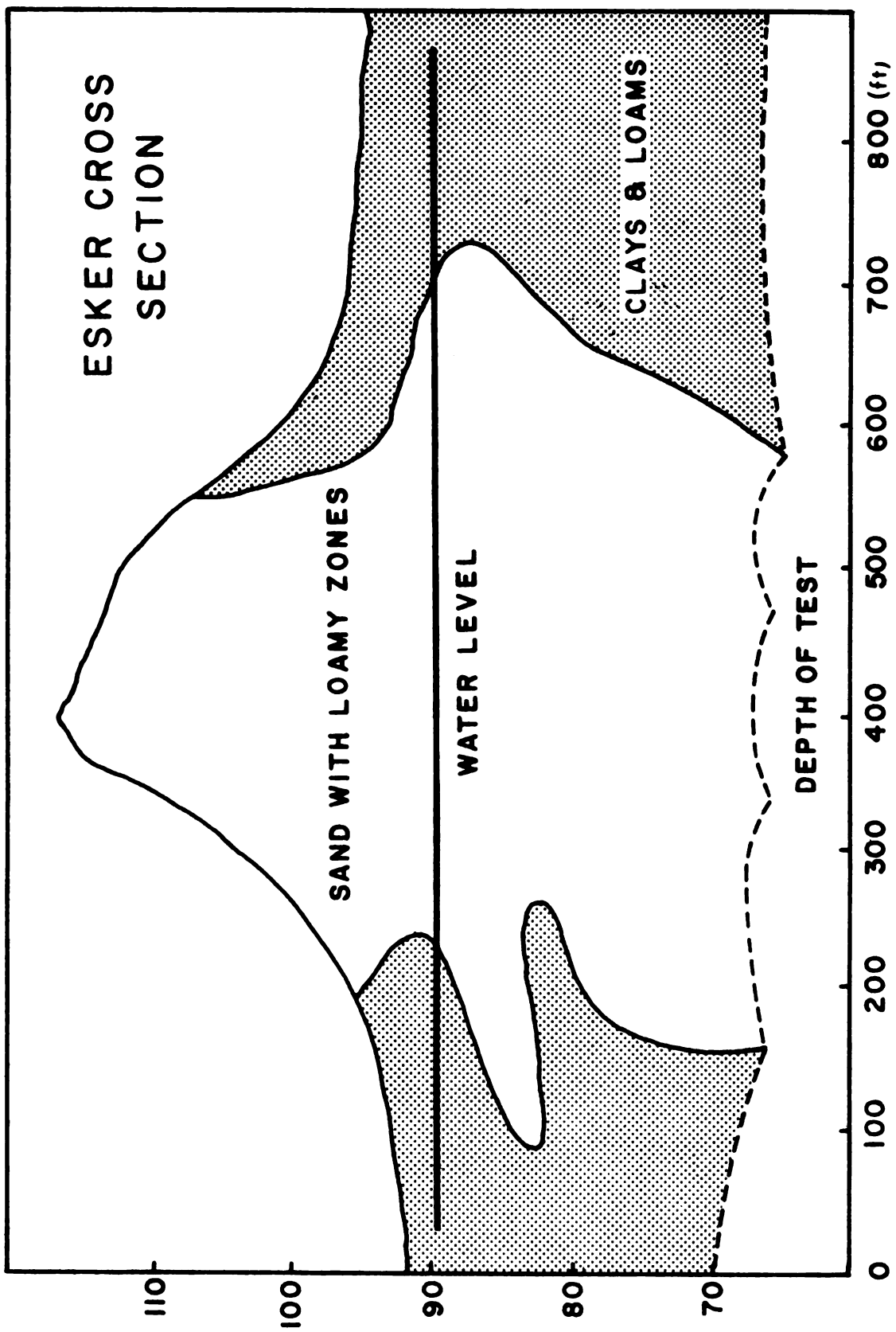
ESKER CROSS SECTION
SAND WITH LOAMY ZONES
WATER LEVEL
CLAYS & LOAMS
DEPTH OF TEST
110
100
90
80
70
0
100
200
300
400
500
600
700
800 (ft)
SOURCE: STATE OF MICHIGAN HIGHWAY DEPT.

Figure 4

(personal communication with H. Ketchum, 1971). Another company engaged in sand and gravel excavation estimates that the value of the raw material (pit run), at about $0.05 per cubic yard in 1930, is presently priced at $0.20 per cubic yard (personal communication with E. Scarlett of Scarlett Gravel Company, 1971). Another excavator who deals primarily with fill sand estimates that in 1960 raw material (pit run)[2] was valued at $0.10 per ton[3] while the value has presently risen to $0.25 per ton in 1971. Labor cost contributes a major portion of the price of the material. When raw material which has a value of $0.25 per ton is loaded on a truck, the value rises to $0.75 per ton (personal communication with O. Solomon of Solomon and Sons, Excavating, 1971). All those in the sand and gravel business contacted agreed that the rise in value of the materials is a function of increased demand combined with increased expenses for equipment and labor. In 1946, a 5 yard dump box truck cost approximately $1,600.00 while a comparable 5 yard dump box truck in 1971 cost approximately $6,300.00. Wages for truck drivers were $4.02 per hour in 1969 and have increased to $5.60 per hour in 1971 (personal communication with H. Ketchum, 1971). The value of the raw materials from the esker have increased as a result of three factors: increased demand, decreasing supplies, and increasing costs of production and processing.

There appears to be concern among some of the various companies engaged in sand and gravel excavation not to deplete their resources too fast. As the amount of material declines in the Lansing area a sharp increase in price is expected (personal communication with B. Esterline

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[2]Pit run is the unprocessed material as it lies in place in the esker.

[3]One ton equals about 1.5 cubic yards.

of Builders Redi-Mix, 1971). As the demand for raw materials that are used in construction and general fill increases, the value of the raw material will also increase. Increased value of raw material will likely be reflected by the reworking of some of the quarries that have previously been abandoned and the hauling of raw materials from greater distances.

Present Land-Use Patterns

The analysis of present uses of the land may help provide a general basis for reference when predicting future land-use patterns. Present trends could well provide important information for future evaluation. For the purpose of this study, the land use associated with the esker was divided into the following groups: idle, mining, industrial, commercial, residential, agricultural, transportation, and public service.

Public service: This group includes all public lands used by the federal, state, township, or city governments for providing social, cultural, and health needs. In this category are two cemeteries, Mount Hope and Maple Ridge. Both of these features are of long duration and indicate that early settlers attached a special significance to the nature of the esker. Another public service usage is a land-fill project which occupies most of Section 2, T3N, R2W. At this time, the project is expected to be completed in the next three to four years. Public service land use illustrates two ways in which the esker has been of public service. In the case of the cemetaries the topography and well-drained character of the esker was a major consideration, while in the case of the public land fill, location of an excavated portion of the esker

within a major urban area was a major factor determining usage. The latter is a good example of sequential use of the esker site.

Transportation: This grouping includes all existing street, highway, and railroad rights-of-way. At various points the esker is crossed by county and city roadways and in one place by rail lines. The most significant portions occupied by transportation routes are parts of I-96 and Cedar Street. In Sections 24 and 25, T3N, R2W, Hogsback Road was built on the crest of the esker. After Cedar Street was constructed, Hogsback Road became less significant as a transportation route. This change of traffic flow has allowed Hogsback Road to be closed to through traffic. At the present time, active mining has removed much of the former route of the road and serves as another example of sequential use of the site.

Residential: This includes the domiciles of families or household units and the surrounding land normally used by the occupants of the household. Residential land is generally associated with well-drained soils. The Lansing Topographic Quadrangle of 1911 shows a pattern of housing preference on the esker as opposed to the adjacent poorly drained soils. Part of the same pattern exists today. Homes built on the esker are most numerous in Holt where there is a well-defined residential area along Delhi, N.E., and Hill Street. Indications are that some of these houses were built as early as 1864 (personal communication with K. Lamereaux, 1971). In the areas adjacent to active mining the residential areas may be encroached upon by quarrying activities. An example of such a situation is in Section 25, T3N, R2W, where an excavating company owns most of the homes built along the flank of the esker and has removed one residence in the past two years in order to obtain more sand and gravel.

Commercial: These parcels of land have establishments which supply services and goods to the public. Commercial enterprises found in the study area include three lumber dealers, a golf driving range, a restaurant, an auto dealership, and a tire outlet. The esker itself provided little impetus for these operations to come into being. Rather it was the need to occupy a site in close proximity and accessible to transportation arteries. Commercial land use of the esker site is expected to increase in the future.

Industrial: Industrial land uses are those which are primarily engaged in processing, manufacturing, or assemblage of products. In the study area five such operations are noted. All of them are aggregate plants and occur more or less equally spaced along the esker. When the raw material supplies are exhausted in the immediate vicinity of the plants, the site is then used to stockpile raw materials hauled to the area or for equipment storage. Most of the operators state that when hauling concrete in redi-mix trucks or hot asphalt from the plants they would prefer to work within a 15 to 20 mile radius because of cost of operating the equipment.

Mining: Lands classified in this category are those in which extractive processes involving earth materials are taking place. At the present time three sand and gravel quarries are in operation. The major locational factor is obviously the availability of materials. At the present time remaining supplies of sand and gravel are scarce and production practices tend to indicate this awareness. Solomon and Sons, Excavators could not give an exact estimate of how long their material would last because of uncertain economic conditions. However, they did conjecture that all of their material could be removed in less than one

year by concentrated activity. Builders Redi-Mix estimates that they have approximately 300,000 yards of sand that can be used for fill. The duration of this material supply was not known because production was being held constant in lieu of higher prices for the raw material. Scarlett Gravel Company officials estimate that they remove approximately 160,000 tons per year at their location south of Holt. The raw materials at that site are expected to last about six years at present excavation rates.

Idle: All land that is vacant or underdeveloped is included within this category. Idle land comprises the most extensive land use associated with the esker. The land in this group can be subdivided into areas of abandoned quarry operations[4] and areas of the remaining esker. As a result of excavations, linear ponds with zones of spoil occur along the trend of the esker. Only a limited portion of the esker remains undeveloped. The majority of the undeveloped esker occurs south of Holt along the east side of Cedar Street in Section 25, T3N, R2W. The land classified as idle represents an important group because it is anticipated that most of the future land-use changes on the esker site will take place on these parcels of land.

Agricultural: Land used primarily for the production of plants and animals for commercial purposes is termed agricultural. On the portion of the esker in the study area there is no land that fits this description at the present time. The closest approximation to agricultural land occurs in Section 11, T3N, R2W, where a plot of land is used as a pasture for horses. The lack of crop land found on the

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[4]This group also includes a plot of land that is quasi-agricultural, in the sense that it is used as a pasture for horses for various lengths of time.

esker is directly related to the steep slopes and droughtiness of the soil. In Ingham County eskers were mapped primarily as Bellfontaine loamy sand[5] and described as having "only small value for general farming" (Ingham County Soil Survey, 1941, p. 21). In the study area agricultural land appears as a very poor competitor and has been replaced by more profitable uses (Figure 5).

Findings and Results

The land-use patterns associated with the esker can be analyzed both temporally and spatially. Public service land uses have an average age of 99 years and are located within and near the southern margin of Lansing's corporate boundaries. Residential land uses have an average age of 57 years and occur in two clusters, one in the southeastern part of Lansing and the other around the Holt area. These two uses utilize the esker site rather than the raw materials and have been able to endure for the longest time period of any of the other categories.

Mining operations average 47 years in existence at the three sites although extraction processes have been identified at 13 locations in the study area. The largest portion of the esker that remains for potential extraction totals approximately 3,100 feet south of Holt along Cedar Street. There has been considerable variation in the duration of mining at a particular site ranging from 60 years to two years. As expected there was a definite trend for sites to be opened at more recent dates as distance from the Lansing urban area increased (Figure 6).

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[5]Bellfontaine has now been replaced by the name Boyer-Spinks on soils maps being constructed by the Soil Conservation Service.

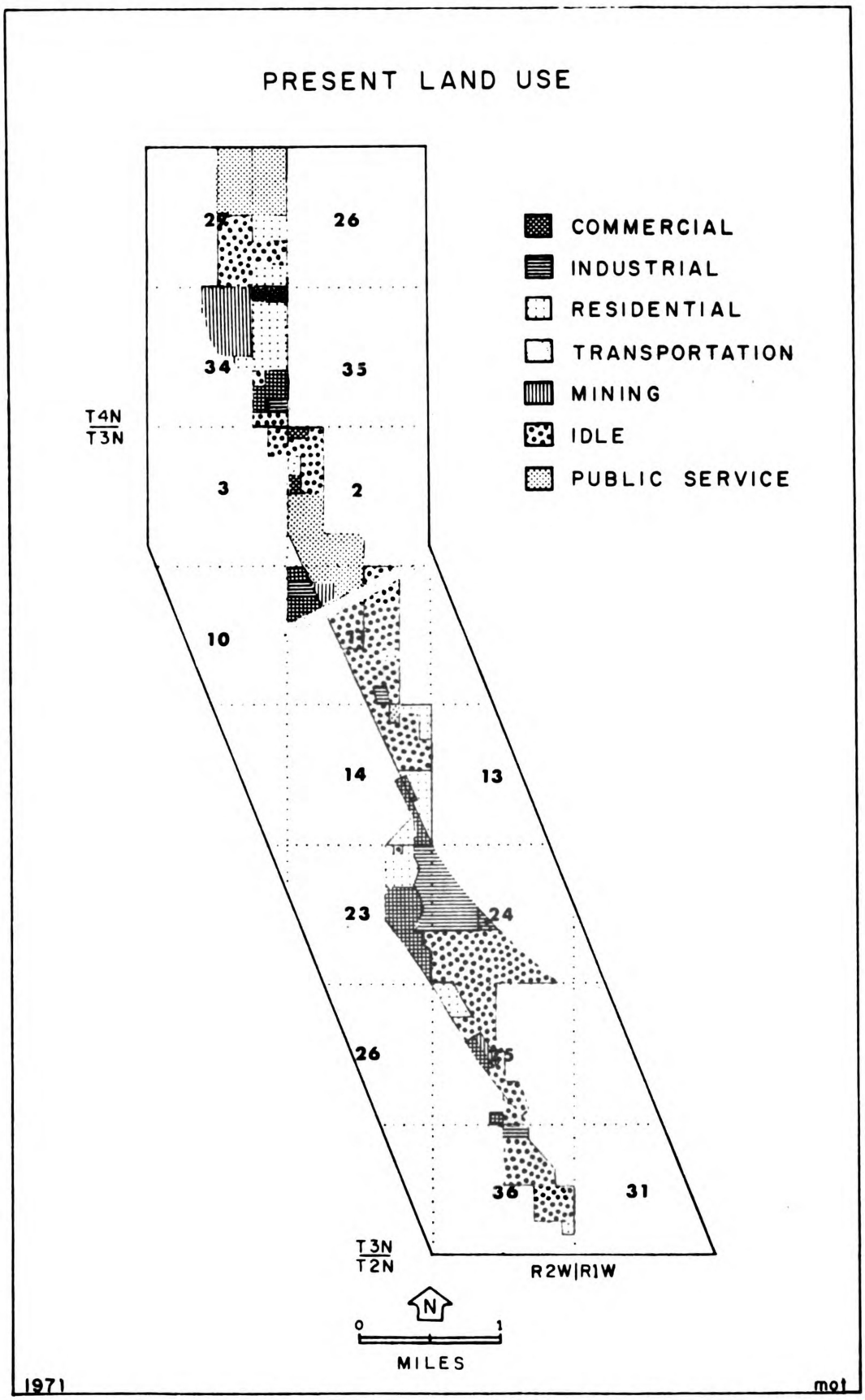
PRESENT LAND USE
COMMERCIAL
INDUSTRIAL
RESIDENTIAL
TRANSPORTATION
MINING
IDLE
PUBLIC SERVICE
T4N
T3N
25
26
34
35
3
2
10
11
14
13
23
24
26
25
36
31
T3N
T2N
R2W|R1W
N
0
1
MILES
1971
mot

Figure 5

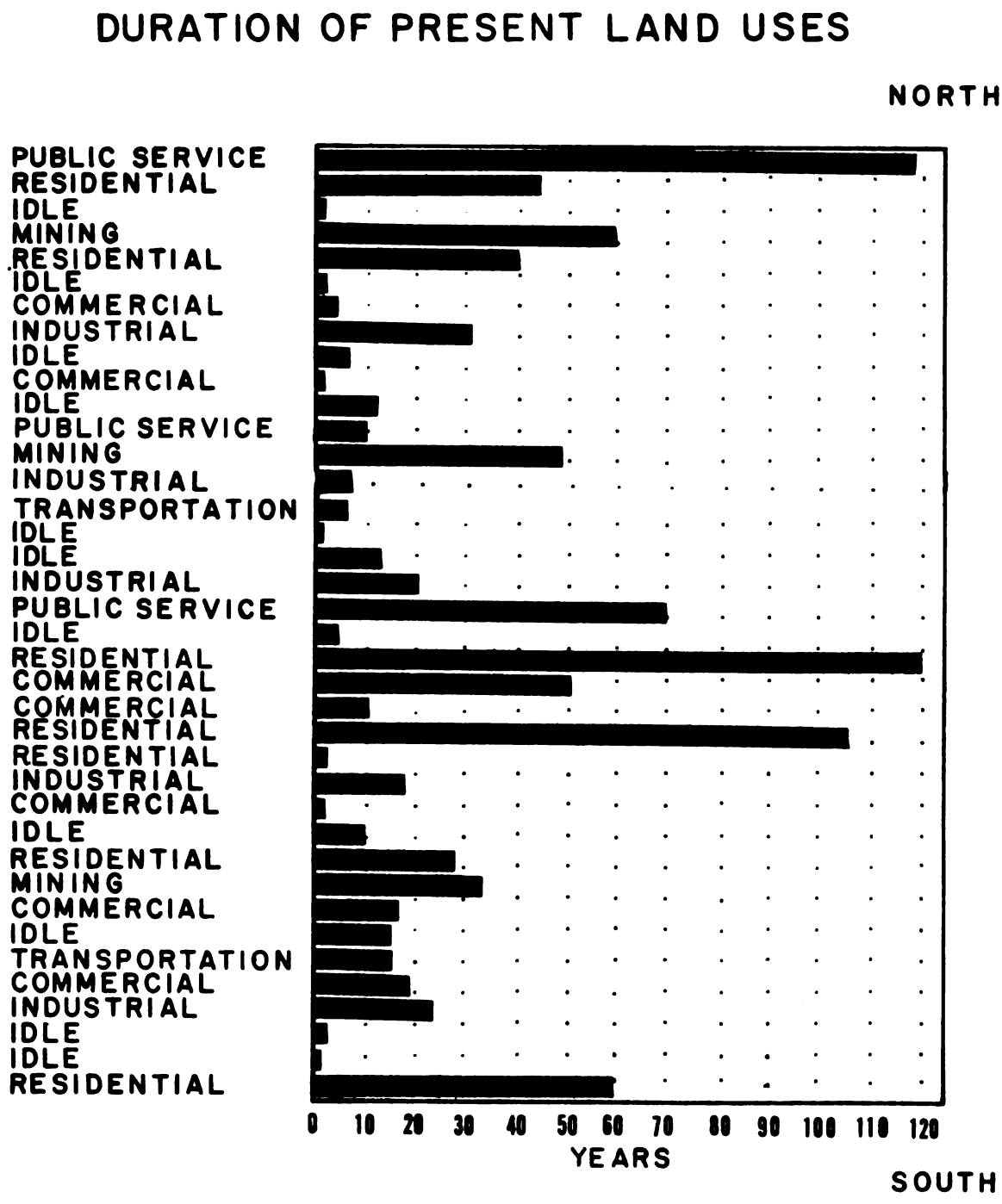
DURATION OF PRESENT LAND USES
NORTH
PUBLIC SERVICE
RESIDENTIAL
IDLE
MINING
RESIDENTIAL
IDLE
COMMERCIAL
INDUSTRIAL
IDLE
COMMERCIAL
IDLE
PUBLIC SERVICE
MINING
INDUSTRIAL
TRANSPORTATION
IDLE
IDLE
INDUSTRIAL
PUBLIC SERVICE
IDLE
RESIDENTIAL
COMMERCIAL
COMMERCIAL
RESIDENTIAL
RESIDENTIAL
INDUSTRIAL
COMMERCIAL
IDLE
RESIDENTIAL
MINING
COMMERCIAL
IDLE
TRANSPORTATION
COMMERCIAL
INDUSTRIAL
IDLE
IDLE
RESIDENTIAL
0 10 20 30 40 50 60 70 80 90 100 110 120
YEARS
SOUTH

Figure 6

Industrial land uses have the next highest average duration with a mean age of 19 years. The occurrence of the five nearly equally spaced aggregate plants follows the development of mining activities because they were initially concerned with processing of the raw materials from the esker. Due to exhausted supplies none of the plants process any material from their respective sites.

Commercial land uses have a mean duration of 15 years. The spatial pattern of these activities are found in two clusters, one within and near the southeast portion of Lansing and the other cluster in Holt. The commercial uses occupy altered or reclaimed portions of the esker. The low mean age may indicate that commercial activities may be increasing as urbanization encroaches.

The land-use category which has the lowest mean age of duration is that of idle land. Idle land averages six years in existence and is found throughout the study area in a random pattern. There is no discernible pattern of land being left idle for shorter periods of time within the urban areas, as might be expected.

Of the 38 sites identified, 25 (68%) have been established in the last 25 years. Only seven (18%) are older than 50 years.

Future Land-Use Trends

Future land-use trends will probably be dominated by recreational and commercial activities while other groups such as residential, industrial, agricultural, transportation, public service, idle, and mining are not expected to increase significantly, if at all. The advantages that recreational and commercial land uses have over the other categories will be examined in a regional context.

Commercial: This category will be expected to increase primarily as a function of the site location being able to produce high economic returns. An example of such a situation is the portion of the esker that lies in Sections 23, 24, and 25, T3N, R2W. In these sections the esker is near Cedar Street on its west side and adjacent to idle land on the east. Township officials have designated this one of the most attractive sites for commercial or industrial development in Ingham County (personal communication with M. Dixon, Administrative Assistant to Supervisor, Delhi Township, 1971). The location involved amounts to 684.5 acres of former farm land that lies within one-quarter mile of an interchange with US 127, 2 miles from I-96, and is bisected by the Penn Central Railroad.[6] Locational characteristics such as these make the site very attractive for development.

Recreational: It is expected that recreational land use will probably become the dominant land-use type to evolve on that portion of the esker in the study area. Future recreation development is perhaps best put into perspective by Clawson, who states that, in terms of numbers of people affected, recreation as a major land use is exceeded only by urban uses. He lists some major considerations that are increasing the demands for outdoor recreation. These are population increase, greater per capita income, shortening of the work week, and improved transportation facilities (Clawson, 1963, p. 54). The ownership of most of this type of land will be by township and city governments.

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[6]The land involved is shown in the Ingham County Plat Book (1970) as being owned by D. Holloway and by the Holloway Construction Company, Incorporated of Wixom, Michigan.

The preponderance of recreational land use associated with the esker is primarily a function of political constraints. The contemporary awareness of and demand for outdoor recreational facilities have produced a situation conducive to the development of additional facilities. In Delhi Charter Township it is expected that the recreational needs will approximate 5.5 acres per 1000 population by 1985. The officials are investigating the potential for public and/or private development of gravel pits for community recreational facilities (Comprehensive Development Plan - Delhi Charter Township, 1967, pp. 19-20). At the present time township officials are negotiating to purchase an abandoned gravel pit area in the NE$\frac{1}{4}$ of Section 14, T4N, R2W for park development (personal communication with M. Dixon, Administrative Assistant to Supervisor, Delhi Charter Township, 1971).

A second factor which increases the recreational potential of the land is the nature of the soils. The soils of the esker are well drained and porous, but the adjacent soils in associated troughs are often poorly drained (Soil Survey, Ingham County, 1941, p. 27). (See Figure 7) An example of limitation due to soil characteristics is shown in the Zoning Ordinance of Delhi Charter Township, 1968. Section 6.6 Flood Plain Regulations reads as follows:

> 6.6.1 Intent and Purpose: The purpose of these regulations is to protect those areas of the township which are subject to predictable flooding in the flood plains areas of major rivers, their branches and tributaries within the township so that the reservoir capacity shall not be reduced thereby creating danger to areas previously not so endangered in the time of high water, or to impede, retard, accelerate or change direction of flow or carrying capacity of the river valley or to otherwise increase the possibility of flooding.

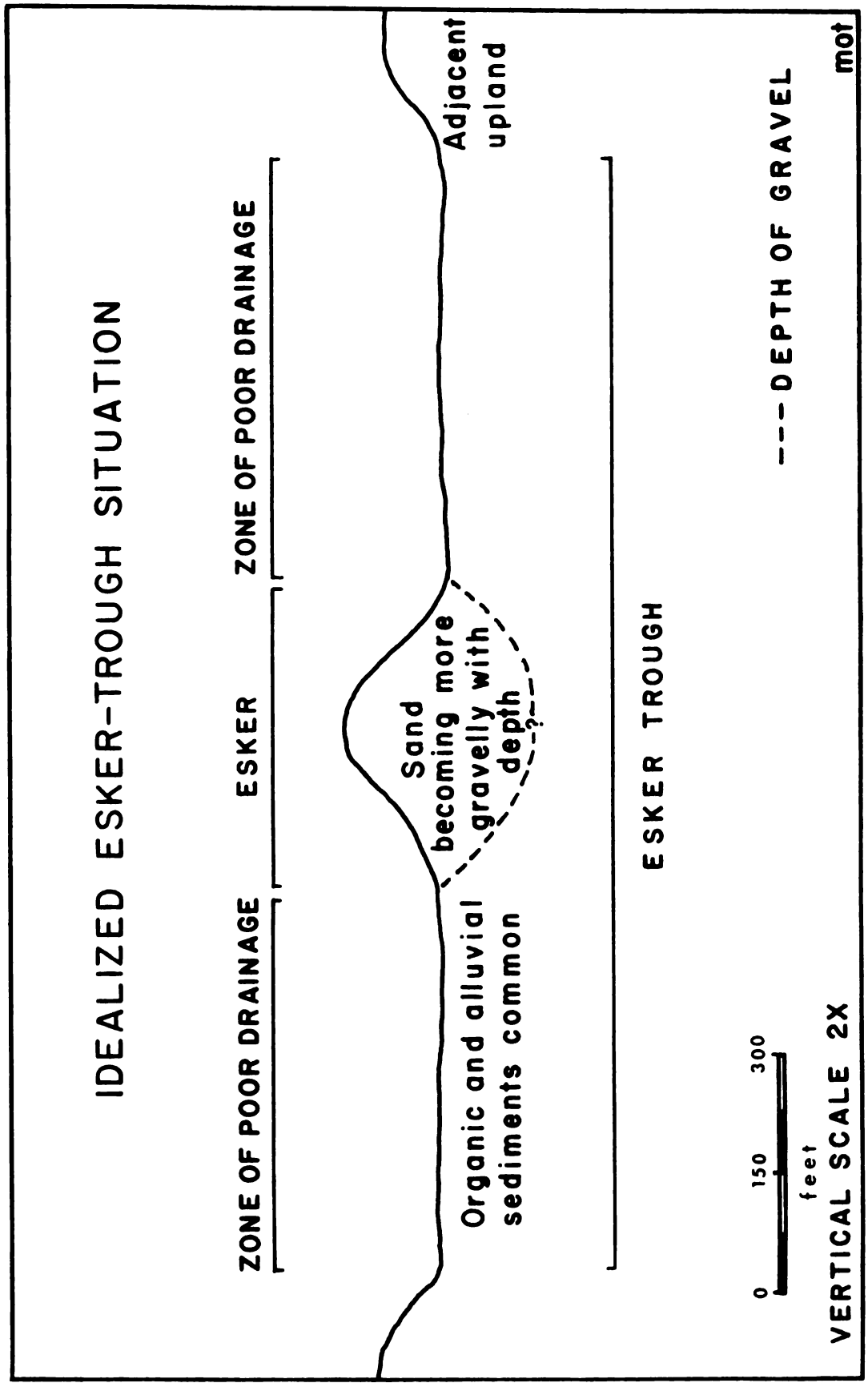
IDEALIZED ESKER-TROUGH SITUATION
ZONE OF POOR DRAINAGE
ESKER
ZONE OF POOR DRAINAGE
Adjacent upland
Sand becoming more gravelly with depth?
Organic and alluvial sediments common
ESKER TROUGH
---DEPTH OF GRAVEL
mot
0
150
300
feet
VERTICAL SCALE 2X

Figure 7

These flood-plain areas are designated by the U.S. Army Corps of Engineers, the Michigan State Resources Commission, or the Township Engineer. Because of the likelihood of flooding and imperfect drainage from septic tank fields, Section 6.6.5 further defines the use potential of poorly drained sites.

> 6.6.5 Restricted Uses: Any structure where human habitation is contemplated as either a place of public gatherings, or employment, shall be prohibited from locating within flood plain areas.

The soils that are designated as being poorly drained are characterized as having severe limitations for residential and structural use. The limitations include a high water table, especially during spring months. Additional limitations are frost heaving, cracking, and wet depressions (Soil Conservation Service Engineering Interpretations for Metamora soil series, 1965).

In the NW$\frac{1}{4}$ of Section 2, T3N, R2W along Aurelius Road, a development is planned by private landowner Peter Denesuk. This property of 59 acres is characterized by a pond along its entire length that was the result of excavating the esker. The land has been classified a flood plain, thereby restricting its use. Plans call for the development of a commercial-recreational facility associated with Kamp Grounds of America in 1972.[7]

Outdoor recreational facilities are probably the most desirable development of the land that has been disturbed by the mining of sand and gravels from the esker. Environmental constraints are not disregarded and public demands are being partially fulfilled when these facilities are developed. Such developments as golf courses, ponds, and scenic areas appear to be the most compatible use of the land in this given situation (Figure 8).

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[7] The term "commercial-recreational" is used to denote private campgrounds and fishing facilities for which users will be charged a fee.

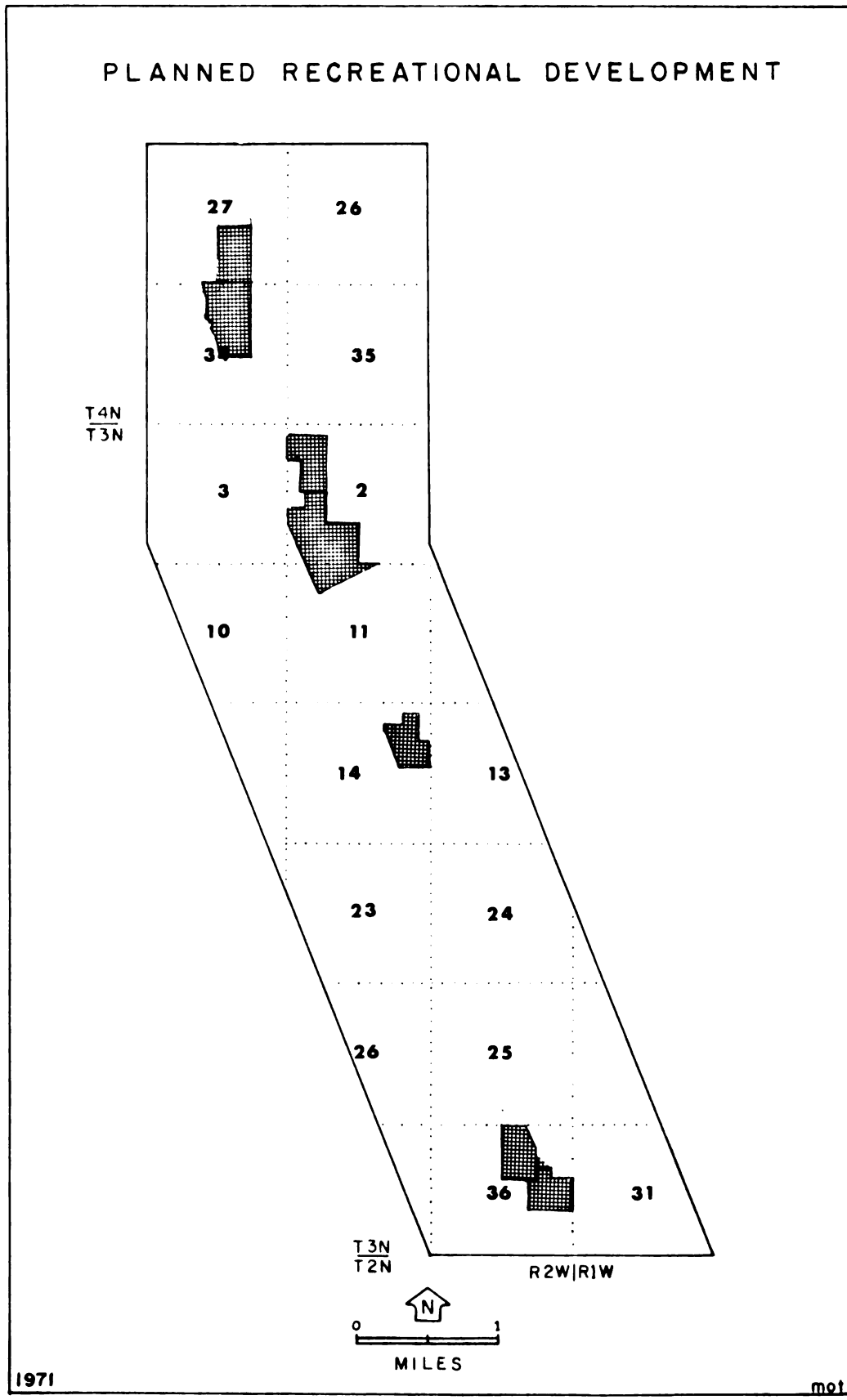
PLANNED RECREATIONAL DEVELOPMENT
27
26
35
T4N
T3N
3
2
10
11
14
13
23
24
26
25
36
31
T3N
T2N
R2W|R1W
N
0
1
MILES
1971
mot

Figure 8

Model of Land-Use Sequence

The change in man's views of the esker is exemplified by the rapid alteration of that landform since about 1911. It has changed from a curious "hogsback" to a valuable economic entity. In this context man can be considered as the modifying agent that has altered the esker. As the demand for raw materials in the esker increased, excavation increased to the point where nearly all of the esker has been removed.

In order to present a meaningful analysis and description of the land-use pattern in the study area, the following model is offered to conceptualize the sequential land use. The purpose here is to select and arrange the field data in such a way as to find a hypothesis (Harvey, 1969, p. 298). The model suggests that, as sands and gravels were removed, several subsequent uses may develop within economic and environmental constraints. Basic assumptions that apply to the model are as follows.

1 - The material comprising the esker may be a valuable mineral resource and the space occupied by the esker may be desirable for utilization.

2 - Man is the active modifying agent.

3 - Man is economically and politically rational.

4 - The changes and events take place through time.

The initial phase of utilization of the esker landform was for agricultural, residential, public service and transportation purposes. These uses were not related to gravel extraction and the degree of transformation of the esker was minimal.

Present land uses which characterize the second phase were set into motion largely as a result of the development and expansion of sand and gravel extraction on a large scale. Land which was formerly used for agriculture, residential, transportation, or idle was transformed by the mining of sand and gravels. A recognition of the potential economic attributes of the esker takes place and selection of that attribute which is most profitable occurs. Utilization of sand and gravels began taking place on available and convertible land near population clusters and their interstices. These developments were accompanied by the building of industrial facilities to process the raw materials.

The third phase is that of subsequent land use. The alteration of the esker results in a distinctive land-use pattern partially due to the massive linear excavations. The future land use will tend to result from the redevelopment of abandoned quarries as reclaimed land for commercial-industrial activities and particularly outdoor recreation facilities.

Within this conceptual framework the gravel extraction activities such as this should be reviewed as intermittently active processes of land-use evolution, and additional development should be anticipated in regard to land use (Figure 9).

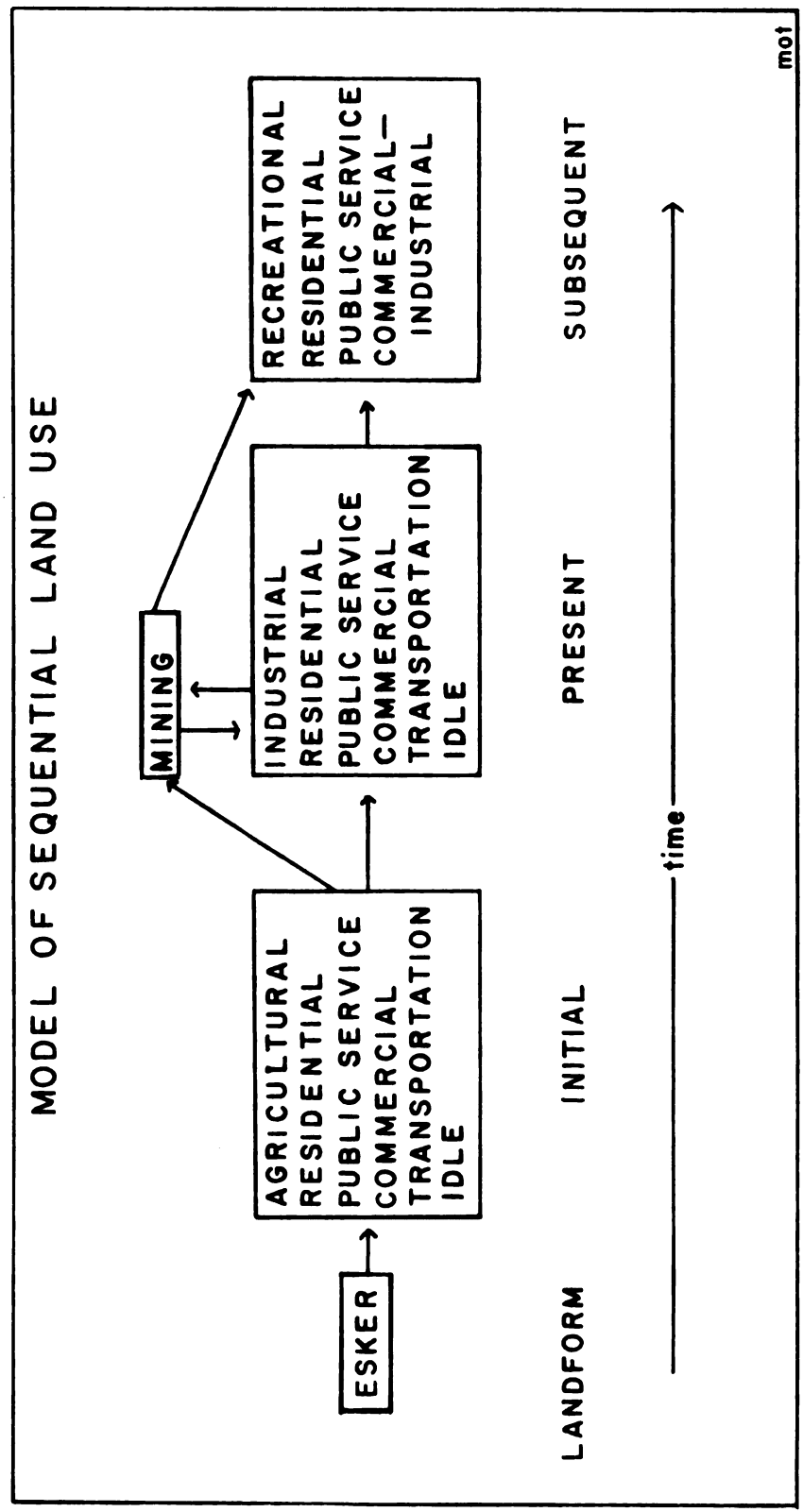
MODEL OF SEQUENTIAL LAND USE
ESKER
AGRICULTURAL
RESIDENTIAL
PUBLIC SERVICE
COMMERCIAL
TRANSPORTATION
IDLE
MINING
INDUSTRIAL
RESIDENTIAL
PUBLIC SERVICE
COMMERCIAL
TRANSPORTATION
IDLE
RECREATIONAL
RESIDENTIAL
PUBLIC SERVICE
COMMERCIAL—
INDUSTRIAL
LANDFORM
INITIAL
PRESENT
SUBSEQUENT
time
mot

Figure 9

CONCLUSIONS

One of the initial goals was to describe and analyze the evolving land-use patterns on an esker landform. From the analysis of the land-use patterns it appears that many of the present land uses were motivated primarily by the perceived economic benefits, particularly those which make use of the raw materials. There is a presence of significant amount of idle land that has resulted from the removal of sand and gravel, abandonment of farm land, and speculation by investors. These rapid transformations and the youthfulness of the land uses on the esker site, are primarily a function of man's decisions, which are the result of technological advances and social change.

On the basis of this analysis meaningful predictions can be made about future land-use patterns and the associated extraction processes. Future land-use will probably be dominated by outdoor recreational facilities which are motivated in part by perceived social benefits and appears to be evolving into a compatible relationship with the nearby urban area. It is further expected that there will be a decline in heavy industrial land use characterized by the aggregate plants. The lack of nearby raw materials, pollution of the air, and the semi-portable nature of the processing plants should allow for this decline. Finally a systematic plan should be developed to utilize abandoned quarries as they become available in order to keep pace with the expansion of the urban area and to reduce potential hazards to life.

Although this study has dealt with only a portion of a geomorphic feature, it is believed that trends and processes which were identified will have application in similar situations.

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