(5) Extensive farming zone

Annual Rainfall	:	Minimal, and even drought-resistant feed crops and cereal crops can often hardly be grown.
Products	:	Livestock (beef cattle) and drought-resistant crops
Area	:	104,000 km² (27% of the total area)
Farming Pattern	:	Large-scale farms at 35%, communal farms at 45%, and national parks at 20%

6–3 Agricultural Production

6–3–1 Production of the Major Corps

According to the survey conducted by the FAO from 1984 to 1986, the annual consumption of grain per capita in Zimbabwe amounts to about 172 kg. The average annual production of maize is about 2.21 million tons with the breakdown shown below:

– Exports–Imports	0.12 million tons
– Reserves	0.39
– Domestic demand	1.70
Production Total	2.21 million tons

The domestic demand of 1.7 million tons can be broken down further as follows:

– Feeds	0.36 million tons
– Seeds	0.04
– Losses	0.24
– Food consumption	1.06
Domestic Demand Total	1.70 million tons

Per capita consumption can be calculated to be 128 kg, using the above figure with a population of 8.31 million during the period in question.

In the meantime, assuming the present population to be about 9.2 million, the required supply of grain is estimated to be 1.58 million tons, where maize accounts for about 75%, or 1.18 million tons.

Tables 6–2, 6–3 and 6–4 show the production, area harvest and yield of the major crops, respectively, during the 9–year period from 1981 to 1989.

Table 6–2 Production of the Major Crops

(unit: 1,000 ton)

Name of Crops	1981	1982	1983	1984	1985	1986	1987	1988	1989
Cereales total	(3,226)	(2,131)	(1,332)	(1,588)	(3,562)	(3,096)	(1,303)	(3,000)	(2,471)
Wheat	201	219	124	99	205	248	215	(260)	(285)
Maize	2,729	1,657	844	1,283	2,711	2,545	931	2,253	(1,861)
Sorghum	263	215	152	175	357	272	129	(178)	(81)
Potatoes	20	25	23	23	27	28	29	(30)	(30)
Sweet Potato	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Cassava	50	60	70	80	82	85	86	(87)	(88)
Dry Pulses Total	19	49	45	45	47	48	45	46	(50)
Soyabeans	65	91	88	90	86	83	104	120	(176)
Groundnuts in Shell	239	111	32	26	68	61	79	135	(101)
Sugarcane	3,551	3,587	3,516	3,778	3,650	4,044	3,800	3,128	(3,622)
Coffee	5	6	10	12	11	14	13	12	(14)
Tea	10	11	11	13	15	16	17	(17)	(17)
Tobacco	78	92	100	125	109	117	131	112	(132)
Cotton	53	56	60	69	103	85	105	120	–
Fruits	(109)	(112)	(116)	(122)	(125)	(129)	(132)	(135)	(139)

Source : Eurostat Report Zimbabwe 1990
in ( ): FAO statistics yearbook

Table 6-3 Area Harvest of the Major Crops

(unit: 1,000 ha)

Name of Crops	1981	1982	1983	1984	1985	1986	1987	1988	1989
Wheat	37	37	35	17	38	43	37	45	(50)
Maize	1,440	1,415	1,340	1,356	1,428	1,350	1,211	(1,300)	(1,198)
Sorghum	211	209	150	167	234	200	180	220	(165)
Potatoes	1	2	2	2	2	2	2	(2)	(2)
Sweet Potato	(3)	(3)	(3)	(3)	(3)	(3)	(1)	(1)	(1)
Cassava	18	19	19	20	20	20	21	(22)	(23)
Dry Pulses Total	36	64	65	65	65	65	70	71	(72)
Soyabeans	37	52	54	50	42	41	48	51	(51)
Groundnuts in Shell	240	191	151	100	133	134	202	211	(210)
Sugarcane	34	32	33	33	33	33	33	32	(31)
Coffee	5	5	6	8	8	8	12	12	(12)
Tea	4	4	4	4	4	4	4	(4)	(4)
Tobacco	44	50	51	55	52	61	66	60	(62)
Cotton	70	56	53	85	101	69	90	95	(91)

Source : Eurostat Report Zimbabwe 1990
in ( ): FAO statistics yearbook 1981 ~1989

Table 6–4 Yield of the Major Crops

(unit: kg/ ha)

Name of Crops	1981	1982	1983	1984	1985	1986	1987	1988	1989
Wheat	5,460	5,846	3,429	5,832	5,660	5,767	5,757	5,778	(5,700)
Maize	2,419	2,419	2,419	946	2,073	1,886	769	(1,733)	(1,612)
Sorghum	592	560	366	330	571	655	267	809	(492)
Potatoes	14,611	15,120	15,333	15,333	15,333	15,333	16,111	(15,946)	(15,789)
Sweet Potato	(1,913)	(1,824)	(1,667)	(1,667)	(1,667)	(1,667)	(2,400)	(2,364)	(2,250)
Cassava	2,778	3,243	3,684	4,103	4,141	4,250	4,095	(3,955)	(3,911)
Dry Pulses Total	1,106	1,107	219	711	729	734	681	687	(689)
Soyabeans	1,743	1,756	1,644	1,795	2,038	2,634	2,167	2,353	(3,453)
Groundnuts in Shell	995	602	213	255	331	531	391	641	(480)
Sugarcane	103,995	113,703	112,805	114,485	111,455	115,152	110,636	97,750	(116,839)
Coffee	1,187	1,201	1,273	1,438	1,438	1,500	1,124	1,083	(1,167)
Tea	2,481	2,660	2,561	3,171	3,659	3,902	3,678	(4,052)	(4,146)
Tobacco	1,764	1,844	1,920	2,284	2,113	1,945	2,002	2,052	(2,129)
Cotton	–	–	–	–	–	–	–	–	–

Source : Eurostat Report Zimbabwe 1990
in ( ): FAO statistics yearbook 1981 ~1989

The production of grain, inclusive of maize, wheat, sorghum and so on, reached a peak in 1985 at about 3.56 million tons, while it was lowest in the drought years of 1983 and 1987 at about 1.30 million tons only.

Thus, there is a grain surplus compared with 2.0 to 3.0 million tons of annual production in normal years, except in drought years. In a drought year, the production of maize falls to only 0.9 million tons, resulting in a supply shortage of about 0.3 million tons. However, the net shortage is considered to be very small because of the maize stock of 0.39 million tons. The domestic newspaper, "The Herald", reports, however, that in 1991 as much as 0.18 million tons of maize will need to be imported.

As for sorghum, annual production reached a peak of 0.35 million tons in 1985, although it has been decreasing to as low as 0.1 million tons in recent years due to the fall in the demand for the crop. The demand for wheat has been increasing, and production has expanded from 0.2 million tons to about 0.3 million tons a year. Potato production has increased from 20,000 tons to 30,000 tons, while cassava production has risen from 50,000 tons to 90,000 tons. Sweet potato production is estimated to have remained at the same level of 1,000 tons.

Soybean production has been increasing steadily from 60,000 tons in 1981 to 180,000 tons in 1989. Other types of bean have remained at the same level of 50,000 tons over the past few years. Ground nut production fluctuates dramatically year by year.

Sugarcane production has amounted to about 3.6 million tons consistently throughout the past few years, as it is controlled by the sugarcane mills near the plantations.

The production of cash crops such as coffee, tea, tobacco, cotton and fruit has been increasing steadily year by year. The increase has been brought about by an expansion of the areas planted in the case of tobacco and cotton, and by the aging of trees in the case of fruit. The production of these cash crops reached the following levels in 1989:

Coffee	14,000 tons
Tea	17,000
Tobacco	132,000
Cotton	120,000

Table 6–5 shows the production, planted areas and yield per hectare of the major crops in each province of the country. Coffee, tea, fruit and some vegetables are produced in Manicaland, as shown in Figure 6–5, where most of the forests and specialized farming zones are located.

Grain and upland crops in general (including vegetables, tobacco and cotton) are mainly cultivated in three provinces in Mashonaland and the Midlands where most of the intensive farming and semi-intensive farming zones exist. These zones are situated in an area from the north to the central part of the country and have an annual rainfall of 600 to 1,000 mm, which means that productivity through natural rainfall is rather high. Where irrigation systems have been adopted, productivity is even higher.

Semi-extensive farming and extensive farming zones prevail mainly in the Matabeleland North, Matabeleland South and Masvingo Provinces. Since the rainfall in these areas is less than 600 mm per annum, agricultural productivity is quite low (see Figure 6–6).

Table 6–5 Major Crops on Commercial Farms by Province, Production in Tons, Area in Hectares and Yield in Tons/ha, 1983

		Manicaland	Mashonaland West	Mashonaland East	Mashonaland Central	Matabeleland North	Matabeleland South	Midlands	Masvingo	Total
Maize	Production	9,914	278,817	107,719	174,344	6,885	2,467	15,202	3,584	598,932
	Area	9,862	121,898	48,457	56,283	2,549	2,305	18,119	12,282	271,755
	Yield	1,005	2,287	2,223	3,098	2,701	1,070	839	292	2,204
Sorghum	Production	649	4,315	418	1,280	263	22	501	88	7,536
	Area	701	3,210	462	933	346	131	710	1,178	7,671
	Yield	926	1,344	905	1,372	760	168	706	75	982
Wheat	Production	18,631	45,202	14,648	23,732	4,400	1,264	694	2,419	110,990
	Area	4,022	8,773	2,542	4,369	844	353	169	475	21,547
	Yield	4,632	5,152	5,762	5,432	5,213	3,581	4,107	5,093	5,151
Groundnuts	Production	198	3,339	4,350	809	250	33	131	43	9,153
	Area	994	2,078	2,920	823	102	221	1,292	2,279	10,709
	Yield	199	1,607	1,490	983	2,451	149	101	19	855
Soyabeans	Production	4,150	40,930	16,250	15,070	28	132	1,438	627	78,625
	Area	2,275	31,939	8,732	10,073	31	123	1,298	438	54,909
	Yield	1,824	1,282	1,861	1,496	903	1,073	1,108	1,432	1,432
Cotton	Production	13,650	39,270	127	48,769	..	2,277	2,129	7,800	114,022
	Area	5,483	27,695	458	25,085	..	856	4,517	3,881	67,975
	Yield	2,490	1,418	277	1,944	..	2,660	471	2,010	1,677
Coffee (1)	Production	6,213	1,391	*	214	..	..	*	212	8,234
	Area	4,849	1,576	*	313	..	..	*	103	6,986
	Yield	1,281	883	*	684	..	..	*	2,058	1,179
Tobacco	Production	6,029	38,262	21,202	27,781	..	..	*	*	93,331
	Area	3,790	19,476	9,511	13,518	..	..	*	*	46,327
	Yield	1,591	1,965	2,229	2,055	..	..	*	*	2,015

Notes : *) Suppressed for confidentiality reasons. 1) Production of coffee relates to large scale commercial farms only.
Source : Central Statistical Office

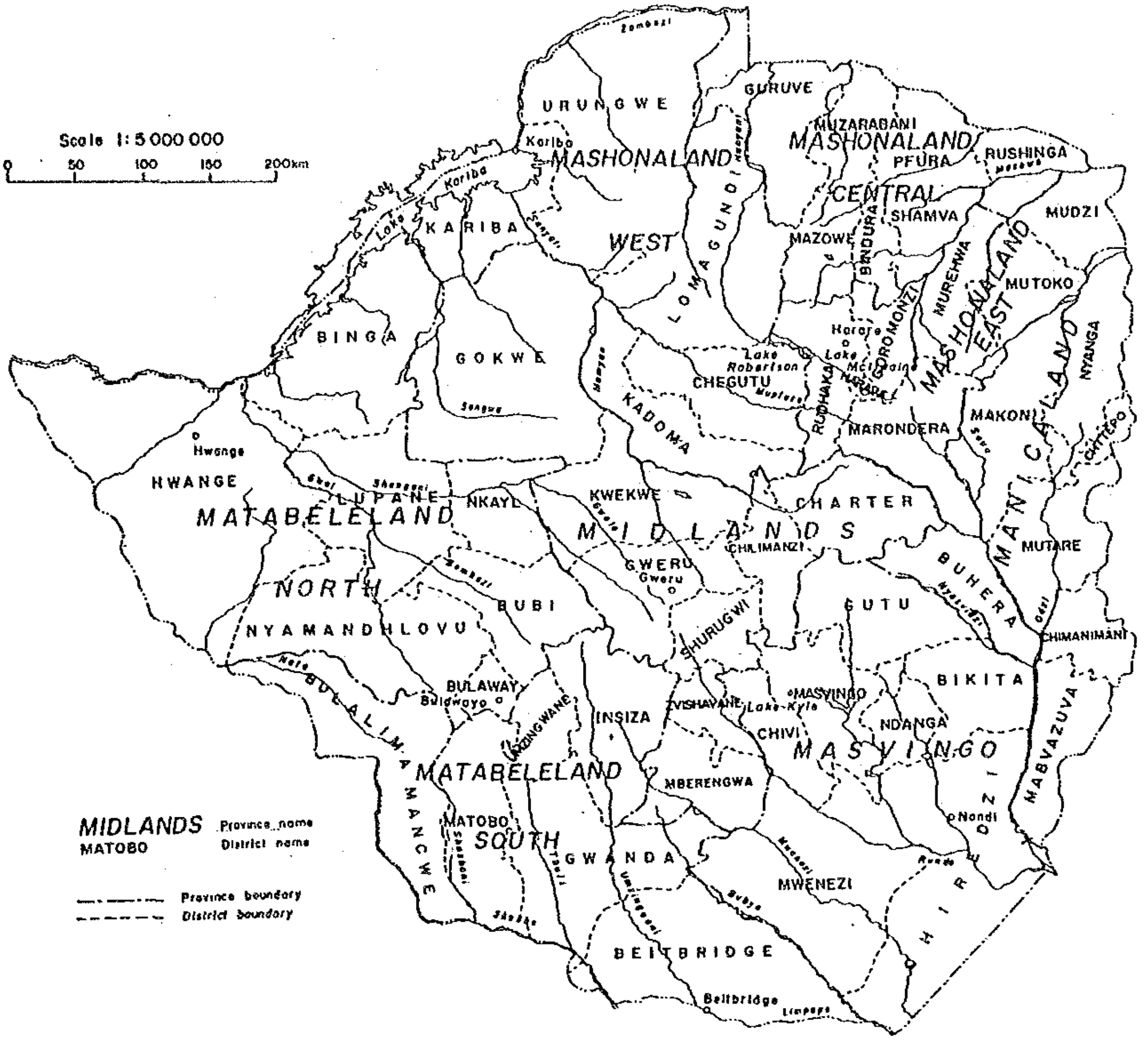

Figure 6–6 Administrative Areas
Source: Ventures Large Print Atlas for Zimbabwe

The production volumes, planted areas and production yields for maize, sweet potatoes and sugarcane are shown in Tables 6–6, 6–7 and 6–8, respectively.

Table 6-6 Maize, Production in Tons, Area in Hectares, and Yield in kg/ha, 1970 ~ 1989

	Commercial			Communal[1]			Total		
	Production	Area	Yield	Production	Area	Yield	Production	Area	Yield
1970	839,627	292,010	2,875	245,700	610,800	402	1,085,327	902,810	1,202
1971	1,400,499	304,017	4,607	455,000	672,000	677	1,855,499	976,017	1,901
1972	1,762,067	338,016	5,213	555,100	664,661	835	2,317,167	1,002,677	2,311
1973	810,358	315,335	2,570	145,000	475,000	305	955,358	790,335	1,209
1974	1,634,356	311,058	5,254	470,000	725,000	648	2,104,356	1,036,058	2,031
1975	1,328,075	278,170	4,774	435,000	725,000	600	1,763,075	1,003,170	1,758
1976	1,287,752	257,301	5,005	550,000	760,000	724	1,837,752	1,017,301	1,807
1977	1,213,285	264,354	4,590	400,000	600,000	667	1,613,285	864,354	1,867
1978	1,178,234	273,144	4,314	450,000	700,000	643	1,628,234	973,144	1,673
1979	721,916[2]	199,430[2]	3,620[2]	420,000	600,000	700	1,144,916	799,430	1,428
1980	910,739[2]	227,733[2]	3,992[2]	600,000	900,000	667	1,510,739	1,127,733	1,340
1981	1,833,395	363,448	5,044	1,000,000	1,000,000	1,000	2,833,395	1,363,448	2,078
1982	1,213,376	316,440	3,835	595,000	1,100,000	595	1,808,376	1,416,440	1,277
1983	624,786	283,880	3,201	285,000	1,050,000	271	909,786	1,333,880	682
1984[3]	678,403	224,586	3,021	454,400	1,136,000	400	1,132,803	1,360,586	833
1985[3]	1,153,000	238,000	4,844	1,558,000	1,018,000	1,394	2,711,000	1,256,000	2,158
1986	–	–	–	–	–	–	2,456,000	1,350,000	1,891
1987	–	–	–	–	–	–	931,000	1,211,000	769
1988	–	–	–	–	–	–	2,253,000	1,300,000	1,733
1989	–	–	–	–	–	–	1,931,000	1,198,000	1,612

Notes:
1) Estimates.
2) Refers to large scale commercial farms only.
3) Provisional data.
Source : Central Statistical Office (1970 ~ 1985)
For 1986 to 1989, FAO statistics yearbook.

Table 6-7 Sweet Potatoes, Production in Tons, Area in Hectares and Yield in kg/ha, 1987 ~ 1989

	Production	Area	Yield
1981	1,000 Ton	–	1,913 kg/ha
1982	–	–	1,824
1983	1,000	–	1,667
1984	1,000	–	1,667
1985	1,000	–	1,667
1986	1,000	–	1,667
1987	1,000	1,000 ha	2,400
1988	1,000	1,000	2,364
1989	1,000	1,000	2,250

Source : FAO statistical yearbook.

Table 6-8 Sugarcane, Production in Tons, Area in Hectares, and Yield in Tons/ha

	Productive area			
	Production	Area	Yield	Non productive area
1970	1,760,000	19,501	90.2	580
1971	1,625,000	16,315	99.6	3,192
1972	1,795,000	19,486	92.1	458
1973	1,806,000	21,883	82.5	526
1974	2,314,000	21,190	109.2	4,140
1975	2,628,000	22,769	115.4	4,041
1976	2,112,000	25,328	83.4	417
1977	3,087,000	26,419	116.8	898
1978	2,635,000	24,677	106.7	343
1979	2,555,000	24,518	104.2	316
1980	2,528,000	24,515	103.1	6,038
1981	3,551,000	34,146	103.9	466
1982	3,587,000	31,547	113.7	533
1983	3,438,000	33,033	104.1	1,400
1984	3,459,000	33,048	104.7	109
1985	3,678,000	33,000	111.5	–
1986	3,800,000	33,000	115.2	–
1987	3,651,000	33,000	110.6	–
1988	3,128,000	32,000	97.8	–
1989	3,622,000	31,000	116.8	–

Note : 1) Provisional data.

Source : Central Statistical Office (1970~1984)
FAO Statistical Yearbook (1985~1989)

6-3-2 Maize

The large-scale commercial farms and the communal peasant farms are the major production areas of maize. The areas planted with maize on the large-scale commercial farms amounted to 260,000 to 340,000 hectares in the 1970's. However, these areas were reduced to 200,000 hectares just before independence due to social unrest. After winning independence, and because the government adopted a policy not to cause the possible outflow of European farm owners by increasing the price of maize so that it was a little higher than that on the international market, the areas planted with maize were increased for a certain period, amounting to 360,000 hectares in 1981.

The areas planted with maize, however, have gradually decreased to only 230,000 hectares lately, because about one-third of the European farm owners left Zimbabwe for other countries, while the domestic farm owners diversified to other kinds of cash crop. At the same time, the price of maize remained at the same level.

The areas planted with maize in the communal areas covered as much as 500,000 to 700,000 hectares in the 1970's. After independence, these areas were increased to more than 1,000,000 hectares with the re-allocation farmland to the communal areas which had been vacated by the outflow of the European farm owners.

The total area planted with maize both on large-scale commercial farms and communal farms amounted to 800,000 to 1,000,000 hectares before independence. The figure jumped to about 1,400,000 hectares in certain years after independence, but fell to 1,200,000 hectares in 1989.

The production yield per hectare shows considerable fluctuations year by year, since it depends so much on the rainfall conditions. In the case of large-scale commercial farms, the yield was more than 5 tons per hectare even before independence owing to favorable conditions such as the soil, climate, irrigation facilities, and established farming techniques. However, in the communal areas, the soil and climatic conditions were less favorable, and production was principally based on the rain-fed conditions with no irrigation facilities. Communal farmers tended not to provide any fertilizer and crop management due to the unstable production prospects. As a result, the yield achieved was a mere 835 kg even in the best year before independence. After independence, however, the yield was improved to about 1.4 tons, as farming techniques were improved and some of the farmland equipped with irrigation facilities was distributed to small-scale farmers in accordance with the resettlement program.

As a whole, the production yield has remained at the same level even after independence. The yield during the drought years after independence, however, has become worse than that before independence. This might be attributed mainly to the fact that the number of planted areas on large-scale commercial farms was reduced, while that in communal areas, which are subject to suffer from drought damage, was increased. Countermeasures to lessen the drought damage will play a very important role in the future development of maize farming.

Before independence, maize production on the large-scale commercial farms reached a peak as high as 1,760,000 tons per year, although it was only half that in the drought years. After independence, production reached 1,830,000 tons for a certain period due to the expansion of the area planted. Thereafter, the planted area have been decreased and, accordingly, production has been maintained at about 1,000,000 tons. In drought years, production reached only 620,000 tons.

As for the communal areas, production was only 500,000 tons before independence. However, with the increased number of planted areas and the application of improved farming techniques, the production volume surpassed the level of 1,5000,000 tons after independence. On the other hand, in drought years, the production level was maintained as low as only 300,000 to 400,000 tons.

Total production over the past 5 years has shown a gradual decrease, although an adequate supply for domestic consumption has been secured, except in the case of the drought year of 1987 when production reached only 930,000 tons. In this respect, there will be no constraint on the quantity of maize used to process cornstarch as a raw material for citric acid production.

6–3–3 Sweet Potato

In Zimbabwe, the production volume of sweet potato is quite small and not shown in the statistics prepared by the government. In accordance with the estimate made by the FAO, the annual production of sweet potato is less than 1,000 tons with a total planted area of a little less than 1,000 hectares. The production yield per hectare is assumed to be around 2.3 tons.

According to AGRITEX, sweet potato is not included in the items of study for development due to the minimal plantation areas. Although the productivity has gradually been improved, it seems rather difficult to increase sweet potato production as required by the citric acid production process.

Since sweet potato can serve as an emergency crop thanks to its drought-resistant nature, the utilization of sweet potato as a side dish as well as a feed for livestock animals might be worthy of further study in Zimbabwe where not much rainfall is expected.

6-3-4 Sugarcane

There are two sugar mills in the southern part of the country where most of the sugarcane is produced on farms owned and run directly by the mills. The plantations are scheduled to meet the requirement of coping with the production capacity of the sugar mills. Sugarcane production is therefore maintained at around 3,600,000 tons a year. By applying the irrigated farming technique developed by the sugar mills, the unit yield is quite high at about 110 tons per hectare. This yield reaches very high standard as compared with the world standard. It has been reported that sugarcane in Zimbabwe retains a higher yield rate of sugar than that in other countries. The total planted area has been maintained at almost the same level of about 32,000 hectares.

6-4 Agricultural Development for Raw Materials Used in Citric Acid Production

6-4-1 Common Problem Areas

The farming zones suitable for upland crops (maize, sweet potato, etc.) can be classified into intensive farming zones with an annual average temperature of 17.5 to 20°C and an annual rainfall of 750 to 1,000mm, and semi-intensive farming zones with an annual rainfall of 650 to 800mm. These zones consist of various types of soil ranging from sand to clay loam. There is drought damage once every four years due to the shallow ploughing depth and the poor content of rapidly available moisture.

Sugarcane is planted mostly in areas classified as semi-intensive farming zones where the temperature is comparatively high at 20 to 22.5°C, but with less rainfall at 450 to 650mm per year. Sugarcane is produced in the alkaline soil of vertisol provided with irrigation facilities.

As a countermeasure to lessen the drought damage, dam construction for irrigation purpose is a primary concern. With the prevailing situation at present, many areas are not equipped with the required irrigation distribution facilities and, furthermore, there is no great water resource potential. Thus, it will take rather a long time and a great deal of funding to secure the necessary irrigation water for ready use. As a possible means of alleviating the drought damage, it will be more practical and effective to implement countermeasures such as improving the soil through the use of fertilizers, deep ploughing, increasing the available moisture in the soil, using rainfall effectively, and minimizing evaporation and transpiration.

From an agro-economic point of view, the necessary countermeasures are discussed in more detail as follows:

(1) Through the application of deep ploughing techniques, permeability could be improved. By means of underdrainage and/or open drainage, excessive water is removed so as to expand the effective root zone. Furthermore, it is necessary to increase the available moisture content by applying more organic substances like manure and so on. In areas of high temperature, as organic substances easily decompose, it is recommended to apply both easily decomposable and non-easily decomposable organic substances at a ratio of 1:1.

(2) Soil in Zimbabwe is apt to eroded easily. Thus, the farmland should be leveled so that it is as flat as possible, and be provided with a retaining wall and ridges laid out on the contour line so as to avoid the surface run-off of important water. With this, percolation into the farmland soil can be accelerated and the effective use of rainfall can be realized. At the same time, soil erosion can be prevented.

(3) As the measure to be adopted to minimize the evaporation and transpiration, mulching should be carried out in between the ridges.

(4) Environmental improvements should be made by revitalizing the forest areas through tree replanting. Forests can function as a tentative storage of rain water, discharging it as underflow water to the neighboring areas where, thanks to this underflow water, crops can be irrigated. With the expanded forest area, the humidity of the country as a whole might be increased, although only slightly. This may be effective in controlling the evapo-transpiration and in minimizing any decrease in temperature.

(5) To secure the required food/grain for domestic consumption, given the fact that less water will be available, certain drought-resistant crops should be introduced.

(6) Different water management techniques are needed for the different growth stages of crops. At the vegetative stage, for example, a drought would effectively stop or suspend the growth, although the crops (leaves and stems) would grow again once water is supplied, thereby causing hardly any damage. At the reproductive stage, however, a drought would definitely affect productivity; that is, grain will never grow if it has once suffered from drought damage.

(7) The development of a water saving culture method should be emphasized in Zimbabwe, as the country is not blessed with rich water resources.

6–4–2 Maize

To produce as much as 3,000 tons of citric acid a year, about 6,000 tons of maize are required. Compared to the total production quantity of maize in Zimbabwe, the required quantity is quite small.

As maize is the staple food of the people of Zimbabwe, production has to be stabilized. However, the production volume has tended to gradually decrease with considerable annual fluctuations. This can be attributed to the fact that the areas planted on highly productive large-scale commercial farms have been reduced, while these planted on small-scale communal farms with lower productivity have been increased. In other words, large-scale farms are equipped with irrigation facilities and are therefore more reliable, while small-scale farms are rain-fed and are thus less reliable.

As for rain-fed farming, there are constraints as described in the previous section. If some of the suggested countermeasures are implemented, higher productivity is expected.

In Zimbabwe, research into and experiments on the farming techniques for the major crops were carried out even before national independence, and guidelines on improved farming methods have been prepared. AGRITEX has been studying how to improve the farming techniques for the major crops and has established technical guidelines on maize cropping so as to achieve high productivity at the international level (see Table 6–9).

Technical guidelines on rain-fed farming are also available, as shown in Table 6–10, although no guidelines of any significance are mentioned in regard to farming during a drought period. There is a quick reference on sowing times, growth, number of days, and the heading time for each variety and at each farmland elevation.

Table 6-9 Cropping Guide (Maize)

Crops name: Maize

(Unit: Per Hectare)

1. Sowing Time

	(1st Planting)	Last week of October (Irrigated)
	(2nd Planting)	Mid November

2. Seed Rate — 50 ~ 60 kg/ha

3. Land Preparation — – Land leveling and pulverization with deep plowing (20-30 cm)

4. Fertilizers Inputs

NUTRIENT STATUS OF SOIL

Fertilize Nutrients	Good	Medium	Poor
	(Kg/ha of fertilizer nutrient required)		
N	Up to 100	100 ~ 160	160 ~ 200
P_2O_5	30 ~ 50	50 ~ 70	70 ~ 90
K_2O	20 ~ 30	30 ~ 50	50 ~ 70

5. Row Space — 75 ~ 90 cm

6. Intrarow Space — 25 ~ 30 cm

7. Irrigation Interval — 7 ~ 10 days (7 days for sandy soils: 10 days for ferhved soils)

8. Thinning or Weeding time — 1 st 5 weeks

9. Pest Control Pesticide Name — Stalk boorer-Thionex or Dipteex at 4

10. Harvesting — Apr./May

11. Average Production — 5 ~ 7 ton/ha

Source : Agritex Station

Table 6–10 Cropping Guide (Maize) on Rain-fed Farming

Crops name: Maize

(Unit: Per Hectare)

1. Sowing Time

	(1st Planting)	Early October to mid November
	(2nd Planting)	Late November to mid December

2. Seed Rate — 50 kg/ha

3. Land Preparation — – Land leveling and pulverization with deep plowing (25 cm)

4. Fertilizers Inputs

(1) Before sowing		
	– Manure	Nil or 10 ton/ha
	– Double Superphosphate	150 ~ 350 kg/ha
	– Ammonium nitrate (34 1/2%)	100 ~ 150 kg/ha
	– Potassium sulfate or chloride	50 ~ 10 kg/ha
(2) At six weeks after emergence		
	– Ammonium Nitrate (34 1/2%)	200 ~ 300 kg/ha
	– Potassium	Nil kg

5. Row Space	90 cm
6. Intrarow Space	30 cm
7. Irrigation Interval	Variable
8. Thinning or Weeding time	Variable but thinning is 2 weeks after emergence
9. Pest Control Pesticide Name	Variable
10. Harvesting	March/April
11. Average Production	4 ton/ha

Source : Agritex Station

6–4–3 Sweet Potato

To produce 3,000 tons of citric acid from sweet potato starch extraction residues, about 200,000 tons of sweet potato are needed. The current annual production of sweet potato amounts to only 1,000 tons, very much lower than the required quantity.

To increase the production of sweet potato to 200,000 tons a year, 83,000 hectares of farmland would be required with an estimated unit yield of 2.4 tons per hectare. If a production yield of 10 tons per hectare was possible as a result of improved farming techniques, 20,000 hectares of farmland would be needed.

In this respect, it is considered almost impossible to increase the production of sweet potato to 200,000 tons a year. As reference for the promotion of sweet potato production in Zimbabwe, the method of cultivation is discussed below:

(1) The temperature suitable for growing sweet potato ranges from 20 to 30°C, the minimum temperature being 15°C, and the maximum 36°C. As the sweet potato consumes about 600 mm of water with a growing period of 150 days, farmland in an area with 600 mm or more of rainfall is preferred for the sweet potato. Sweet potato can be grow in areas with rainfall of less than 600 mm thanks to its drought resistant nature, provided that the unit yield can be allowed to fall.

(2) As for the soil conditions, sweet potato can be grown in any soil, except in areas with extremely bad-drainage with heavy clay or alkaline soil, and with a pH value of not more than 7.0.

(3) As far as diseases and insect pests are concerned, it is preferable to plant sweet potato in an area where no weevils can be found.

Based on the above, the areas suitable for sweet potato production are those located in intensive farming zones and semi-intensive farming zones.

The cropping guide for sweet potato is shown in Table 6–11.

Table 6-11 Cropping Guide (Sweet Potato)

Crops name: Sweet Potato

(Unit: Per Hectare)

1. Planting Time	(Nursery)		
	(Laying-in)	Late September to late October	
2. Transplanting Time		Late October to late November	
3. Seed tuber		1,300 ~ 1,500 kg/ha	
4. Land Preparation			
		– Area of Nursery bed	200 ~ 250 m^2
		– Land leveling and pulverization with deep plowing	30 cm
		– Ridging	30 cm
5. Fertilizer Inputs		– Manure	20 ton/ha
		– N	50 ~ 70 kg/ha
		– P_2O_5	240 ~ 250 kg/h
		– K_2O	180 ~ 200 kg/ha
6. Row Space		90 ~ 120 cm	
7. Intrarow Space		30 ~ 40 cm	
8. Irrigation Interval		15 Days	
9. Weeding time		Variable	
10. Pest Control Pesticide Name		Weevil Control	
11. Harvesting		March ~ June	
12. Average Production		5 ~ 10 ton/ha	

Source : JICA team

The seed tuber should be laid in at the nursery within the period from the latter part of September and the latter part of October, and the seedling should be transplanted to the farms from late October to late November. As much as 1,300 to 1,500 kg of seed tuber are required for an area of one hectare. The nursery should cover 200 to 250 m^2 per hectare.

After ploughing, the use of fertilizers and other techniques in the area of sweet potato cultivation are recommended as follows:

(1) Ploughing depth of 25 to 30 cm with a ridge height of 30 cm

(2) Use of fertilizers (per hectare) consisting of manure (20 tons), nitrogen (50 to 70 kgs), phosphate (240 to 250 kgs), and potassium (180 to 200 kgs)

(3) The application of potassium is essential for the thickening of the tuber, while the application of fertilizers at some depth is preferable.

(4) Ridge width of 90 to 120 cm and 30 to 40 cm spacing

(5) Irrigation water requirement of 45 to 60 mm and an irrigation interval of every 15 days

(6) Weed control should be carried out regularly. As for weevils, ditches should be dug surrounding the farm, or the farm should be inundate before planting.

(7) Harvesting may begin from March and should be completed before the frost sets in fall.

(8) The production yield is expected to be 5 tons per hectare within a few years and about 10 tons within 5 to 6 years.

(9) To achieve a yield higher than 10 tons per hectare, various efforts are needed to improve the seeds, land and soil, as well as intensive fertilization, the provision of irrigation facilities, and farm mechanization.

6-4-4 Cassava

To produce 3,000 tons of citric acid from cassava starch extraction residues, about 150,000 tons of cassava are required. The current annual production amounts to only 90,000 tons, far below the required quantity. Considering the present yield of about 4 tons per hectare, about 40,000 hectares of land would be needed for the production of 150,000 tons a year. For a total production of 240,000 tons, about 60,000 hectares would be necessary. Even if a yield of 15 tons per hectare can be expected in the future, about 16,000 hectares would be required.

Cassava can be grown in variety of soil ranging from sand to loam. Other conditions for better growth are shown below:

- Soil acidity pH value of 5.8 to 7.0
- Deep ploughing with good drainage.
- High temperature (18 to 30°C) and humid atmosphere
- Annual rainfall of 700 to 2,000 mm

The cropping guide for cassaba is shown in Table 6–12.

Table 6–12 Cropping Guide (Cassava)

Crops name: Cassava

(Unit: Per Hectare)

1. Planting Time — Cutting — Late October to Late November
2. Stock Number — 25 ~ 30 cm stock — 13,333 stock/ha
3. Land Preparation
   - Land leveling and pulverization with deep plowing (20 ~ 30 cm)
   - Ridging 25 ~ 30 cm
4. Fertilizers Inputs — (1) Before sowing

N	50 ~ 100 kg
P_2O_5	50 ~ 100 kg
K_2O	75 ~ 120 kg

5. Row Space — 90 ~ 120 cm
6. Intrarow Space — 75 cm
7. Irrigation Interval — Variable
8. Weeding Time — Variable
9. Pest Control — African mosaic superelongation
10. Harvesting — Planting after four to ten month
11. Average Production — 10 ~ 15 ton/ha
12. Cropiing Season — (S: sowing time, P: planting, H: harvesting)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
			H ├	H	H	H	H ┤	S	P ├	P ┤	

Source : JICA team

6–4–5 Others

The cropping guide for sugarcane, which was presented by Hippo Valley Estate, is shown in Table 6–13.

Table 6–13 Cropping Guide (Sugarcane)

Crops name: Sugar Cane

(Unit: Per Hectare)

1. Transplanting Time	(1st Planting)	Feb. -March	
	(2nd Planting)	Aug. -Sep.	
2. Seed Rate		8t/ha	
3. Land Preparation			
	– Land leveling and pulverization with deep plowing		30 cm
	– Time of harrowing		
	– Ridging		
4. Fertilizer Inputs	(1) Before sowing		
	– Manure		Nil
	– Single superphosphate		500 kg/ha
	– Ammonium Nitrate		150 ~ 170 kg/ha
	– Potassium sulfate		50 kg/ha
	(2) Flower-bud-appearing stage		
	– Ammonium		75 ~ 85 kg/ha
	– Potassium		
5. Row Space		1.5 m	
6. Intrarow Space		Overlap	
7. Irrigation Interval		Winter 2 weeks summer 5 days	
8. Pest Control Pesticide Name		Heteronycus Licas 5 kg/ha	
9. Harvesting		Every two years ~ four years	
10. Average Production		115 ~ 80 ton/ha	

Source : Hippo Valley Estates Limited

Chapter 7 Raw Materials

Chapter 7 Raw Materials

7-1 Selection of the Raw Material

(1) Mold, raw materials and fermentation process

Citric acid is produced through the fermentation of carbohydrate using Aspergillus niger; a species of mold which grows black colored fungi. There are many varieties of Aspergillus niger, which shows a different performance with regard to the fermentation of citric acid. Accordingly, the best variety of the mold was searched for in order to identify a specific combination of the raw material and process so as to obtain a high citric acid yield from the fermentation. Industrial citric acid fermentation technology was then established by means of a particular variety of mold together with a certain combination of a raw material and process. Accordingly, the selection of materials is limited by the existing technologies transferable to Zimbabwe.

(2) Fermentation process

In practice, two processes are available at present for citric acid fermentation, namely, solid culture fermentation and submerged liquid culture fermentation. The former mostly prevails in Asia, and the starch extraction residues of sweet potato or cassava are used as the raw material. The latter mostly prevails in Europe and America, and beet molasses or cornstarch is used as the raw material. In Japan, Kyushu Kako Co., Ltd. and Satsuma Kako Co., Ltd. produce citric acid from sweet potato residues by means of the solid culture process, while Iwata Chemical Co., ferment citric acid from cornstarch by means of a submerged liquid culture. Each of these processes uses Aspergillus niger of different varieties, developed independently by each company and consisting of a part of each company's proprietary know-how. Other than these technologies, there is one type of technology developed by Waseda University in Japan for the fermentation of saccharide rich liquid such as the juice taken from canned pineapple residue.

(3) Candidates for the raw materials

Based on the above mentioned conditions, the following materials have been selected as the candidates:

(a) Sweet potato starch extraction residues

(b) Cassava starch extraction residues

(c) Cornstarch

(d) Concentrated juice, raw sugar and molasses obtained from sugarcane during the raw sugar manufacturing process

(e) Syrups and molasses obtained from raw sugar during the sugar refining process

Among the above materials, materials (d) and (e) have not been utilized in the industrial production of citric acid except sugarcane molasses, while the materials have been proven that they can be utilized for citric acid fermentation by a laboratory experiment.

(4) Solid culture fermentation

The creation of more employment is an important target for the industry of Zimbabwe. The solid culture fermentation process is more labor intensive, and requires less capital than the submerged liquid culture process. Accordingly, this study first deals with materials such as (a) sweet potato starch extraction residues and (b) cassava starch extraction residues. However, this study has clarified that there is only a slight possibility of establishing sweet potato or cassava starch industry in Zimbabwe, because these potatoes have not yet been cultivated on a scale adequate to support the industry.

As an alternative for the application of the solid culture fermentation process, materials such as (d) sugarcane molasses and (e) syrups, soaked in bagasse, have been studied. Although sugarcane molasses is used in industrial citric acid production by means of the submerged liquid culture fermentation process, no solid culture process has yet been developed for the molasses at the industrial level. At the same time, molasses is utilized for various purposes such as ethanol, cattle feed and yeast production in Zimbabwe, while a certain amount of molasses is imported from other countries to supplement domestic production. Molasses for citric acid production cannot therefore be supplied domestically, but should be supplied by an increase in imports from neighboring countries.

There is also raw sugar and other intermediates from sugar manufacturing and refining processes, which are soaked into bagasse, as the materials for solid culture fermentation. However, these are more expensive materials than molasses, while there is no existing industrialized technology for these materials. The development of the needed new technology might cost a considerable amount of money and time. Nobody may have an interest in the development, because these materials are too expensive to establish the industry competing with industries based on materials such as molasses or potato residues.

(5) Cornstarch

As a consequence of the above, there is only one candidate, cornstarch, that remains. Nevertheless, the field survey discovered a quite unexpected fact that cornstarch is more expensive than raw sugar in Zimbabwe.

However, cornstarch for citric acid production is available at a very reasonable price in the U.S.A. So it is believed that cornstarch is the most prospective material for Zimbabwe to realize a competitive price through their own efforts in the near future. Cornstarch is therefore considered to be the basic raw material for the basic design.

(6) Fermentation tests

Despite the selection of the material mentioned above, samples of materials such as sweet potatoes, cassavas, molasses, raw sugar and other sugar-related materials are collected in Zimbabwe, as well as cornstarch for the fermentation tests, in order to obtain useful reference data for any alternative consideration of the project in the future. Fermentation tests have been carried out by Kyushu Kako Co., Ltd., Iwata Chemicals Co., Ltd. and Waseda University for each related process and on each specialized material, respectively. The results of the tests are reported in Chapter 10.

(7) Summary

Discussions on each material and chemicals expected to be used in the process are detailed for solid culture fermentation and submerged liquid culture fermentation, respectively, in the following part of this chapter.

A summary of the discussions on the selection of the raw material for the basic planning of a citric acid plant is shown in Table 7-1.

Table 7-1 Summary of Raw Material

Material	Process	Availability	Industrial Technology	Material Cost
Sweet potato residues	○ Solid culture	× No	○ Exists	N.A.
Cassava residues	○ Solid culture	× No	○ Exists	N.A.
Cornstarch	○ Submerged culture	○ Good	○ Exists	△ (*)
Sugercane molasses	○ Solid culture	× Imported	× No	○ Reasonable
Sugercane intermediate products	○ Solid culture	○ Good	× No	× Expensive

Remark : (*) Expensive, but has the possibility of being reasonable.
Simbols : ○ ....Acceptable.
× ....To be rejected.
△ ....Not preferable, but acceptable.

7-2 Solid Culture Fermentation

7-2-1 Sweet Potato

(1) Cultivation

Sweet potato grows in areas where the no frost period continues for over 120 days. When the atomospheric temperature is below 15°C, growth stops and if the temperature goes down below 10°C, its leaves turn yellow and withers. Sweet potato grows well in a slightly acidic soil; pH 5.0-6.3 and with good drainage. Most of the arable land in Zimbabwe satisfies the above conditions with a few exceptions. As a matter of fact, many small sweet potato gardens can be seen all over the country. However, the cultivation technology is still primitive, and the yield is rather poor in general.

(2) Production

About 9,000 t/year of starch extraction residues is required for 3,000 t/year of citric acid production. And about 187,000 t/year of sweet potato must be cropped for about 47,000 t/year of starch production. No statistics of the sweet potato crop in Zimbabwe are available. However, the F.A.O. (Food and Agriculture Organization of the United Nations) reports that sweet potato production is less than 1,000 t/year. The F.A.O. also assumes that the sweet potato yield is 2,250 kg/ha, or about 1/10th of the Japanese yield. It has been observed that many farmers grow sweet potato directly from a cut piece of potato without preparing vines in a nursery, which means that a good yield cannot be expected. At the same time, it should be noted that weevils damage the sweet potato crop in certain areas of Zimbabwe.

(3) Price

Small quantities of sweet potato are sold in local markets. The retail price is between 0.8–2.0 Z$/kg, based on experiences when samples for the fermentation tests were purchased. There is a wide variation in price depending on selling location, even in the city of Harare. Zimbank published the price as Z$2.5 to 3.5 p.o. in a newspaper ("The Herald", June 5, 1991). "p.o." means a pocket which may contain 10 to 15 kg of potatoes. Accordingly, it is reasonably assumed that farmers may demand 0.25 Z$/kg or a higher price for the production of sweet potatoes in the quantity demanded by the industry.

(4) Potato starch extraction residues

Potato starch has a higher price than cornstarch in Asia, because Asian people prefer potato starch for cooking and cake-making. However, no preference for potato starch by African people can be expected. Such a large amount of sweet potato starch as 47,000 t/year is difficult to sell in Africa. Accordingly, any prospect for about 9,300 t/year of sweet potato residues produced as a residual of potato starch production cannot be obtained.

(5) Summary and conclusion

Sweet potato residues are made from the starch industry and have no commercial value. Solid culture fermentation uses trays and a fermentation chamber instead of tanks, which means that the construction cost of the plant is by far less than that incurred by submerged liquid fermentation. It is also labor intensive, because the trays should be moved by manpower instead of pumps in the case of the liquid tank fermenter.

The solid culture fermentation process seems to be preferable for Zimbabwe in these respects. However, sweet potato cultivation on the scale sufficient for the industry has not yet been established. It might take at least several years, as well as a great deal of capital investment, to develop.

The price of sweet potato may not be less than 0.25 Z$/kg. The starch content of sweet potato is about 27%, compared with maize which contains more than 70% starch. Sweet potato cannot compete with maize at the price of 0.27 Z$/kg as a starch material. As mentioned previously, there is no prospect for a potato starch market. Therefore, it is very difficult to expect the development of any citric acid industry based on sweet potato starch extraction residues in the near future in Zimbabwe.

(6) Submerged liquid culture fermentation of sweet potato

The sweet potato is utilized for citric acid production by submerged liquid culture fermentation in China. In this case, a whole potato, not residues only, is utilized. However, as mentioned previously, the price of the sweet potato might not be so competitive, while 3,000 t/year of citric acid production requires about 20,000 t/year of sweet potatoes, or more than 20 times of today's production in Zimbabwe. This case also cannot be realistic.

(7) Rice bran

Furthermore, in the case of citric acid fermentation using the sweet potato or sweet potato residues, rice bran should be added as a nutrient. About 1,000 t/year of rice bran is needed for the production of 3,000 t/year of citric acid. This quantity of rice bran is also very difficult to obtain in Zimbabwe, as explained later in sub-section 7–2–5. This is also a negative factor.

7–2–2 Cassava

(1) Cultivation

Cassava is drought-resistant crop, so it has attracted the attention of agricultural developers. After suffering repeated droughts, the cultivation of cassava has been taken up as an important theme in Zimbabwe. The ARDA (Agricultural and Rural Development Agency) carried out test cultivations twice in 1981 and 1984/85 in Chisunbanje. However no satisfactory result was obtained, because the soil was not adequate in the tested area. The Biomass User's Union is testing the cultivation of cassava on a small scale at Binga on the coast of Lake Kariba. However no result has been reported as yet. Cassava cultivation is still at the experimental stage in Zimbabwe, and definitive prospect for a commercial plantation has yet been obtained.

Potassium rich soil, which is adequate for cassava cultivation, is widely available in Zimbabwe. In particular, the Kariba coast area has adequate soil for cassava cultivation, but is not yet well developed.

There are numerous cassava plantations in Asia and Brazil. However, there are criticisms that cassava impoverishes the soil, especially when cassava crops over and over on the same land, within a few years, and the yields are going down desperately. Experiences in other countries should also be fully studied before the start of a large-scale plantation.

(2) Summary and conclusion

Cassava production of about 148,000 t/year is necessary in the case where starch extraction residues are utilized, and about 25,000 t/year of cassava is required when whole cassaba is utilized. Therefore, even if the development of a plantation progresses smoothly, production cannot reach this scale within just a few years. The production cost of cassava is also very difficult to forecast at present. As mentioned in sub-section 7–2–1, it is difficult to establish the potato starch industry. Rice bran as nutrients for fermentation is also not available in Zimbabwe. These difficulties are no better than in the case of the sweet potato.

Cassava cannot be recommended as a material for the project at this moment. It may be reexamined after its plantation has been established.

7–2–3 Sugarcane Molasses

(1) Production

Two private companies, Triangle Ltd. and Hippo Valley Estates Ltd., produce raw sugar from cane in Zimbabwe. Both companies possess their own sugarcane field, and almost 90% of the cane used in the production is supplied from their own field. Sugar production is 460,000 t/year in total, and both companies have an equal share.

About 120,000 t/year of their production is sent to a refinery of ZSR (Zimbabwe Sugar Refinery) Ltd. in Harare, while about 80,000 t/year is sent to a refinery of ZSR Ltd. in Bulawayo, the rest of the raw sugar being exported. When crystallized raw sugar is separated by a centrifuge in the sugar production process, molasses appears as the residue. Molasses contains non-crystallized sugar with other contaminants. The sugar can be utilized for citric acid fermentation.

(2) Disadvantage

The beet sugar process also yields molasses, called beet molasses. Beet molasses is a common material for citric acid production by fermentation in Europe. Compared with beet molasses, sugarcane molasses has a thicker color and is contaminated by more impurities. Sugarcane molasses had been considered inadequate for the fermentation process for a number of years. However, the discovery of a new variety of mold has made it possible to use molasses for citric acid production. Recently, environmental regulations have brought about higher effluent treatment costs in the case of sugarcane molasses, which means that many citric acid producers are changing the material from sugarcane molasses to other materials. Sugarcane molasses is apt to discolor the product, which in turn affects the commercial value of the product. A greater decoloring cost is needed in the case where sugarcane molasses is used as a raw material.

(3) Availability

Triangle Ltd. produces alcohol from molasses to be blended with gasoline, while they also mix it with cattle feed produced from bagasse. Triangle Ltd. imports a certain amount of molasses from Zambia after the complete utilization of domestic molasses, and utilizes it in alcohol production.

Hippo Valley Estate Ltd. produces drinking spirits, yeast and other pharmaceutical chemicals from molasses, and the small surplus is sold to Triangle Ltd. The effluent from the processes at both companies is returned to the cane fields, diluted in irrigation water.

The price of molasses imported from Zambia is 200 Z$/t, which is still attractive compared with those of other materials.

(4) Fermentation process

In the U.S.A., sugarcane molasses is fermented using the submerged liquid culture process. However, no such process exists in Japan. If this technology is to be utilized, it must be transferred by a company which has the technical know-how. However, the technology is generally exclusive to their affiliates. The development of such technology independent from that company is almost prohibitive because of the cost and time required.

An alternative may be the adoption of solid culture fermentation technology based on the technology developed by Waseda University, although there is no experience of it being applied on an industrial scale application.

(5) Summary

In summary, sugarcane molasses is attractive in terms of price. However, it is difficult to obtain the process know-how, while there is the risk of a considerably higher cost for effluent treatment and the decoloring process. The most crucial factor is that the material is not domestic, but must be imported.

7–2–4 Intermediate Products from the Sugar Industry

(1) Sugar

It has been proved in experiments that sugar is a good material for citric acid fermentation. However, sugar is considerably more expensive than molasses. In the case of ZSR Ltd., refined sugar is priced as 1,000 Z$/t and in the case of Triangle Ltd. and Hippo Valley Estate Ltd., the price of raw sugar is 600 Z$/t. Such prices are very competitive in the international market.

(2) Concentrated sugarcane juice

Concentrated juice from sugarcane can be extracted at the sugar factory, although it is not available on the market, which means that there is no market price. However, it may be slightly less expensive than sugar. The juice partly contains molasses, which can be a nutrient for Aspergillus niger.

(3) Affination syrup and process molasses

Another material called affination syrup is obtained as concentrations from the washed down water of raw sugar at the refinery. Process molasses is a residual from this syrup after the crystallization of sugar and separation by centrifuge. Some of the affination syrup is utilized for the fermentation of drinking spirits, too. The quantity of the syrup can be adjusted using more washing water and, in this case, the sugar contents are automatically varied. The syrup contains elements of molasses as the nutrient for fermentation. The process molasses obtained from affination syrup is a molasses with fewer contaminants than sugarcane waste molasses and is also suitable for citric acid fermentation. However, the molasses is already completely utilized for the production of spirits, yeast and other pharmaceutical products, so there is no surplus.

(4) Summary

A sufficient quantity for the industry is available in the case of affination syrup or concentrated sugarcane juice. However, their prices are directly related to that of raw sugar, and a low price can hardly be expected similar to that of residuals.

Raw sugar and the raw sugar-related materials mentioned in this section have not been used for the industrial purpose of citric acid production, because they are not attractive in terms of price compared with that of molasses and cornstarch.

These materials are not suitable for the establishment of a competitive export industry for citric acid production, while there is no particularly strong incentive to commence its development.

7-2-5 Rice Bran

Rice bran is added to the raw material as a nutrient, when the existing solid culture fermentation process is adopted. The quantity of the rice bran is normally about 10% weight of residues, which means that it is about 1,000 t/year in the case of 3,000 t/year citric acid production.

The rice crop is about 700 t/year in Zimbabwe, so that less than 60 t/year of rice bran can only be produced, a quantity insufficient for the process.

Rice bran is used because of its low price. However, it must be imported in the case of Zimbabwe, which means that it loses its advantage. The exportation of rice bran is very rare. However, rice exporting countries such as Pakistan or Thailand would export. No export system exists at present and the import price cannot be estimated. However, it is probably less than 200 Z$/t, including the cost of transportation.

7-2-6 Bagasse

Aspergillus niger is planted in an adequate solid medium in the case of solid culture fermentation. Shallow pallets filled with the medium are arranged on shelves in the fermentation chamber, and the fermentation process take place. The medium is good for aeration, and keeps the carbohydrate material, water and nutrients in it. The performance of the pulp contained in sweet potato residues or cassava residues is good. However, as an example, the massese obtained in the production of the Chibuku beer is inadequate because of the lack of the water-containing capability.

Bagasse has been proved to be good for the medium, as well as sweet potato and cassava pulp. Bagasse is a pulp after the juice has been removed from sugarcane. Bagasse should be dried and completely sterilized. Fine pulp and coarse pulp should be mixed for the medium. If any bacteria or mold other than Aspergillus niger exist in the pulp due to insufficient sterilization, it may destroy the activity of Aspergillus niger and may seriously damage the fermentation process.

Bagasse is used as a fuel for steam boilers both at Triangle Ltd. and Hippo Valley Estate Ltd. The fuel for their boilers is also supplemented by coal, in the case of a bagasse shortage, which means that, when bagasse is used for citric acid production, coal can supplement it. The price of bagasse may be determined by the comparable heat value of coal, namely, in the ratio of the heat value of dried bagasse, about 20 MJ/kg; and the heat value of Wankee coal, about 30 MJ/kg.

The amount of bagasse needed may vary according to the characteristics of the raw material. However, it is probably 3,000 to 10,000 t/year for 3,000 t/year citric acid production.

7–2–7 Nutrients and Chemicals

Sulfuric acid, slaked lime, activated carbon and several other chemicals are needed for the extraction, neutrization and refining processes. This is explained in the next section 7–3, because they are common with the submerged liquid culture fermentation process.

Nutrients other than rice bran may be used for seed preparation. This will also be explained in the next section.

7–3 Submerged Culture Fermentation

7–3–1 Issues Concerning Cornstarch in Zimbabwe

(1) Cornstarch

Cornstarch is produced from maize. Among various kinds of starch, cornstarch is considered to be the most reasonable in terms of price and is utilized by industry. For example, a derivative of cornstarch, corn syrup, is less expensive than sugar and is widely used in soft drinks in many countries.

(2) Food & Industrial

Food & Industrial, a division of Delta Consolidated Ltd, is the sole producer of cornstarch in Zimbabwe at present. Cornstarch is sold at the price of 1,341–1,558 Z$/t, which is expensive. This may be the result of the obsolete process, the small amount of production such as 1,000 tons per month, and no utilization of by-products such as corn oil and corn meal.

(3) Yellow maize and white maize

There are two basic species of maize; yellow maize and white maize. The cornstarch made from these two species of maize is equally good for citric acid production by fermentation.

Table 7–2 shows an analysis of Zimbabwean maize, together with the values in the standard tables of food composition in Japan. White maize is mostly consumed as a staple food of the Zimbabwean people, while yellow maize is consumed for other purposes such as cattle feed. Yellow maize used to be less expensive than white maize. However, the GMB (Grain Marketing Board) has reported that the same price will be applied in 1991/92.

(4) Control by the Grain Marketing Board

The GMB used to control the price of maize. Maize was exclusively dealt with by the GMB, in other words, nobody except the GMB was allowed to sell or purchase maize without special permission from the government of Zimbabwe. However, the government decided in 1990 to gradually deregulate such control. The GMB has disclosed that the purchase price will be 270 Z$/t and the sales price will be 365 Z$/t for the 1991/92 season. The GMB has explained that the difference between these two prices is the cost for stabilizing the supply of maize by stocking maize in their numerous silos and depots located throughout the country. In spite of the efforts of the GMB, the control has exaggerated instability over the long term; the GMB has purchased excessive quantities of maize for years, and their stockpile have led to a financial burden, resulting in a large deficit. This might be the result of a price control higher than the demand-supply balancing point. Recently, commercial farmers have been transferring their crop from maize to other profitable crops because the GMB has turned to a low purchasing price policy, while there is the threat that maize exports from Zimbabwe will come to a halt.

Table 7–2 Analysis of Zimbabwean Maize

(Unit : %)

Composition	Zimbabwean Maize*		Standard Tables of Food Composition in Japan.
	White	Yellow	
Water	11.5	11.2	14.5
Protein	6.8	7.9	8.6
Lipid	3.8	4.1	5.0
Ash	1.1	1.2	1.3
Carbohydrate	77.7	75.6	70.6
(Non-Fiber)			(68.6)
(Fiber)			(2.0)
Energy (kJ/100g)	1,509	1,509	1,463

Note: * These samples were provided by the GMB in June, 1991, and were analysed by the Japan Food Analysis Center in July, 1991.

(5) Effects of deregulation

As a step to deregulate the control of the price of maize, yellow maize, red solghum and millet have been allowed to be sold by producers since April, 1990 and the GMB remains a "residual buyer" of these crops. However, white maize is still under the control of the GMB.

The average yield of maize by commercial farmers in Zimbabwe is 3 to 5 t/ha. However, specialized farmers are very efficient in producing maize, the yield rearching 10 to 12 t/ha, exceeding the 7 t/ha range which is normally expected in the largest maize exporting country of the U.S.A. Accordingly, after the deregulation, they will be competitive with farmers in any other country, which means that industries based on cornstarch will be encouraged. The purchasing price of maize is 270 Z$/t (90 US$/t) under the GMB and maize is sold at 111 US$/t in the U.S.A. (F.A.O. statistics, 1989), so the market price of yellow maize is assumed to be between 270 Z$/t and 330 Z$/t in Zimbabwe in 1991.

(6) Production cost

Cornstarch is an intermediate product of an industrial process, so the market price is not reported publicly. It is said that 70% of the cost of cornstarch is the material cost of maize.

The cost of cornstarch is assumed to be roughly 200 US$/t (about 600 Z$/t) in the U.S.A.

(7) Cornstarch produced in Zimbabwe

The cornstarch produced in Zimbabwe is not only expensive, but also low in quality at present. Food & Industrial has two production lines. These lines use almost the same production process, although the washing cyclones at the final purification stage are different, which means that the amount of residual protein in the products is also different. One line produces a slightly better product than the other, but both products still have higher protein contents than the required specification of cornstarch for citric acid production by fermentation.

The result of the fermentation test conducted in 1990 using a sample provided by Food & Industrial was not satisfactory due to the overgrowth of mycelium, assumed to have been caused by the high protein contents. New samples of the improved product of Food & Industrial were brought to Japan and tested in August 1991, the results of which are explained in Chapter 10.

(8) Availability of cornstarch

Food & Industrial has a capacity of 1,000 tons per month of cornstarch production in total. 500 tons per month are sold as dry powder, while the other 500 tons per month is used internally for corn syrup production. Consequently, the factory has no margin to provide about 4,100 t/year of cornstarch for the production of 3,000 t/year of citric acid. If the factory is to supply it, another production line will have to be installed.

(9) Production process

Cornstarch is produced by the wet mill process in modernized factories. However, Food & Industrial has adopted the dry mill process. The difference between the two processes is that maize is ground as wet grain after being steeped in a weak sulfurous acid solution in the case of the wet mill process, while maize is ground as dry grain and later steeped in a weak sulfurous acid in the dry mill process. In the case of the wet mill process, grinding is carried out in two steps. Oil rich germs are separated after the first coarse grinding, and pulp and protein are removed after the second fine grinding. The starch milk thus obtained is then sent to multistage hydrocyclones to be washed and refined. In the case of Food & Industrial's process, however, dry maize is ground into fine powder and steeped, whereupon the milk is filtered to remove the pulp. After that, the oil and protein are removed and washed by hydrocyclones. It seems that the oil and protein are richer in the milk sent to the hydrocyclones in this case compared with the wet mill process, and these contents remain in greater quantity in the products.

Food & Industrial has studied the introduction of wet milling process with the assistance of a Belgium company. However, a definitive schedule for such modernization has not yet been fixed.

Cornstarch from the wet mill process is not only better in terms of quality, but also the process is advantageous for collecting and utilizing the by-products such as the corn oil taken from germ and cattle feed using protein, which reduces the production cost by selling these by-products.

The adoption of the wet mill process will be seriously considered by the cornstarch supplier in this project. More details of the wet mill process are given in attached Appendix II, "Cornstarch Production and Its Uses".

(Reference Data)

Cost of cornstarch produced by the wet mill process

Assuming:

(a) Starch contents of the material maize	;	70%
(b) Price of maize	;	300 Z$/t
(c) Construction cost of the starch factory	;	Z$30,000,000.-
(d) Capital expense ratio	;	20%
(e) Labor	;	15 workers with an average salary of $2,500.- each
(f) Production	;	Maize 100 t/day × 335 days/year operation, cornstarch production; 25,500 t/year

Cost calculations:

Capital cost	30,000,000 × 0.2	=	6,000,000 (Z$)
Labor cost	2,500 × 12 × 15	=	450,000
Material cost	33,500 × 300	=	10,050,000
Utility cost			410,000
Total			16,910,000
Credit from by-products			3,100,000
Total Expenditure			13,810,000
Unit production cost of cornstarch:			13,810,00/25,500 = 542 (Z$/t)

This calculation is a rough estimation of the cost at the factory, so it will be subject to re-examination after a detailed study.

The transportation costs, overheads and an adequate amount for contingencies will also be applied to it.

7-3-2 Nutrients and Additives for the Fermentation Process

(1) Amylaze

For the production of citric acid, starch is firstly transformed to saccharide. The saccharide then turns into citric acid. Consequently, much of the citric acid fermentation process consists of a step whereby saccharide is produced from starch using amylase: an enzyme. However, the saccharification of starch is preceded by the activity of Aspergillus niger in advance and partially in parallel with citric acid fermentation in Iwata Chemical's process, which means that amylase is not required for saccharification in this case.

Prior to saccharification, starch should be dissolved in water. Cornstarch contains a large-size polymer which is difficult to dissolve in water. Therefore, in order to make a solution, a small amount of amylase is added so as to disconnect the molecular chain of the starch. This process is called liquefaction.

It is necessary to use approximately 4 t/year of amylase for the production of 3,000 t/year of citric acid in Iwata Chemical's process. α-amylase, specified for use in the liquefaction of starch, will have to be imported for this purpose.

(2) Ammonium nitrate (NH_4NO_3)

As the nutrients for Aspergillus niger, approximately 90 t/year of ammonium nitrate is needed for 3,000 t/year of citric acid production.

Sable Chemical Industries Ltd. manufactures 220,000–240,000 t/year of ammonium nitrate in Zimbabwe. Most of this is used for agriculture, but should not be affected by the need to share 90 t/year.

(3) Potassium dihydrogen phosphate(KH_2PO_4)

Potassium dihydrogen phosphate is commonly known by the brewing industry as a nutrient for fermentation. Approximately 20 t/year will be imported for a 3,000 t/year of citric acid production.

(4) Magnesium sulfate ($MgSO_4 \cdot 7H_2O$)

Magnesium sulfate is used as an adjustment agent for the magnesium content of the medium. The amount needed will be approximately 5 t/year. Since magnesium sulfate is not produced in Zimbabwe, it will have to be imported.

(5) Chemicals for adjusting the metal elements

Zinc sulfate ($ZnSO_4 \cdot 7H_2O$), cupric sulfate ($CuSO_4 \cdot 5H_2O$), manganese sulfate ($MnSO_4 \cdot 6H_2O$), ferrous sulfate ($FeSO_4 \cdot 7H_2O$), etc. may be needed in order to adjust the trace-metal contents of the medium. The amount of each chemical that may be needed will be 500 kg/year or less. These chemicals will have to be imported.

7–3–3 Chemicals for Refining Citric Acid

(1) Sulfuric acid (H_2SO_4)

Zimphos (Zimbabwe Phosphate Industries Ltd.) produces 155,000 t/year (100% H_2SO_4 equiv.) of sulfuric acid from imported sulfur and domestic pyrite. The metal contents are controlled under 30 ppm Fe, 1 ppm Mn, trace Cd, 5 ppm Pb, 2 ppm As and 10 ppm Cu.

Approximately 3,000 t/year of sulfuric acid is needed to dissolve the raw calcium citrate for refining.

(2) Slaked lime

An analysis of the slaked lime brought from Zimbabwe by the survey team is shown in Table 7–3 with the relevant data.

Table 7–3 Analysis of Slaked Lime

(Unit : %)

Produced Country	Zimbabwe				Zambia		U.S.A.	Japan
Sample No.	1	2	3	4	5	6	7	8
	Used by ZSR	G & W Ordinary	G & W No. 1	G & W Chemical	Used by ZSR	NDOLA	High Calcium	Used by Iwata
CaO	66.01	49.52	66.93	63.87	66.48	71.84	71 – 74	73.95
MgO	0.80	7.74	0.88	0.64	0.87	0.87	0.5 – 2	0.53
Fe_2O_3	0.97	0.54	1.37	1.63	0.09	0.10	0.3 – 0.7	0.83
Al_2O_3	0.47	7.30	0.29	0.21	0.20	0.23	(as R_2O_3)	0.15
SiO_2	1.15	6.21	3.97	6.97	0.67	0.77	0.2 – 0.5	0.14
LOI	29.12	26.77	24.81	24.97	30.96	25.67	– –	– –
CO_2	11.26	– –	5.40	8.57	14.90	– –	0.3 – 0.7	– –
H_2O	17.86	– –	19.41	16.40	16.06	– –	24 – 25	– –
Price (Z$/t)	229.69	187.2 Ex. Work			308		48–55US$/t Bulk	

In the table, Nos. 1 and 5 are samples taken from the sugar refinery of ZSR Ltd. Sample No. 2 is data provided by G & W Industrial Minerals Ltd. as sample data of their own product. Nos. 3 and 4 are the analyzed results of samples provided by G & W. Sample No. 6 is an analysis of a sample of Zambian lime provided by A.I. Davis. No. 7 is reference data taken from the "Encyclopedia of Chemical Technology, 3rd edition": this data shows the quality of ordinary high-calcium slaked lime commercially available in the U.S.A. No.8 shows an example of Japanese slaked lime obtained from a citric acid factory. The items of analysis contain some differences where "– –" shows no data obtained, and some of the data for No.2 are calculated from the original data for the table. The calcium contents are not shown by $Ca(OH)_2$, but by CaO in the customary manner. The CaO content is calculated from the measured result of all the calcium components. In this case, the difference between CaO and $Ca(OH)_2$ is H_2O. The H_2O is included in LOI (loss on ignition). The conversion of CaO to $Ca(OH)_2$ is explained in Note 1 below:

[Note 1]

In this note, [ ] means content.

$[Ca(OH)_2]$ can be calculated using the ratio of the molecular weight of $Ca(OH)_2$, 74.09, and CaO, 56.08.

Therefore:

$$[Ca(OH)_2] = 1.321 \times [CaO]$$

After this conversion, the figures for the LOI content and H_2O content are adjusted by 0.321 [CaO] in order to balance the table.

The conversion is based on the assumption that all the calcium components are from $Ca(OH)_2$, which means that, if other elements such as CaO, $CaSO_4$, $CaCO_3$ and so on are abundant, a slight error may occur.

Slaked lime is mixed with the crude citric acid liquor removed from the fermentation tank, in order to form calcium citrate for precipitation and separation. Accordingly, when water-soluble citrate is formed by a component in the slaked lime, it does not precipitate, so it is lost in the waste water. Furthermore, when insoluble contaminants exist in the slaked lime, they will be mixed in the calcium citrate and brought to the next process.

The product shown as No. 2 in the table has a high content of MgO compared with others. When MgO reacts with citric acid, it forms magnesium citrate, $Mg_3 (C_6H_5O_7)_2$, which is soluble in water by 1.8% at 25°C. The crude liquor contains approximately 10% citric acid as a solution in water. Approximately 2,500 tons of slaked lime are used for 3,000 tons of citric acid production. If lime No. 2 is used, 2,500 × 0.0774 = 193.5(t) of MgO will be mixed with the 30,000 tons of liquor, and there will be a yield of 772 tons of magnesium citrate. A large part of the magnesium citrate, corresponding to 1.8% of 30,000 tons of neutralized water, 540 tons, will be lost in the waste water. The loss of 540 tons of magnesium citrate causes a loss of 503 tons of CAM, citric acid monohydrate, which means a 17% loss of the total product. The assumed CAM price is 5,000 Z$/t. 503 tons of CAM costs Z$2,515,000, which could never be compensated by the difference with the cost of slaked lime. The MgO component of 1% may be compensated by a difference in the cost of slaked lime of 174 Z$/t. Accordingly, slaked lime with an MgO content of less than 1% will be worth considering. Calculations concerning the above part of the explanation are shown in Note 2.

[Note 2]

$$3MgO + 2C_6H_8O_7 = Mg_3 (C_6H_5O_7)_2 + 3H_2O$$

Molecular weights :

MgO–40.3, $C_6H_8O_7.H_2O$–210.14, $Mg_3 (C_6H_5O_7)_2$–451.17

Therefore,

$$193.5 \times \frac{451.17}{3 \times 40.3} = 722 \text{ (t)}$$

$$722/30{,}000 = 0.024 > 0.018$$

Then, $Mg_3 (C_6H_5O_7)_2$ in the 30,000 tons of waste water will be:

$$30{,}000 \times 0.018 = 540 \text{ (t)}$$

$C_6H_8O_7.H_2O$ in the waste water will be:

$$540 \times \frac{2 \times 210.14}{451.17} = 503 \text{ (t)}$$

$$503/3{,}000 = 0.168$$

Assuming that the price of citric acid is 5,000 Z$/t, then;

$$503 \times 5{,}000/2{,}500 = 1{,}006 \text{ (Z\$/t)}$$

These are the criteria for the price difference of slaked limes.

Nos.1, 2, 3 and 4 commonly have a high content of iron oxide, Fe_2O_3. A small amount of iron is harmless to human health. Other than the British Standard, there are no written regulations on ferric components. However, each standard specification requires colorless products. The ferric components strongly affect the color of the product, which means that their inclusion should be very carefully avoided.

In particular, in the case of exportation or sales to multinational companies, a slight color difference in the product may cause severe damage in terms of competitiveness.

If the Fe_2O_3 content is 1%, the 2,500 tons of slaked lime will contain $2{,}500 \times 0.01 = 25$ (t) of Fe_2O_3. The iron contained in the Fe_2O_3 will be 17.5 tons and, if the total amount of iron contaminates the product, the iron contents will be $17.5/3000 = 0.0058 = 5{,}800$ ppm, which is more than 100 times the upper limit of 50 ppm specified by the British Standard. Therefore, it can be easily understood that any slaked lime with such a high Fe_2O_3 content as Nos.1, 2, 3 and 4 is not acceptable.

Fe_2O_3 is soluble in acid. When neutrization is started, Fe_2O_3 is dissolved in the crude liquor. However, when the liquor becomes neutral or alkalic, Fe_2O_3 does not dissolve. Furthermore, the dissolved ferric ions start to form hydrates which precipitate. Accordingly, this may vary according to the extent of neutrization, although a certain amount of the ferric components will contaminate the product. The precipitation of the ferric components may be prevented by stopping the neutrization at high acidity. However, the high acidity of the waste water causes a loss of citric acid.

The use of an ion exchanger is common practice for removing the ferric components in the case of carbon hydrate material origin contamination, so the same method may be applied for slaked lime origin contamination. However, the resin for the ion exchanger must be imported, as well as the ion exchanger itself. This disadvantage cannot be avoided in terms of capital and operational costs.

The slaked lime shown as No.8 in Table 7–3 is specified as a food additive. However, it still has an Fe_2O_3 content of 0.09%, while the neutrization is controlled to stop at pH5.5 with the usage of this slaked lime, and no ion exchanger is installed in the downstream process.

The slaked lime shown as No. 8 is not an ideal one. However, the limes shown as Nos.1, 2, 3 and 4 have too high an Fe_2O_3 content to be used in the same way as No. 8. It should be at least at the same level as that of No. 8, which means an Fe_2O_3 content of 0.1% or less.

The slaked limes produced in Zimbabwe and Zambia commonly have a high CO_2 content in the form of $CaCO_3$. Slaked lime is produced from quick lime, CaO, by adding water. Quick lime is made of limestone which consists of $CaCO_3$. Limestone is calcined in a kiln. The high CO_2 content means that a certain amount of unburned limestone remains in the slaked lime. Poor calcination control is a problem for these products.

The Al_2O_3 and SiO_2 contents are also high in these products. Al_2O_3 and SiO_2 are soil components. Consequently, this problem can be avoided to a large extent through careful control at the quarry. Pure Al_2O_3 and SiO_2 are not soluble in acid. However, the indicated value is not for any pure material, but the simple conversion of the measured result of the Al and Si components. Consequently, some parts of these components may be sulfate, phosphate and so on, which are normally contained in soil. Parts of these compounds are soluble in sulfuric acid and might cause a high ash content in the product.

To summarize the above discussions, it is advisable not to use No. 2 because of the high MgO content, and not to use Nos. 1, 3 and 4 because of the high Fe_3O_2 content, in order to avoid the high risk of product discoloring. Compared with these products, Nos. 5 and 6 are better. However, they are not calcined well and are also contaminated with too many soil components such as Al_2O_3 and SiO_2. Their quality is therefore doubtful.

It should be requested that the quality of these products be improved by a more strict control of the calcination temperature and a more careful dressing of the limestone.

Zimbabwean slaked lime contains more ferric components than Zambian slaked lime, which means that Zimbabwean slaked lime has a darker gray color than that from Zambia. In order to improve the disadvantage in terms of color, many factories add a small amount of NaCl, mixing it with the limestone upon calcination. NaCl forms ferrous chloride which evaporates from the kiln at high temperature. It is advisable for a Zimbabwean producer to study this method.

As an example of the price in the U.S.A. shown in Table 7–3, slaked lime is not so expensive for production work. Therefore, it is recommendable to use imported slaked lime of adequate quality for the starting period of the project. Then, after the quality has been improved with Zimbabwean slaked lime, the imported slaked lime can be replaced with the domestic product.

(3) Activated Carbon

Activated Carbon is used for decoloring the citric acid. It is added to the crude citric acid solution after dissolving it from calcium citrate using sulfuric acid. It is then removed by filtration. For this purpose, powdered activated carbon, less than 150 μm in size made from materials such as coconut husks, is generally used. The amount of activated carbon required for 3,000 t/year of citric acid production is 15 to 30 t/year.

In Zimbabwe, ZSR Ltd, produces 416 t/year of bone char from animal bone for the purpose of decoloring sugar. The bone char is granulated and regenerated in a Herreshoff Kiln for repeated use. Some of the bone char is sold externally at the price of 2,000 Z$/t. Bone char has a carbon content of about 10%, a calcium phosphate content of about 75%, and a calcium carbonate content of 2 to 9%. Bone char has an active surface with the porous texture of bone which is covered by carbon film.

Calcium phosphate is a kind of hard material which is difficult to make into a fine powder, so bone char consists of granules 590 to 2,380 μm in size, but is not adequate for use in the same way as the powdered carbon mentioned previously.

As its porosity is created by the natural texture of bone, the surface area ratio is limited to 70 to 150 m^2/g, although commercially available powdered activated carbon has a surface area ratio of 700–1,300 m^2/g. Consequently, a significantly larger amount and a longer processing time are required for decoloring with bone char, compared with activated carbon. Bone char has the advantage of repeatable use, as well as having a certain characteristic preferable for sugar decoloring, which means that it is used widely by sugar refineries. However, it is very rare to be used for other purposes.

No example of the use of bone char for citric acid decoloring is reported, so the following explanation is based on the hypothetical assumption that bone char is used for the citric acid decoloring process.

Calcium phosphate is not soluble in citric acid. However, calcium carbonate reacts with citric acid and precipitates to form calcium citrate, thus, although it may not be such a large amount, some of the citric acid is lost when mixed with the filter aid. The consumption of bone char would be about 10 times more than that of the powdered activated carbon because of the surface area ratio and other performance differences. Assuming the price of powdered activated carbon to be 880 Z$/t, powdered activated carbon would be economical. Furthermore, the granules of bone char require huge tanks for the process, while its regeneration would need an investment in a kiln. An operation with granular carbon is more complicated than an operation with powdered carbon.

(4) Filter aid

A mixture of diatomaceous earth is used as a filter aid for the filtration of citric acid after fermentation. Approximately 330 t/year of filter aid will have to be imported for 3,000 t/year of citric acid production. The filter aid should avoid any contents soluble to citric acid.

(5) Potassium ferrocyanide ($K_4[Fe(CN)_6]$)

Potassium ferrocyanide is used for removing the iron contents and avoiding the discoloring of the crystals contained in citric acid. It may not be necessary when pure cornstarch is used as a material.

7–3–4 Packing Material

Citric acid is sold as crystals of citric acid monohydrate in most cases. However, sometimes it is sold as a powder of anhydride upon the request of certain customers.

It is usually packed in 25 kg or 50 kg bags. It is important to use high-quality bags for marketing purposes. Because citric acid easily absorbs moisture in the air and the product should be kept free from the inclusion of foreign substances, customers have a keen interest in good packaging.

It is recommendable to use a five-ply paper bag including a single-ply liner of polyethylene or polypropylene.

There are several bag manufacturers in Zimbabwe, most of them having the potential ability to manufacture bags for citric acid. However, their existing products are not satisfactory. Among them, Hunyani Paper Sacks, a division of Hunyani Paper and Packing Ltd., has the high potential to make such bags.

Chapter 8 Plant Site and Infrastructure

Chapter 8 Plant Site and Infrastructure

8–1 Plant Site

8–1–1 Character of the Citric Acid Industry

Compared to other large scale chemical industries, the citric acid industry is rather a small one. The output of this project is 3,000 ton/year of citric acid, and so, assuming the price is 5,000 Z$/ton, the total sales revenue will be Z$15,000,000 per year. In the case of submerged liquid fermentation, 4,100 ton/year of cornstarch will be necessary as the carbohydrate material for the project. This corresponds to about 12 t/day if the plant is operated for 333 days/year, and so the quantity of materials to be handled is not so large. It is assumed that the electric demand will be about 1,500 kW and water consumption will be about 1,300 m^3/day. Accordingly it is not so difficult to find a site for the project in an industrial city or town. Fermentation plays a most important role in this industry. Engineers who are experts in fermentation are indispensable. The plant must be operated by trained technicians so that it is important to recruit educated people. In the case of solid culture fermentation, there may be work for unskilled labor such as simple carrying or handling of trays. However there is no work of this kind in the submerged liquid fermentation plant, because the plant consists of tanks interconnected with pumps and piping. Also it is well equipped with modern instruments and is automated.

The international market for citric acid is highly competitive and competitive prices and quality can be realised only by strictly controlling the production process.

The plant processes discharge waste water and the steam boiler produces smoke, but the amounts are small, and the hazard to the environment will be minimal as a result of the countermeasures described in Chapter 9.

Fermentation is based on the activity of microbes. The life of the microbes is sustained by constant contact with air which is supplied by electrically driven equipment. Consequently any interruption of the electrical supply changes the nature of the microorganisms and causes serious damage to the production. Stability of the electrical supply is an important factor when selecting a site.

As mentioned in Chapter 7, candidates for the carbohydrate material are;

(1) Sweet potato starch extraction residues

(2) Cassava starch extraction residues

(3) Cornstarch

(4) Concentrated juice, raw sugar and molasses obtained from sugarcane during the raw sugar manufacturing process.

(5) Syrup and molasses obtained from raw sugar during sugar refining process.

Sulfuric acid and slaked lime are also used in the process in amounts almost equal to the weight of carbohydrate material, as explained in Chapter 7.

The main product from the plant is, of course, citric acid, but the plant also produces gypsum in amounts greater than the weight of the main product. Gypsum is used for mixing in portland cement, gypsum board and agricultural use. However, the demand is not so stable, and so it must be stocked somewhere.

The plant site must be selected, considering the above mentioned characteristics of the industry.

8–1–2 Geographical Characteristics of Zimbabwe

Zimbabwe is an inland country, so there is no sea-port. All rivers in Zimbabwe including the Zambezi, Limpopo, and Save are not navigable by cargo ships. Consequently, trade depends on ports in Mozambique and the Republic of South Africa. Cargoes are mostly transported to and from the ports by railway.

A large part of the land is at a high altitude between 1,000 to 1,500 m above sea level, and this area is called the "highveld". The north-east part of the highveld is called Mashonaland, and the city of Harare is at the center of Mashonaland. Most of Mashonaland has enough rain for agriculture and has good crops of wheat and maize. Midland is located in the south-west of Mashonaland, and industrial cities such as Gweru, Kwekwe and Kadma are located there. Midland has mines and industries as well as agriculture. Matabeleland is located south of Midland. An industrial city, Bulawayo is at the center of Matabeleland. Most of Matabeleland is dry savanna, where farmers are raising cattle. Hwange, located near the north-west border, has a large coal mine.

In the south of the country, bordering with Mozambique and the Republic of South Africa, is an area at a comparatively low altitude between 350 and 500 m above sea level. The area is called the "lowveld". The lowveld consists mainly of the Masvingo province and partly of Matabeleland South and Manicaland. Masvingo, with a population of 30, 642, is the administrative center of the area, however the city is located at the edge of the highveld at 1,070 m above sea level. Chiredzi, with a population of 10,520, is the largest city in the lowveld, and is 429 m above sea level. The lowveld has little rain. Two large sugar factories belonging to the Hippo Valley Estate and Triangle Estate are operated near Chiredzi. Sugarcane is cultivated by irrigation in the estates. The east part of the lowveld is the Save river area, where irrigation has been developed for cotton and wheat plantations by ARDA. Manicaland is in the east part of Zimbabwe, where there are mountains higher than 1,500 m above sea level, and a good rainfall. Forestry for wattle is carried out, and also a variety of agricultural products such as tea, coffee, grapes and oranges are produced there. Mutare, with a population of 69,621 and an altitude of 1,120 m, is the capital city of Manicaland.

The Zambezi valley is in the north part of Zimbabwe, where the land is at a relatively low altitude, less than 1,000 m above sea level. The area is dry and not yet much cultivated. Binga, a village on the shore of Kariba lake and 620 m above sea level, is a center for developing the area.

8–1–3 Raw Material Sources and the Citric Acid Plant Site

For an industrial plant site, a location near the area where raw material is produced is advantageous. Firstly, the site location will be discussed from the viewpoint of material supply.

(1) *In the case of sweet potato residues*

Sweet potato residues come from the sweet potato starch production process. There is no sweet potato starch industry in Zimbabwe. As discussed in Chapter 7, there is also little possibility of an industry in future. However, for the sake of discussion, potential sweet potato growing areas such as Mashonaland, Midland and the Tokwe river area to the north of Masvingo, are assumed to be the potato starch production area. The Save river area does not have adequate soil for sweet potato cultivation. Accordingly, Harare and surrounding cities, cities in Midland, Triangle and the Hippo Valley, would be candidates for a citric acid industry site. Triangle and Hippo Valley have sugar factories, and so it would be easy to construct a citric acid factory attached to one of the existing factories.

(2) In the case of cassava residues

As explained in Chapter 7, cassava cultivation has been tried at Chisumbanje in the Save river area, but was not successful. At present, a trial cultivation is proceeding at Binga on the shore of lake Kariba, but, in this area, agriculture is still at a very primitive stage. Binga is the administrative and sight-seeing center of the area, but it is still a small settlement. A 3 meter wide paved road connects Binga to Dete near Hwange. Also there is a 7 meter paved road from Harare to an intersection near Karoi and from there a 3 meter wide paved road goes to Binga. Electricity is transmitted from Hwange through the Simangani substation by a 33 kV line. There is no railway near the settlement. Boats can navigate as far as Kariba dam, but cannot reach to Victoria Falls because of the rapid current.

There is no city water system yet in Binga. The nearest city to Binga is Hwange, about 150 km distance by road.

If a cassava starch factory is constructed at Binga, considerable investment for infrastructure will be necessary. The same infrastructure would also be necessary for a citric acid factory if the plant was to be at Binga.

Hwange has a population of 39,202 and is located at 760 m above sea level. There is a large colliery and a thermal power station there. A railway passes through the city, and an industrial infrastructure has been developed. It would be more practical to select Hwange as the site for the citric acid plant and transport the raw material from Binga.

(3) In the case of cornstarch

Harare has been selected as the most preferable site, in the case of cornstarch, and details will be discussed in Section 8-1-4.

(4) In the case of concentrated juice, raw sugar and molasses from sugar cane

As mentioned before, sugarcane is processed by the two factories of Hippo Valley and Triangle. Accordingly, near or inside one of these factories are the best candidate sites for the citric acid plant. One of the factories should be selected as the material supplier and the citric acid plant should be constructed along side the factory. Each sugar factory has a good infrastructure and is well equipped with boilers fueled by bagasse and each also has a steam turbine electric generator. There is a good possibility of receiving steam and electric power from these facilities.

(5) In the case of syrup or molasess obtained from a sugar refinery

It is advantageous to select a site near a sugar refinery when this is the source of raw material. There are two sugar refineries in Zimbabwe at present; one in Harare and another in Bulawayo. There is no significant difference between the two, so the plant site should be selected near the refinery which is to supply the raw materials. An advantage of Harare is that there is a sulfuric acid supplier in the city. However Bulawayo is located at a shorter distance from the Republic of South Africa, which is the largest potential market for the citric acid produced in Zimbabwe. The water supply is better in Harare at present, but an improvement is expected in Bulawayo.

8–1–4 Site Selection in the Case of Cornstarch

Cornstarch is produced solely by Food & Industrial which is located in Chitungwiza, a satellite city of Harare. However, they do not have enough surplus capacity to sustain the citric acid industry, and so the existing factory will have to be expanded or a new factory constructed to supply cornstarch to the *citric acid industry.*

Cornstarch is made from maize. Maize is the staple food of the people in Zimbabwe, so that it is cultivated almost all over the country. However most of the commercial production is concentrated in Mashonaland. The production of maize by commercial farmers in 1983, is shown in Table 8–1.

Table 8–1 Maize Production of Commercial Farms by Province in 1983

Province	Production (t)	Area (ha)	Yield (t/ha)
Manicaland	9,914	9,862	1.005
Mashonaland West	278,817	121,889	2.287
Mashonaland East	107,719	48,457	2.223
Mashonaland Central	174,344	56,287	3.098
Matabeleland North	6,885	2,549	2.701
Matabeleland South	2,467	2,305	1.070
Midland	15,202	18,119	0.839
Masvingo	3,584	12,282	0.292

Source : Statistical Yearbook of Zimbabwe 1989

Mashonaland West produces the largest amount and, when the production of Mashonaland East and Mashonaland Central is added to it, the total for Mashonaland is over 90% of the Zimbabwe production. The yield of maize is best in Mashonaland Central, and Matabeleland North, Mashonaland West and Mashonaland East have similar yields. Mashonaland East is the province with Harare at its center and has cities such as Chitungwiza, Marondera and Norton. Mashonaland West is located to the north west of Harare and Chinhoyi is the capital of the province. At Banket, a town located near Chinhoyi, it was planned to construct a plant for making butanol from maize as a substitute for diesel oil. Mashonaland Central is located to the north of Harare, and Bindura is its capital. Glendale, an agricultural center is located to the west of Bindura. The commercial maize production area expands in a north west direction from Harare. Other areas, of course, produce maize, but do not have a significant surplus after satisfying the staple food supply. Accordingly, the site for the cornstarch factory should be in one of these three areas; Harare and its satellite cities, Chinhoyi/Banket or Bindura/Glendale.

No satisfactory basis has been found for determining the minimum size of an economically feasible cornstarch factory. However, it is said that a cornstarch factory using 100 t/day of maize is practically the smallest size for a modern factory. Considering this size of factory, Midland does not have sufficient commercially available maize. Consequently, Gweru, Kwekwe and Kadoma cannot be considered, in spite of the very good infrastructure in these cities. Bulawayo, Masvingo, Mutare and Hwange are far from commercial maize production areas, so these cities also do not seem to be good candidates for the site. Figure 8–1 shows agricultural production in Zimbabwe. It is very clear that Harare, Chinhoyi and Bindura are located at the center of the maize production area. A map of Mashonaland covering the maize production area, is shown in Figure 8–2.

Norton, located 40 km west of Harare, has a large silo belonging to GMB (Grain Marketing Board). Banket also has one and Glendale has one at a concession located about 10 km west of the village. All these silos are located along the railway and transportation of maize is mainly dependent on the railway.

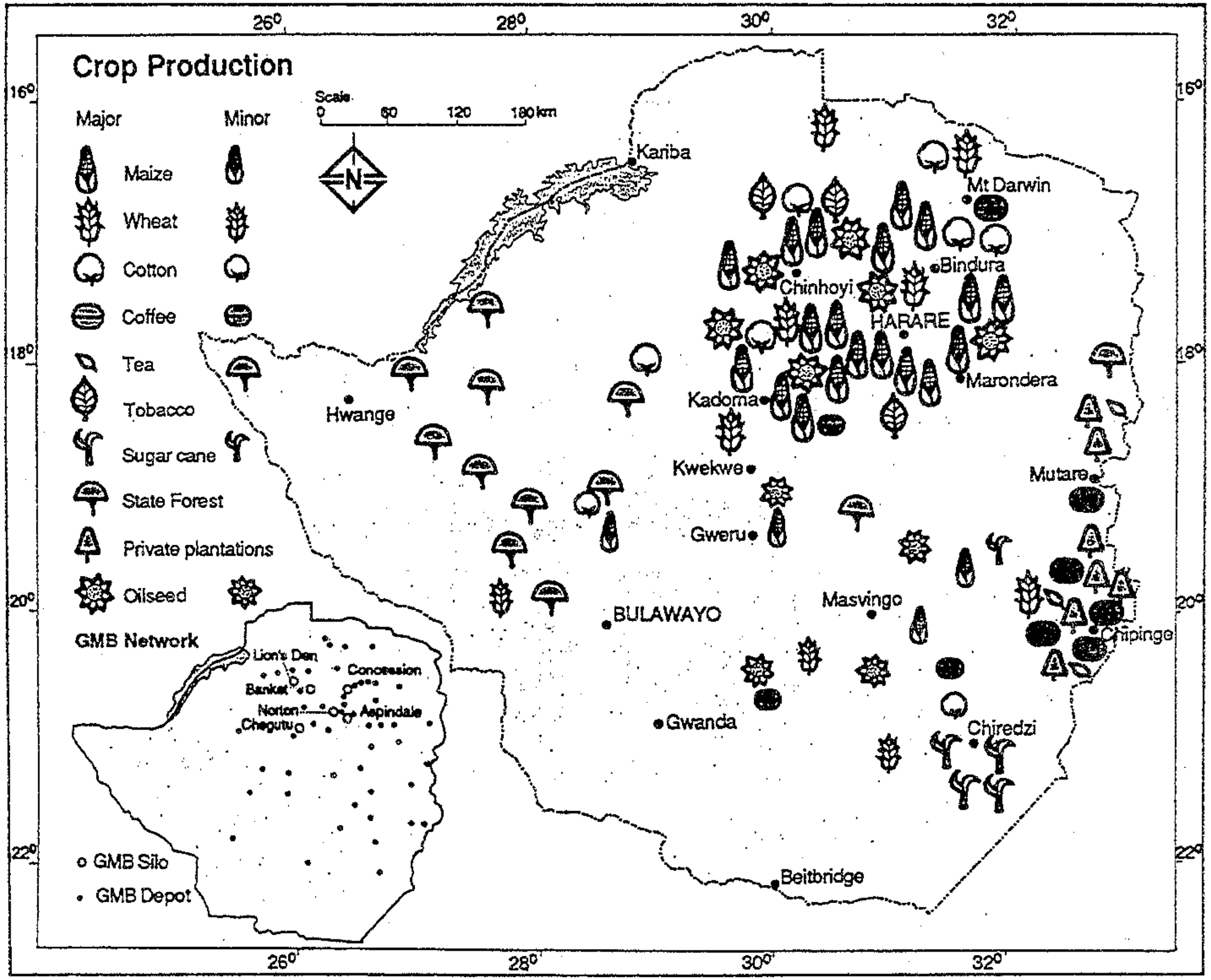

Figure 8–1 Agricultural Map

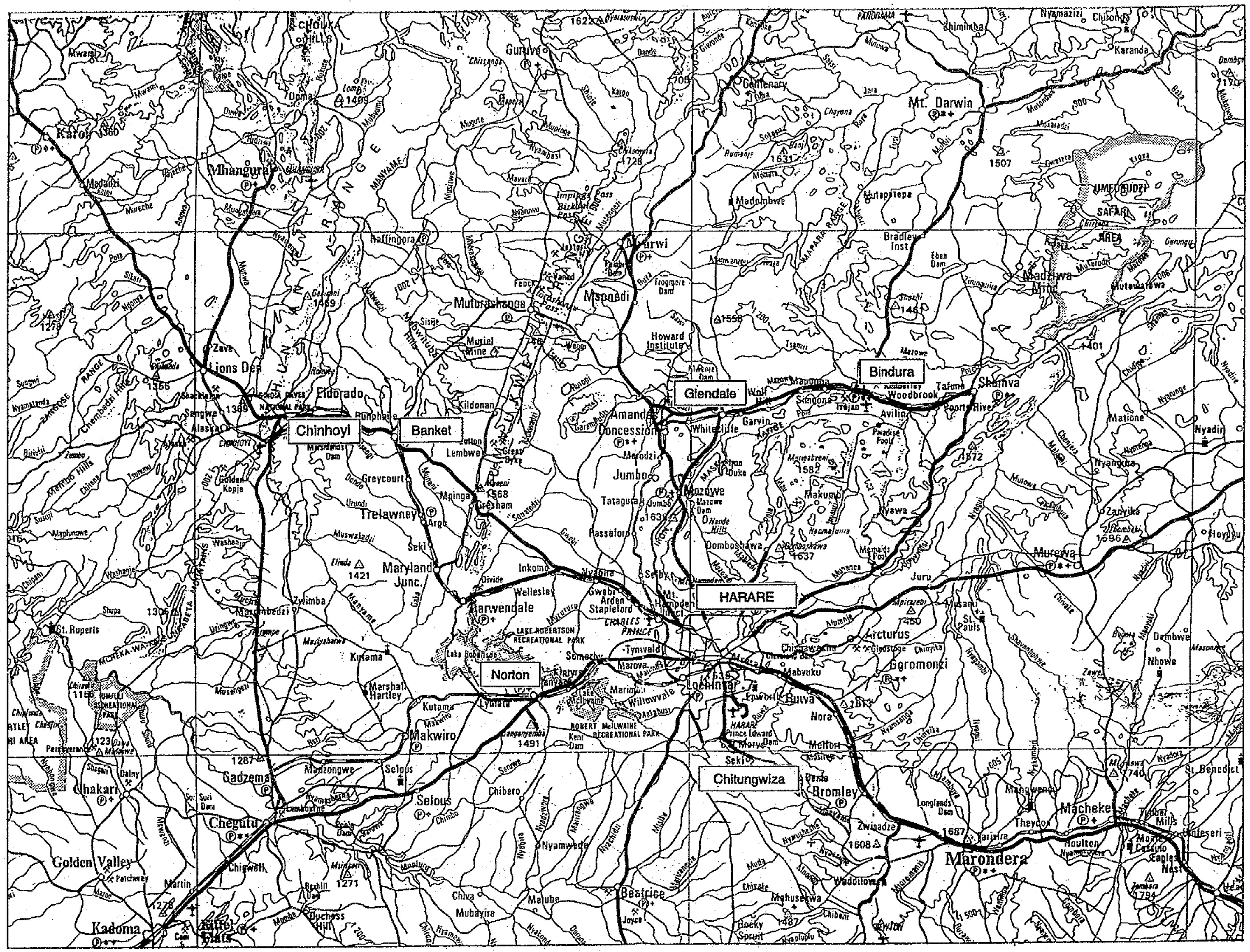

Figure 8-2 Map of Maize Prducing Area in Mashonaland

8-1-5 Site of the Citric Acid Plant

As discussed in the previous section, three areas; Harare and its surroundings including Chitungwiza and Norton, Chinhoyi/Banket and Bindura/Glendale have the potential to establish a cornstarch industry. These areas are within a 120 km radius of Harare, and also are well connected by paved roads and railways to Harare. Consequently, no difficulty is expected if the citric acid plant is built in Harare and the cornstarch plant is built any one of these areas. However, if the citric acid factory is located at Chinhoyi/Banket and the cornstarch factory is located at Bindola/Glendale or vice versa, road and railway transportation may take longer, because all roads and railways between these two areas pass through Harare.

(1) Harare and its satellite cities

Chitungwiza and Norton are located near Harare. Chitungwiza became a city in 1978 as a result of merging three residential towns called Seki, Zengeza and St. Mary. Most of the residents are people of African origin. Recently, the city has been trying to attract industries to the area, but basically the city is a dormitory town for working people. The population was 235,000 in 1985, but it is still growing very rapidly, and may be more at present. As a large labor force lives in the city, many workers commute to their working places in Harare by bus. The distance between the borders of the two cities is only 9 km.

Norton is a small city, with a population of 12,360, which is located near the road and railway from Bulawayo to Harare. A substation of the 330 kV transmission line from Kariba is located there and there is a paper factory in the city. The city is on the shore of Robertson lake, and the surrounding areas are irrigated for winter wheat cultivation. Agriculture is well developed and includes maize cultivation in the rainy season.

The railway extends east and west from the center of Harare. The largest industrial area of the city extends to the east along the railway and large industrial factories are crowded into the districts of Workington, Southerton and Willowvale.

There is a railway station called "Lochinvar" in the area, and so for the purposes of this report it is called Lochinvar industrial area. The Lochinvar industrial area is near a residential area for workers and also near to the city of Chitungwiza mentioned earlier. The business center and government office district of Harare are located to the north of the central station, and further north are various districts of the city with high government officials' and rich peoples' residences, universities and laboratories. The railway extends westward in the direction of Mutare. There are also several factories along this line. For the purposes of the report this is called the Msasa industrial area because there is a railway station called "Msasa" there. The locations of Lochinvar and Msasa are shown in Figure 8-3. These industrial areas in Harare, have good infrastructures including roads, railways, water and sewage. On the other hand it was found that the industrial area in Chitungwiza does not yet have such a complete infrastructure as that of the industrial areas in Harare.

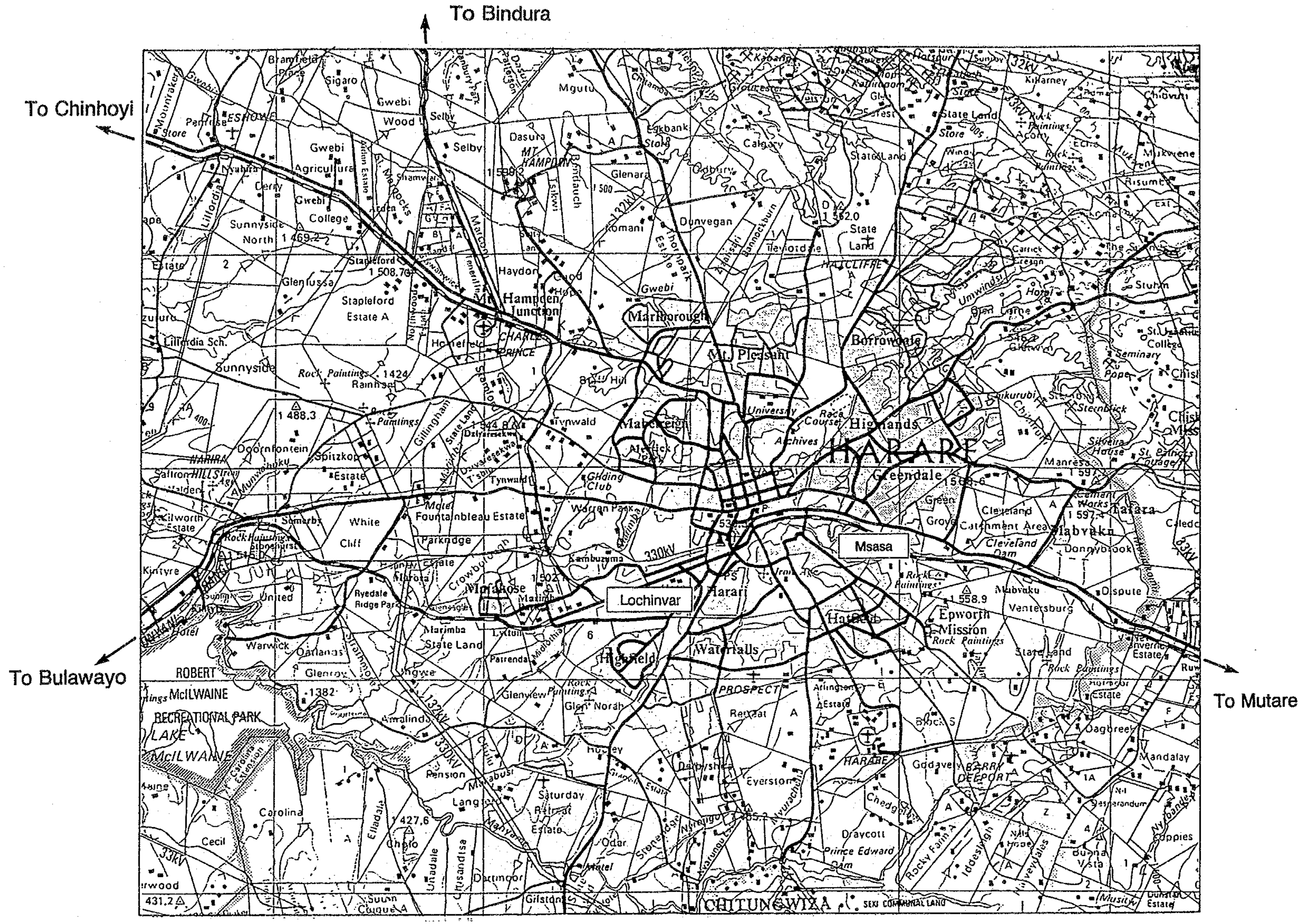

Figure 8–3 Map of Harare

(2) Banket/Chinhoyi

Banket is a village with a population of 5,698. The village was founded by miners, but, at present, the village is the center of a large agricultural area where cattle, cotton and tobacco are produced. A research station for Burley tobacco and a coffee processing plant are there.

Chinhoyi is a small city with a population of 24,322. Lime stone is produced near the city, and also a mine near the city produces gold, chromium and copper. The city is located in the same agricultural area as Banket. Chinhoyi cave is a famous sight-seeing place, and attracts many tourists, so the city has tourist facilities including an hotel. A brewery and several small engineering factories are also located there.

(3) Glendale/Bindura

Glendale is a village with a population of 6,076, and it is a commercial center for a large agricultural area where cotton and maize are cultivated. The village has a factory for ginning cotton and the development of a textile industry is planned. A mine near the village produces pyrites.

Bindura is a town with a population of 18,243, and it is the capital of Mashonaland Central Province. The town was started by gold miners and produces nickel at present. A smelter is operated in the south part of the town. Like Glendale, the town is surrounded by a rich agricultural area, which produces maize and cotton. Cotton ginning and several small local industries are located there.

Summarizing the above situation, except in case where attractive incentives are offered as part of a local development plan, Harare, where the population is 656,000, has obviously better conditions than any of the other candidate cities, towns or villages, in respect of infrastructure, industrialization and recruitment of workers. Accordingly, there is no doubt that it is best to select a site in Harare if one is available. A summary of the study is shown in Table 8–2.

Table 8–2 Summary of Site Selection

	Population	Industria-lization	Railway	Road	Electricity	Water	Distance to Harare
Harare	656,011	◎	◎	◎	◎ 330kV	◎	0 km
Chitungwiza	235,000	○	×	○	○ 132kV	○	9–20 km
Norton	12,360	△	◎	◎	◎ 330kV	○	40 km
Banket	5,698	△	○	○	○ 33kV	○	95 km
Chinhoyi	24,322	△	○	○	○ 132kV	○	115 km
Glendale	6,076	△	○	○	○ 33kV	○	85 km
Bindura	18,243	△	○	○	○ 132kV	○	88 km

Note: Population, Information based on Encyclopedia Zimbabwe, Quest Publication
Railways, Banket, Chinhoyi, Glendale and Bindura are connected to Harare.
Roads, Banket and Chinhoyi are connected to Harare and Zambia.
Chitungwiza, Glendale and Bindura are connected to Harare.

8–1–6 Site in the City of Harare

The industrial areas of Harare have spread along the railway, accordingly the areas extend east and west and also to the south of the city. The western part, namely the Lochinvar industrial area is the largest and busiest industrial area. A sugar refinery, a slaked lime supplier, a cement supplier, bottlers of fresh drinks and so on are crowded into the Lochinvar area. However, it is rather difficult to find adequate vacant space for a new factory in the Lochinvar area at the moment. If a site can be found, it would be worth considering it as a candidate site for the project. The area has road and railway communications to the industrial cities of Midland and Bulawayo. Also, as mentioned before, the area is near to Chitungwiza where many workers live.

It is easier to find a new site in the Msasa industrial area than in Lochinvar. Factories are not so crowded there. The Zimphos factory is about 10 km from the center of the city. The factory produces superphosphate as its principal product, however it also produces sulfuric acid, which is an important material for citric acid production. Sulfuric acid is a material which requires careful handling, and so it is advantageous to select a site near the sulfuric acid supplier, from the view point of safe transportation. Another issue for the production of citric acid is storage of gypsum. Gypsum is not such marketable by-product and it is almost valueless. Its selling price is 25 Z$/t in Zimbabwe. The problem with gypsum is the large output, approximately 5,600 t/year in the case of a 3,000 t/year citric acid plant.

Gypsum is used mostly for cement and agriculture as mentioned before, but the demand for it fluctuates, especially in the case of agriculture, so that storage is necessary. Zimphos has a huge stock pile of gypsum near its factory, because they produce about 70,000 t/year of gypsum as a by-product. Adding about 5,600 t/year to the pile may be acceptable to Zimphos.

There is a vacant area adjacent to the existing Zimphos factory which would be adequate for constructing the citric acid factory. The factory has complete facilities such as electric power, water supply and sewage which could easily be extended into the citric acid factory site. The site is located near to the 7 meter paved road between Harare and Mutare, and also near to the railway. The Zimphos factory has a railway siding which could also be easily extended into the new factory. A diesel shunting locomotive is available in the siding. There is also space for workers' homes after the construction of the citric acid plant. Zimphos has already constructed a work peoples' village near the factory, and the number of houses could be increased and other facilities such as clinics and shops could be built for the benefit of the employees, in order to recruit high quality staff.

The site is located at one of Harare's two industrial areas, however the distance from the site to a factory in the Lochinvar industrial area is 10 to 15 km, so that transportation between the two areas does not present any serious problem. Figure 8–4 shows a map of the area surrounding Zimphos and the Zimphos factory is shown on the map as the "Fertiliser Factory".

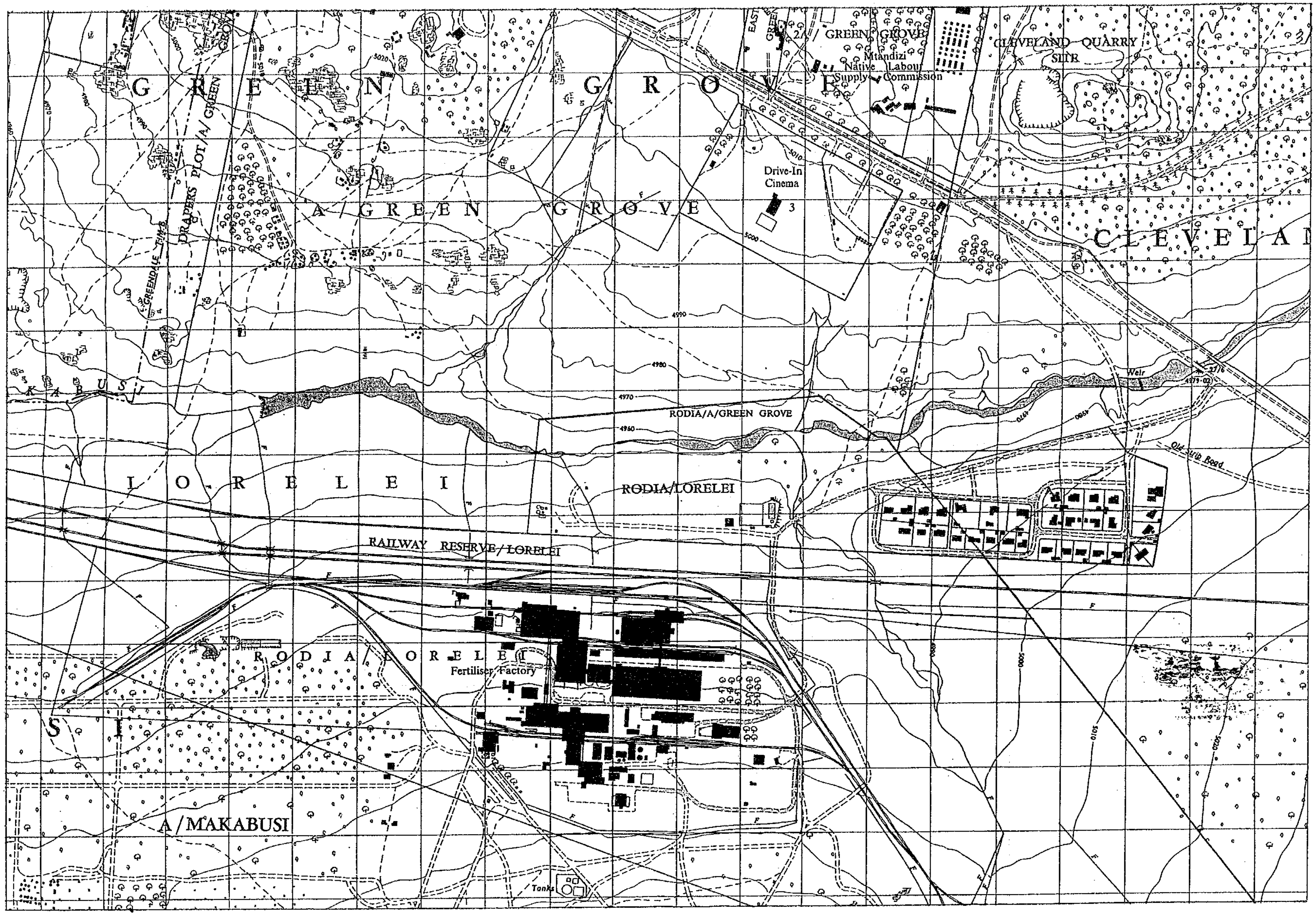

Figure 8–4 Map of the Site

8–1–7 Geological Features and Climate Condition at the Site

(1) Georogical features

Harare is located on the Zimbabwe Carton, a formation which was produced in Precambrian ages and dates back 575 million years ago. It is very stable, and no dangerous earthquakes occur.

The surface soil of the site is covered with hard clay. It is said that the water table is about 30 meter below the surface so the total depth of the clay layer is not certain. However, deep wells have been sunk to about 60 meters, so that the layer might be thicker than 60 meters. There are many high buildings in Harare, and there is no distinct difference in soil conditions between the city center area and the site. Consequently no difficulty is expected in building a factory.

The land is fairly flat all over the surrounding area.

(2) Climate

The city of Harare is located at a low latitude; 17°50' South. Consequently, there are almost no tyhoons or hurricanes. In the season from November to April, the prevailing wind direction is from the north-east and it rains frequently. In the season from May to October, the prevailing wind direction is from the east or south west and there is almost no rain. Careful installation of lightening arrestors is required, because thunder storms are experienced in the rainy season.

The monthly average temperature, rainfall and relative humidity are shown in Table 8–3.

Table 8–3 Meteorological Data

Month	1	2	3	4	5	6	7	8	9	10	11	12
Temperature (°C)	20.6	20.7	19.9	17.2	16.7	13.5	13.9	16.3	19.1	21.8	21.4	20.9
Rainfall (mm)	235.2	166.6	88.5	44.6	13.2	7.5	0.2	2.0	8.3	37.3	93.7	201.0
Relative Humidity (%)	77	79	72	67	61	59	51	47	45	46	61	72

Remarks : Average of 1951—1960,

Source : *Chronological Scientific Tables Maruzen 1988.*

Harare is located in the interior of a continent, so that the temperature varies very widely between day and night. However absolute humidity, namely wet bulb temperature does not vary so much and dew forms rather frequently at night.

As shown in Table 8–3, the monthly average temperature is in the 13° to 22°C range and humidity is not as high as other tropical areas throughout the year, and so the climate is pleasant all through the year.

(3) Latitude, longitude and altitude of the site

Location and altitude of the site are as follows:

- Location : 17°50' South and 31°08' East
- Altitude : 1,530 m above sea level

As the site is located at a high altitude, the atmospheric pressure is low. The pressure difference should be carefully taken into account when designing equipment which is sensitive to atmospheric pressure.

8–2 Infrastructure

8–2–1 Electricity in Zimbabwe

(1) Electric demand

In Zimbabwe electricity is supplied by ZESA (Zimbabwe Electricity Supply Authority) and is controlled by the Electric Act of 1985 which gives the company a monopoly.

ZESA's electricity sales amounted to 8,556 GWh in 1988/89 fiscal year. Figure 8–5 shows sales statistics. A sharp increase in sales can be seen between 1985 and 1986. However, this was caused when the municipal electric utilities were absorbed by ZESA, and so it does not mean any increase of actual demand.

As shown in Figure 8–6, domestic electric consumption increased by about 3% per year, during the 10 years starting from 1979, which is almost equal to the population increase.

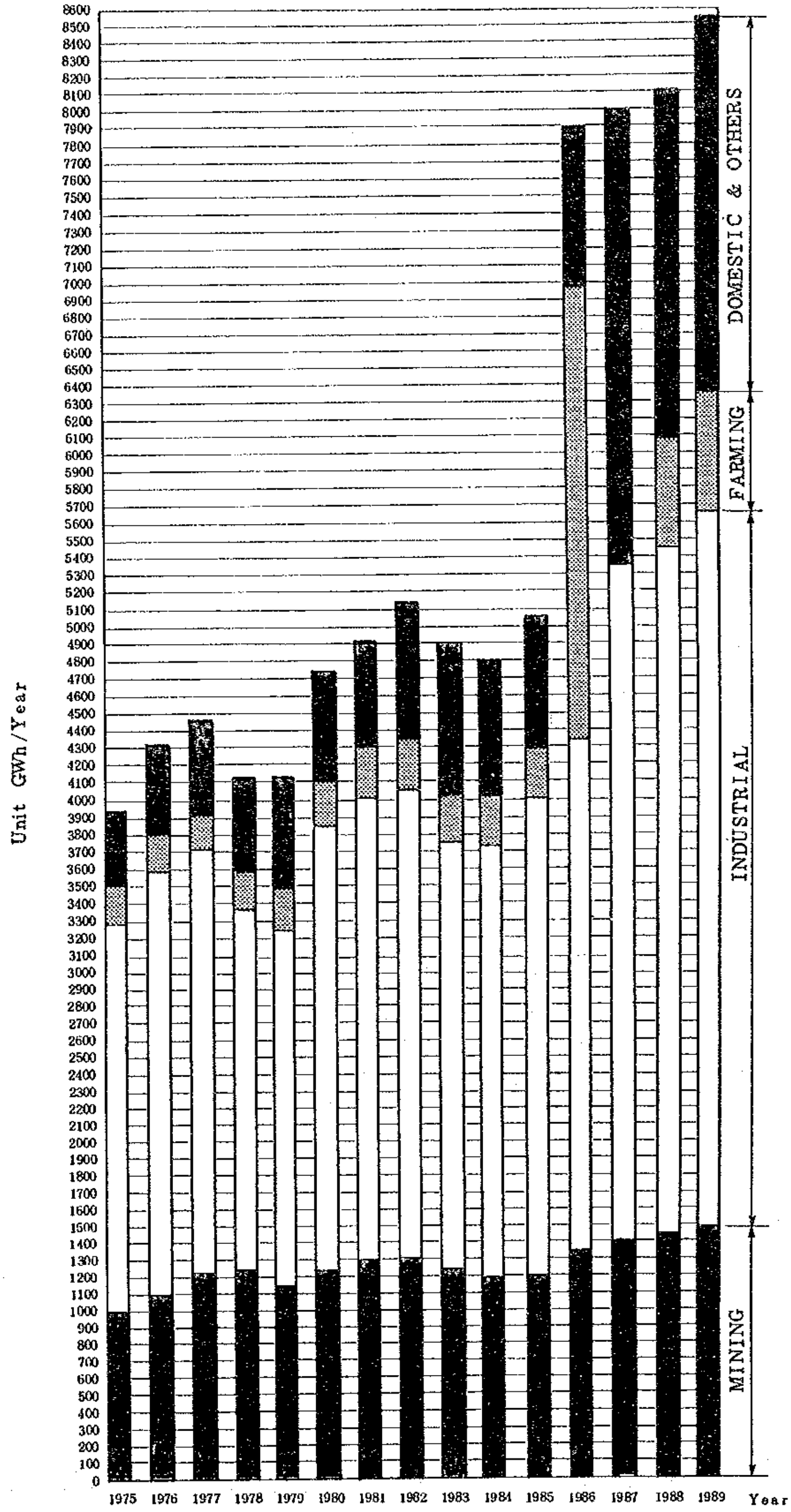

Figure 8–5 Electric Sales by ZESA
(Source: ZESA Annual Report 1989)

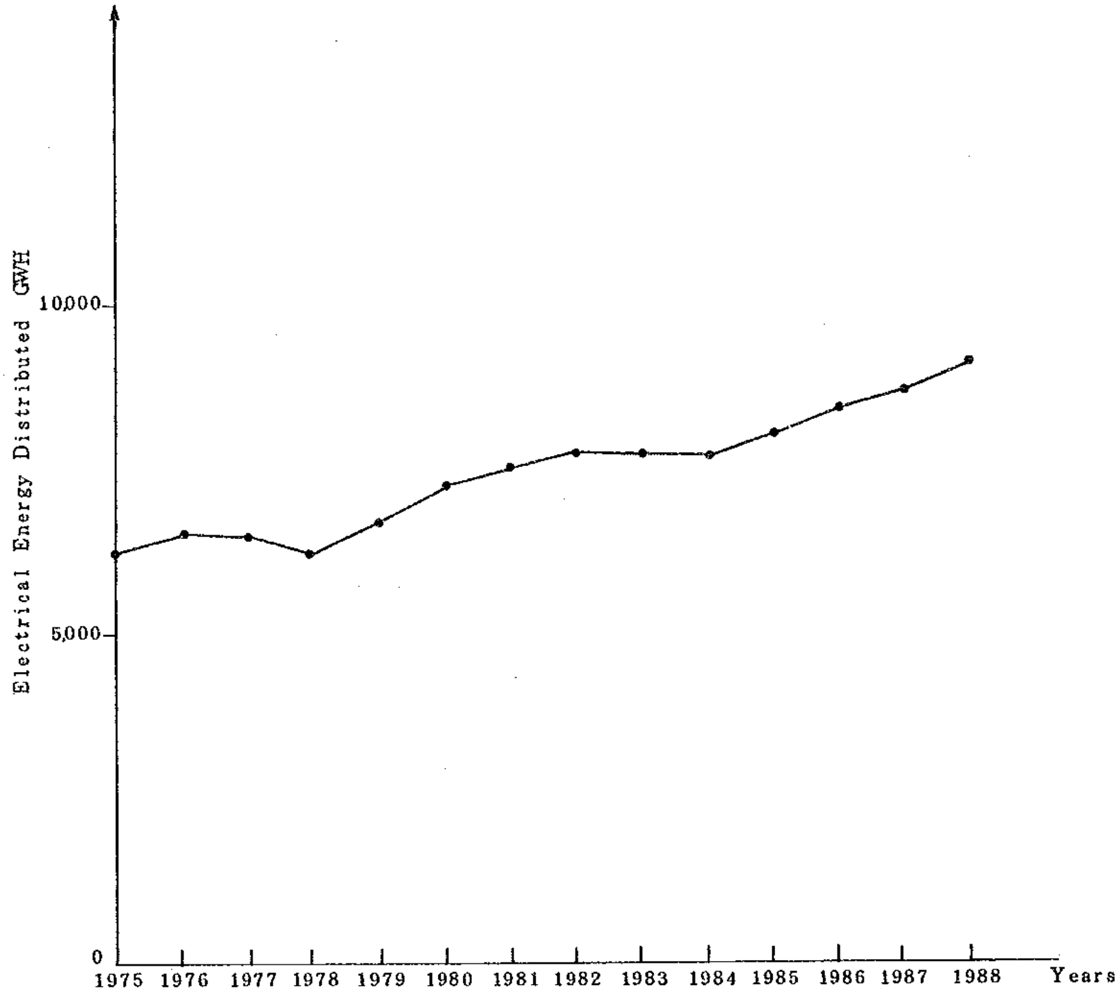

Figure 8–6 Electric Energy Distribution
(Source : STATISTIC YEAR BOOK OF ZIMBABWE 1989, Central Statistic office)

(2) Electric network

Figure 8–7 shows the main electric network in Zimbabwe. The two major power stations of Kariba and Hwange are connected to large cities such as Harare and Bulawayo by 330 kV transmission lines. These trunk lines branch out into 132 kV, 88 kV, 66 kV and 33 kV systems. A 330 kV line was built between Chertsey, Tokwe and Triangle in 1989, which reinforced the electric supply to the lowveld area. Also a 132 kV transmission line was constructed between Triangle and Beitbridge which had previously been supplied by a diesel power station and imported power from the Rebublic of South Africa.

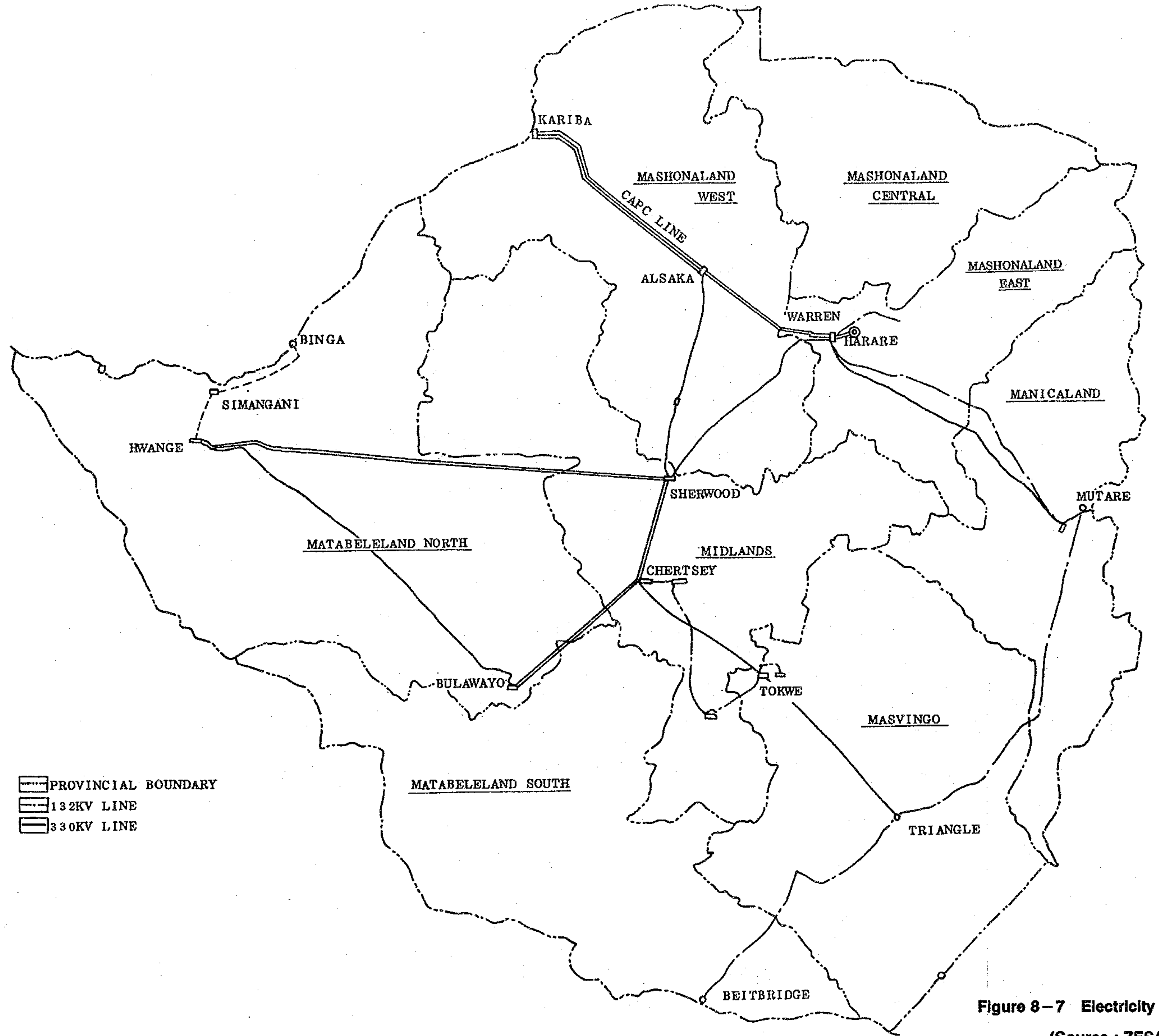

Figure 8－7 Electricity Network in Zimbabwe

(Source : ZESA Map, 1989)

As a result of completing these lines, all the cities in Zimbabwe are now interconnected by a completely unified electrical network. Especially, the industrial areas of Harare, Bulawayo and Midland cities are well interconnected with the power stations of Kariba and Hwange, by two or more 330 kV lines. Consequently, electricity is very reliable in this area.

(3) Power stations

Power station belonging to ZESA are shown in Table 8–4. The Kariba power station is located at the end of Kariba lake which was formed by damming the Zambezi river. The power station has a total power generating capacity of 666 MW, and produces about 34% of the total demand in Zimbabwe. Hwange power station is a modern thermal power station, which burns coal produced by the near-by open cast colliery. Its total electric generating capacity is 920 MW, which corresponds to about 52% of the total demand in Zimbabwe. ZESA imports about 10% of its electricity from Zambia. The rest is supplied by power stations in Harare, Munyati and Bulawayo, but these are old municipal power stations and their facilities are obsolete, so that they are used only for peaking and standby purposes.

Table 8–4 Zimbabwe Power Stations –Generator Capacity

Plant Name	No. of Unit	Max. Output per unit (MW)	Total (MW)	Generators Rating (MVA)
< Hydro Power Station >				
–Kariba	6	111	6 × 111	6 × 111.1
< Thermal Power Stations >				
–Hwange 1	4	120	480	4 × 133.1
–Hwange 2	2	220	440	2 × 244.1
–Harare	8	2 × 30 2 × 30 2 × 10 2 × 7.5	135	169
–Munyati	7	2 × 10 5 × 20	120	150
–Bulawayo	5	2 × 10 5 × 20	120	153

Source : ZESA Annual Report, 1989.

Privately owned power stations are not common in Zimbabwe. They exist only in Triangle and Hippo Valley, where sugar manufacturers generate electric power by burning bagasse. Their surplus electricity is also fed into the ZESA network.

Zimbabwe's peak demand was 1,429.7 MW in 1988/89, so that the total generating capacity of the power stations provides sufficient margin.

(4) Importation of electricity

The Zimbabwean electric network is connected to the Zambian system at Kariba and to the Mozambique system at Mutare. Two major hydro power stations at Kariba North and Kafue Gorge are connected to Zimbabwe through 330 kV lines belonging to CAPC (Central Africa Power Corporation) and Zimbabwe imports electricity from these Zambian power stations.

Trouble was experienced in 1988, due to a fire in Kafue Gorge power station which coincided with a turbine problem at Hwange power station. This sort of trouble might be considered to be quite exceptional.

(5) Operation of the power stations

In 1988/89, Hwange power station operated with an overall availability of 89.95% and a load factor of 68.82% for Stage 1 and 62.27% for Stage 2. Also Kariba power station operated with an availability of 94.41% and a load factor of 54.86% in the same year.

Transmission line losses were 3.04% and distribution losses were 6.17% in 1988/89. These operational results are excellent and compare favourably with those of utilities in industrialized countries.

8-2-2 Electricity in the Harare Area

(1) Power source

Electricity is mainly supplied from Kariba South power station and the two Zambian stations; Kariba North and Kafue Gorge, to Harare through the CAPC transmission line.

The line consists of three circuits, two circuits are connected directly to Warren substation which is located near Harare, and another is connected to Sherwood substation. There is a two circuit 330 kV line coming from Hwange to Sherwood, and also Sherwood is connected to Warren via the Norton substation by a 330 kV circuit. Therefore, even if there is a failure at Kariba power station or on the transmission line, an alternative supply is provided by Hwange power station. In addition to the safeguards mentioned above, there is a power station with a total capacity of 135 MW in Harare. The power station is obsolete and has a low efficieny, but it can be used as a back-up in an emergency.

Considering all these factors, electricity should be very reliable in the Harare area, if ZESA operates the system properly.

(2) Distribution

Electricity is distributed to most of the city area of Harare from the old metropolitan power station, and the power station is connected to the Warren substation by two 330 kV lines.

The plant site assumed in this project is located about 8 km from the metropolitan power station. Distribution is by underground cable and is very reliable.

(3) Electricity Tariff

According to the ZESA tariff list, revised on 1st of November 1990, tariffs are categorized as follows: 1) metered domestic consumers, 2) load limitted domestic consumers, 3) low capacity commercial, industrial and mining consumers, 4) low capacity agricultural consumers, 5) street lighting, 6) high capacity commercial, industrial and mining consumers and 7) high capacity agricultural consumers.

In this project the factory will be in category 6) high capacity commercial, industrial and mining consumers.

This tariff category is applied to an industry, which has a contract of over 300 kVA maximum demand with ZESA. In this Case, the following tariff will be charged:

(1) A fixed monthly charge of Z$22.50

(2) A monthly maximum power demand charge of Z$22.50 per kVA.

(3) Energy consumption charges at 2.15 Z¢/kWh between 0600 and 2200 hours, and 1.88 Z¢/kWh between 2200 – 0600 hours.

Assuming a maximum power demand of 2000 kVA and a consumption of 1,152,000 kWh per month with 24 hour continuous operation;

Fixed charge			22.5 (Z$)
Maximum demand charge	2,000 × 22.5	=	45,000
0600 – 2100 consumption	1,152,000 × 2/3 × 0.0215	=	16,512
2200 – 0500 consumption	1,152,000 × 1/3 × 0.0188	=	7,219.2
	Monthly Total		68,753.7 (Z$)

Average rate per kWh: 68,753.7/1,152,000 = 0.05968 (Z$/kWh)

As a result, the average charge per kWh is 5.968 Z¢/kWh (equivalent to 1.95 US ¢/kWh). This charge is extremely low compared with other countries. An earlier tariff list produced in October 1988 was as follows:

Fixed charge	Z$22.0
Maximum demand charge	18.74 Z$/kVA
0600 – 2200 consumption	1.91 Z¢/kWh
2200 – 0600 consumption	1.69 Z¢/kWh

Calculated from the above formula using the same conditions as for the previous calculation, the average charge would have been 5.09 Z¢/kWh in 1988, so that the tariff increase during the two years has been about 17%.

However, the exchange rate for U.S. dollars was US $1.0 = Z$1.8 in 1988, and is US $1.0 = Z$3.06 in 1991. Consequently when calculated in U.S. dollars, the cost of electricity has gone down about 37%, from 2.8 US¢/kWh to 1.95 US¢/kWh during these two years. This low energy price does not seem reasonable in the long term. It is feared that the capital invested by the utilities, which use imported equipment for their plants, will not be fully covered by amortization. ZESA should adjust the tariffs to maintain and expand their facilities taking devaluation of the Zimbabwean dollars and inflation into account.

8–2–3 Water Resources in Zimbabwe

(1) Rainfall

There is a rainy season and a dry season in Zimbabwe. It does not rain during almost the whole of the dry season, so that water has to be stored in ponds for use during the dry season. The rainy season normally starts in October and ends in April. Rainfall varies very much from year to year. Figure 8–8 shows rather extreme records for a dry year and a wet year.

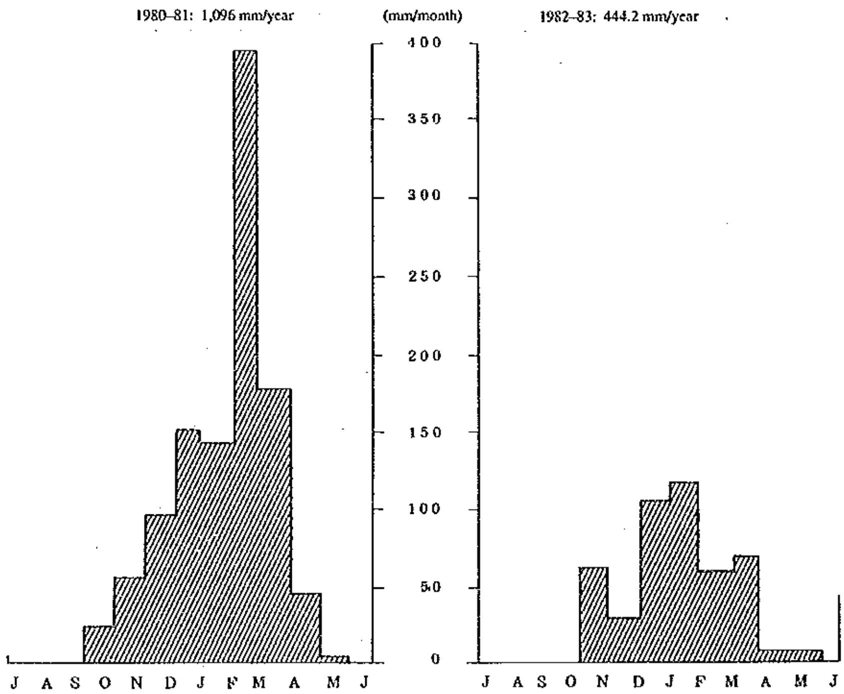

Figure 8–8 Rainfall in Harare
(Source: Atlas for Zimbabwe 4th Ed, College Press 1985)

(2) Water storage

Water is generally stored in artificial lakes constructed by damming rivers and there are numerous artificial lakes all over the country. Lake Kyle in Masvingo and Lake Robertson and Lake McILwaine near Harare are large water storage lakes.

(3) Distribution

Industrial water is supplied by the same distribution pipe lines as domestic tap water in Zimbabwe.

Water storage dams are constructed and controlled by the Ministry of Energy and Water Resources in principle. However, water is distributed to factories and houses by municipal authorities. The piped water supply reaches almost the complete city area, in every major city.

Dams are also being constructed by the government according to a long term plan. Therefore, no difficulties exist for water supplies in the major cities except Bulawayo where a new pipeline is needed between the water storage dam and the water treatment pond in the city. The government authority gave an assurance that this will be completed within a year. Accordingly, water supplies could be assured for the project in every major city. However, there are many towns and villages without piped water, for example, the place where the cassava experiment is located, Binga, has no public tap water, in spite of its location near Kariba lake.

It is said that the severe drought which is affecting Zimbabwe in 1991, may be experienced once in 25 years. The water shortage is particularly serious in the lowveld area, however no cities have stopped supplying tap water and sugar factories are operating normally.

There is no doubt that water is a most importance and precious resources for agriculture in Zimbabwe. There are still wide areas of the land which are not yet well utilized for agriculture because of lack of water. Efforts are needed to save water.

8–2–4 Industrial Water in Harare

(1) Resources

Harare has two large reservoirs, namely Lake Robertson and Lake McILwaine. There are also many small water storage ponds around Harare, and it is expected that water demand upto 1995 can be satisfied by existing storage facilities.

As mentioned before, there is no separate supply for industrial water and domestic tap water. Both are treated and distributed in the same way.

The municipal waterworks supplies 387,000 m^3/day and this is increasing by 27,000 m^3/day at present.

A filtration plant and a pumping station are located at Warren.

(2) Sewage

A sewage system is provided for the most populated area of the city, but, in principle, areas with less than one family per half acre do not have mains sewage. Most of these families use septic tanks.

The Zimphos factory in the Msasa district is connected to the sewage system which could be extended to the site proposed in the project without any difficulty. Industrial effluent is discharged to the sewers after rather simple treatment in most cases.

(3) Precautions against water supply interruption

Frequent failure or interruption of the water supply is not anticipated in Harare. However, it is recommended that a water storage pond or a bore hole should be provided to ensure a secure supply of water.

(4) Water quality

The results of an analysis by the city authorities are shown in Table 8–5. The treated water is slightly alkaline and soft. It is not extremely pure but is potable.

The water is acceptable as process water for citric acid fermentation as well as for industrial cooling water.

Table 8–5 Typical Analysis Results for Treated Municipal Water

pH	8.3
Total Dissolved Solid (mg/l)	134.0
Suspendid Solid (mg/l)	0.50
Turbidity (Nephelometric Turbidity Units)	0.50
Color (Hazen Units)	< 5.0
Phenolphthalein Alkalinity (mg/l $CaCO_3$)	2.0
Methyl Orange Alkalinity (mg/l $CaCO_3$)	78.0
Total Hardness (mg/l $CaCO_3$)	74.0
Permanent Hardness (mg/l $CaCo_3$)	Nil
Temporary Hardness (mg/l $CaCo_3$)	78.0
Dissolved Oxygen (mg/l)	7.0
4 Hr Permanganate Value (mg/l)	0.50
Ammonia (mg/l NO_3 N)	0.05
Nitrite (mg/l NO_2 N)	Nil
Nitrate (mg/l NO_3 N)	0.005
Iron (mg/l Fe)	0.02
Manganese (mg/l Mn)	0.01
Aluminium (mg/l Al)	0.02
Calcium (mg/l $CaCO_3$)	38.0
Magnesium (mg/l $CaCO_3$)	36.0
Sulphate (mg/l SO_4)	15.0
Chloride (mg/l Cl)	20.0
Fluoride (mg/l F)	0.40
Phosphate (mg/l P)	0.01
Silicate (mg/l SiO_2)	4.0

Source : City of Harare

8-2-5 Water Tariff

(1) Water supply by the government

As mentioned before, water storage dams are controlled by the central government, so that water is sold to municipal governments by the Ministry of Energy and Water Resources. Then the water is treated and sold to individual users by the city authorities. There are also some exceptional cases where municipal governments such as Harare have their own water storage ponds.

The Ministry of Energy and Water Resources sells water at 5.8 Z¢/m^3. The price is expected to increase by 10% soon. The cost to the cousumer is around 60 Z¢/m^3 in almost every major city, and there is not much difference between the various cities.

(2) Water supply by the city of Harare

In the case of Harare, the categories of the water tariff are as follows: 1) single family dwellings, 2) commercial and industrial use (with sewage), 3) flats, 4) miscellaneous, 5) commercial and industrial use (without sewage), 6) commercial and industrial use (local government area), and 7) all consumer outside municipal area.

The project would be in category 2) commercial and industrial use (with sewage),for which 59.5 Z¢/m^3 (corresponding to 0.194 US¢/m^3) applies. In the existing tariff list, the same price applies to the category without sewage, but this tariff includes a fee for sewage. For users outside the municipal area, the water tariff increases slightly to 66 Z¢/m^3. The minimum monthly charge is Z$5.45 in all cases.

As municipal water, this price is quite reasonable, but for industrial purpose, it may be slightly expensive.

8-2-6 Transportation

(1) Rail and road transport

Materials and products of the project are expected to be transported by railway. Paved roads connecting major cities in Zimbabwe are well developed, however the number of vehicles is not sufficient to transport large quantities for long distances, because the import of trucks is restricted due to foreign currency limitations. The railway is commonly used for this purpase.

Since 1990, the government of Zimbabwe has proceeded deregulations on import restriction, including transportation vehicles, and the rationalization for railway transportation systems. Thus, remarkable improvement for the transportation is expected in near future.

(2) NRZ (National Railways of Zimbabwe)

As shown in Figure 8-10, NRZ (National Railways of Zimbabwe) railway system is well developed and connects all major cities in Zimbabwe. All lines are single track. Electrification has already been completed between Harare and Bulawayo.

As shown in the figure, there are railway connections to Zambia at Victoria Falls, to Mozambique at Machipanda and to the Republic of South Africa at Beitbridge.

(3) Routes for export and import

Zimbabwe is an inland country, so that it is necessary to transport export goods to sea ports in other countries. The nearest port to Harare is Beira in Mozambique, to which it is connected by a railway line through Mutare and Machipanda. This route is called the Beira line. However, this route is affected by an insurrection and theft in Mozambique. Another line, called the Limpopo line connects Harare and the port of Maputo through Chicualacuala, but this line is also affected by insurrection and theft. Therefore, most goods to and from Zimbabwe are transported via Beitbridge and are exported or imported through ports in the Republic of South Africa.

However, when pease returns to this area after apartheid ends in the Republic of South Africa, the Beira line will be usable again. For this line, the transportation cost of, for example, sugar is 68.27 Z$/t.

(4) Sidings

The railway line from Harare to Mutare passes through the Msasa industrial area of Harare. This line is connected to the Beira line. The Zimphos factory has railway sidings from this line which could be extended into the project site and an existing shunting locomotive could handle wagons for both plants.

Figure 8–9 Road Map

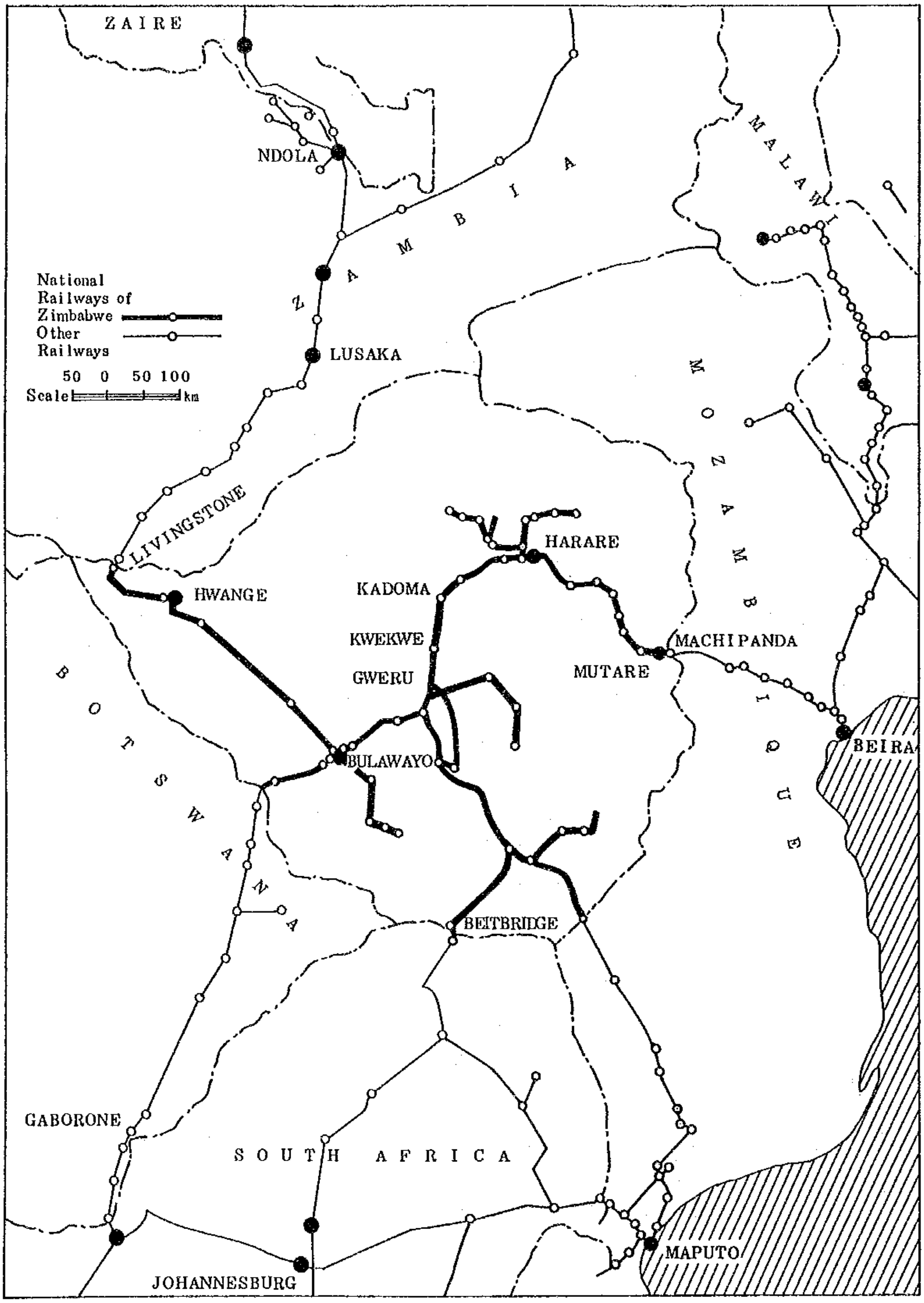

Figure 8–10 National Railways of Zimbabwe
(Source: Land survey office NRZ)

Chapter 9 Environmental Protection

Chapter 9 Environmental Protection

This chapter describes environmental protection measures and facilities for the citric acid plant. Facility costs are given in Chapter 13 "Plant Construction and Construction Costs".

The proposed citric acid plant produces substances which have an environmental impact. Among these substances, waste water is of most concern for environmental protection, because it contains a large amount of organic material and would show a high figure for BOD (Biochemical Oxygen Demand). In particular, the large amount of waste water generated by the fermentation process will show a high BOD figure, as it contains a large amount of organic materials, such as culture medium remaining at the end of fermentation, and also unused phosphorus and potassium. This waste water will cause eutrophication of rivers, lakes and marshes if discharged without treatment. Also boiler exhaust gas must be treated to prevent air pollution.

In order to plan environmental protection measures for the citric acid plant, several studies were carried out to make sure that the wastes conformed to Zimbabwe standards. Effective use of wastes as by-products was also considered as far as possible.

9–1 Environmental Protection Acts of Zimbabwe

The environmental protection laws enacted and issued in the Republic of Zimbabwe replace or amend the Atmospheric Pollution Prevention Act and Water Pollution Prevention Act of the old Rhodesian government, which were enacted in 1971.

9–1–1 Atmospheric Pollution Prevention Act

The atmospheric pollution prevention act was enacted in 1971 and amended in 1973. This act consists of the following seven parts:

Part I Air Pollution Advisory Board

Part II Control of Noxious and Offensive Gas

Part III Control of Atmospheric Pollution by Smoke

Part IV Control of Atmospheric Pollution by Dust

Part V Control of Atmospheric Pollution by Fumes from Internal Combustion Engines

Part VI Air Pollution Appeals Board

Part VII General

The noxious or offensive gasses defined in Part II are as follows:

(1) a gas containing or consisting of carbon monoxide, hydrocarbon, alcohol, phenol, tar, organic acid or a derivative thereof, halogen, organic nitrogen, sulphur, cyanide, cyanogen, ammonia, inorganic acid or acidic oxide;

(2) a fume containing or consisting of aluminium, antimony, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, phosphorus, potassium, selenium, silica, sodium, sulphur, tellurium, tin, tungsten, vanadium, or zinc;

(3) a dust consisting mainly of asbestos dust, cement dust, cotton dust, oxides of iron or phosphate or dust from a stone-crushing plant

(4) an odor from a meat or fish processing factory, paper works, purification plant or tannery;

(5) any particulate matter, gas, fume, dust or odor not referred to in paragraphs (1) to (4).

This Part also defines that:

The Ministry of Health has authority to designate a smoke control area and dust control area. In the designated areas, certain processes cannot be constructed or operated without permission from the Ministry. Industries subject to regulations in gas control areas are the fifteen (15) industries consisting of sulphuric acid, phosphoric acid, superphosphate, copper and/or nickel, iron and steel, cement, ferro-alloys, lead, gas and coke, ammonia, nitric acid, ammonium nitrate, granular fertilizer, arsenical ores and concentrates, and thermal power.

Specific values are not defined in this act. However, the regulation (control of emissions) issued in 1977 specifies that the maximum exhaust concentration of lead shall be less then 23 milligram per cubic meter and the minimum height of a chimney shall be 30 meters.

Smoke regulated in Part III includes micro particles contained in fly ash, soot and smoke. The Ministry of Health has authority to designate smoke control areas, in the same way as for gas and dust. Contents of the regulations include controls and regulations for smoke color and concentration, fuel, and fuel burning applications.

Part IV describes regulations, to control the quality and quantity or prohibit the use of substances causing environmental pollution by dust.

As stated above, the atmospheric pollution prevention act has substantially no specific values. However, an environmental impact assessment is required by the Ministry of Health, when a factory is to be constructed. Items to be included in an "Application for the Regulation of a Specific Process" are the name of the firm, location of the plant, area of site, name and title of person responsible for air pollution control, nature of specified process, general description of equipment for control of emissions to atmosphere, chimney specification and other details. After discussions with responsible people in the Ministry of Health, the permission for constructing a factory will be granted. Although specific values are not defined, evaluation will be made by referring to environmental protection measures taken by existing factories in the area where the plant is to be constructed.

9–1–2 Water Pollution Control Act

The law relating to water pollution control is the Water (Effluent and Waste Water Standard) Regulation, 1977. This regulation defines limits for two zones, namely, Zone I catchment areas and Zone II catchment areas depending on whether the rivers flow through high population density areas or low population density areas. For Zone I catchment areas, specific rivers are mentioned by name and the remaining areas are defined to be Zone II areas.

Prescribed standards of effluent and waste water for these two zones are shown in Table 9–1. In addition to the items in this table, there are regulations for color, odor and taste, and radioactive substances. The regulation aims to define standards which will not cause pollution in the area.

Table 9–1 Prescribed Standards of Effluent or Waste Water

	Zone I catchment area	Zone II catchment area
pH	6.0–7.5	6.0–9.0
Temperature of water	25°C or less	35°C or less
Dissolved oxygen	75% saturation or more	60% saturation or more
Chemical oxygen demand (COD)	30 mg/liter or less	60 mg/liter or less
Oxygen absorption by water	5 mg/liter or less	10 mg/liter or less
Total undissolved solids	10 mg/liter or less	25 mg/liter or less
Total dissolved solids	The total dissolved solids content of the receiving water must not be increased by more than 100% and the total dissolved solids content of the effluent shall not exceed 100 mg per liter.	500 mg/liter or less
Soap, oil and grease	nil	2.5 mg/liter or less

Source : Water (Effluent and Waste Water) Regulation, 1977

Standards for the City of Harare, when industrial effluents enter into their sewerage system, are shown in Table 9–2.

Table 9–2 Standards for the Control of Industrial Effluents Entering into the Sewerage System of the City of Harare

pH	6.9–9.0
Settleable solids (cm^3/liter)	less than 10
Heavy Metals (individual) (mg/liter)	less than 50
Fats (mg/liter)	less than 400
Cyanides	Nil
Calcium carbide	Nil
Organic solvents	Nil
Mineral (engine) oil	Nil
Bitumen	Nil

Source : City of Harare

Regulations for the maximum permissible concentrations of various chemical compounds are shown in Table 9–3.

Table 9–3 Maximum Permissible Concentrations of Certain Chemical Constituents

(Unit: mg/liter)

Constituent	Zone I catchment area	Zone II catchment area
Ammonia free and saline (as N)	0.5	0.5
Arsenic (as As)	0.05	0.05
Barium (as Ba)	0.1	0.1
Boron (as B)	0.5	0.5
Cadmium (as Cd)	0.01	0.01
Chlorides (as Cl)	50	100
Chlorine residual (as free chlorine)	Nil	0.1
Chromium (as Cr)	0.05	0.05
Copper (as Cu)	0.02	0.5
Cyanides and related compounds (as CN)	0.2	0.2
Detergents (as manoxol-OT)	0.2	1.0
Fluoride (as F)	1.0	1.0
Iron (as Fe)	0.3	0.3
Lead (as Pb)	0.05	0.05
Manganese (as Mn)	0.1	0.1
Mercury (as Hg)	0.5	0.5
Nickel (as Ni)	0.3	0.3
Nitrogen total (as N)	10.0	10.0
Phenolic compounds (Phenol)	0.01	0.1
Phosphate (as P)	1.0	1.0
Sulphate (as SO_4)	50	200
Sulphides (as S)	0.05	0.2
Zinc (as Zn)	0.3	1.0
Total heavy metals	1.0	2.0