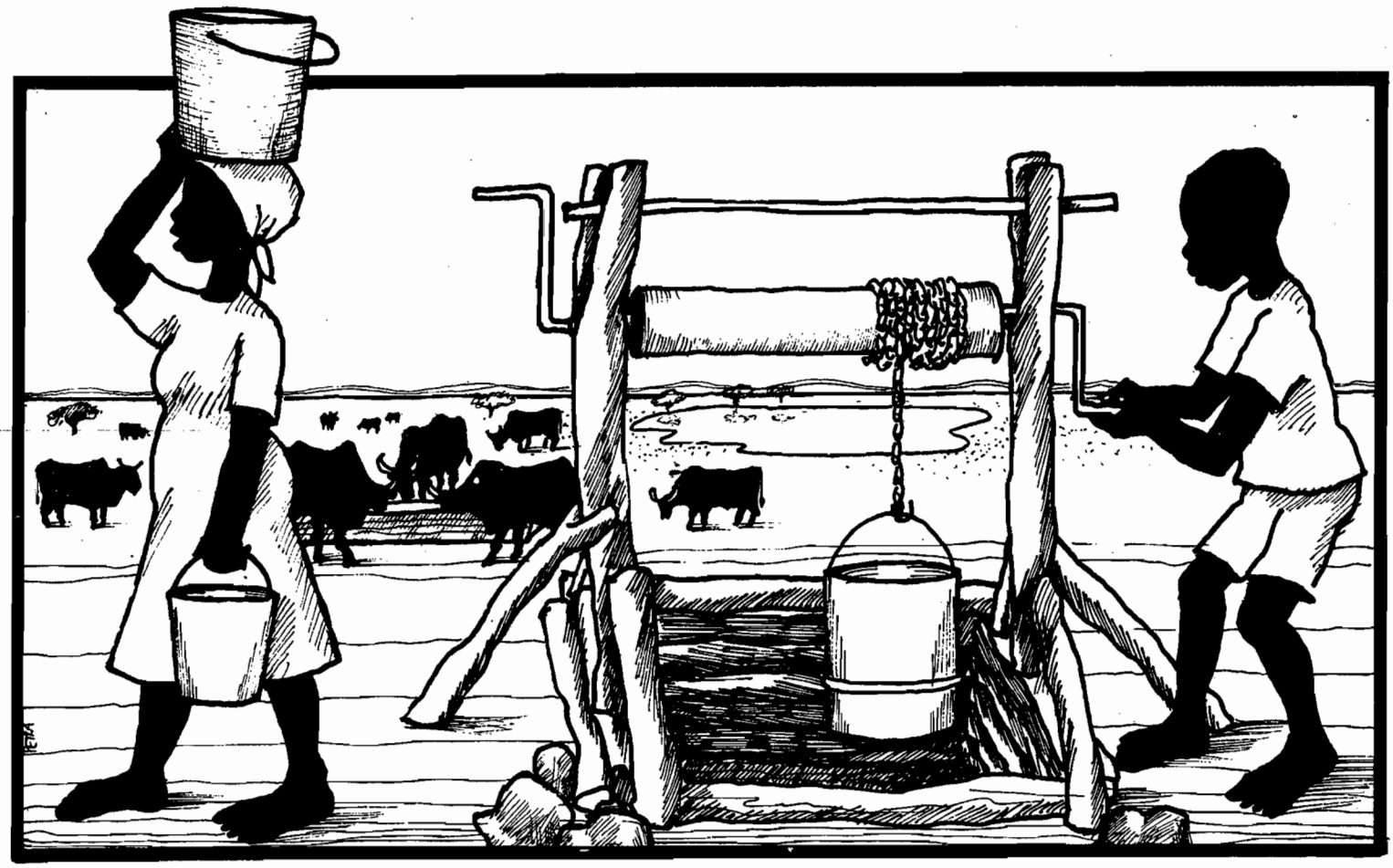
Keeping Cattle & the Cost of Water in Eastern Botswana



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WATER POINTS SURVEY PUBLICATIONS

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2. Charles Bailey, Louise Fortmann, and Emery Roe. 1980. Key to Water Points Survey Maps. Ministry of Agriculture.

3. Charles Bailey. 1980. Keeping Cattle and the Cost of Water in Eastern Botswana. Ministry of Agriculture.

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7. Elaine Aderhold. 1981. Rangeland Monitoring Methodology Based on Landsat Date: Case Study in the Republic of Botswana. Unpublished Masters Thesis(Cornell University).

8. Charles Bailey. 1981. Keeping Cattle and the Development of Water Resources in Eastern Botswana. Unpublished PhD. Dissertation (Cornell University).

KEEPING CATTLE AND THE COST OF WATER IN EASTERN BOTSWANA

Charles Bailey

Ministry of Agriculture

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CAVEATS AND ACKNOWLEDGMENTS

The usual pattern in doctoral research is to finish the dissertation and then write the articles. In this instance the pattern is reversed. The reader is thus cautioned that material appearing in this article is to be further refined and extended in an upcoming dissertation. In the interim, the author would be very pleased to receive comments addressed care of the Department of Agricultural Economics, Cornell University, Ithaca, N.Y. 14853, USA.

The data on which this article is based came from many sources, chief among which are the 246 Batswana cattle holders who patiently and repeatedly submitted to questioning about their husbandry practices. This paper literally could not have been written without their help plus the diligence of the Water Points Survey enumerating staff. Other essential information came from interviews with officials in the Ministry of Agriculture (the home base of the Water Points Survey), the Ministry of Natural Resources and Water Affairs, and the Roads Department, as well as private contractors, drillers, and water point owners in the 12 surveyed communities. Without the energy and insight of Dr. Louise Fortmann and Emery Roe, my two friends and colleagues in the Water Points Survey, this whole enterprise would have been quite impossible. Professor Daniel G. Sisler at Cornell read an earlier draft of this paper, and his comments greatly improved the present version.

I am grateful for the assistance of all these people, but the responsibility for any errors of fact or interpretation of course remains my own.

INTRODUCTION

The goal of the Water Points Survey[1] is to provide a better understanding of water use practices and problems in the communal areas of eastern Botswana, that is, the nonfreehold hardveld region. The Survey was carried out by Cornell University researchers in collaboration with the Ministry of Agriculture between August 1979 and December 1980. During this period, information was collected from central and local government officials as well as from Batswana living in 15 communities in the eastern communal area. Over 85% of the water used annually in the eastern communal area is consumed by cattle. This paper presents an analysis of the data concerning the water use strategies of those people in 12 of the 15 communities who at the time of the Survey were keeping cattle, and examines the costs connected with providing this water.[2] Other publications of the Water Points Survey report on water for small stock and human consumption. The map in Figure 1 shows the location of the Survey area and the 12 communities.

People who keep cattle in the eastern communal areas of Botswana live and work in a low-rainfall environment where the number of cattle

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[1] A "water point" is any natural place or man-made structure which yields water.

[2] Twelve communities were originally selected after air photo analysis, canvassing of all available secondary sources of information, consultations with district officials, and extensive touring and talks with chiefs, agricultural demonstrators, and other local people. All statements and conclusions in this paper are made with respect to these 12 communities, though they are judged to be representative of the socioeconomic and water supply situation in surrounding areas. Three more communities selected for their especially difficult water supply problems were added later. These are reported on in other publications of the Water Points Survey.

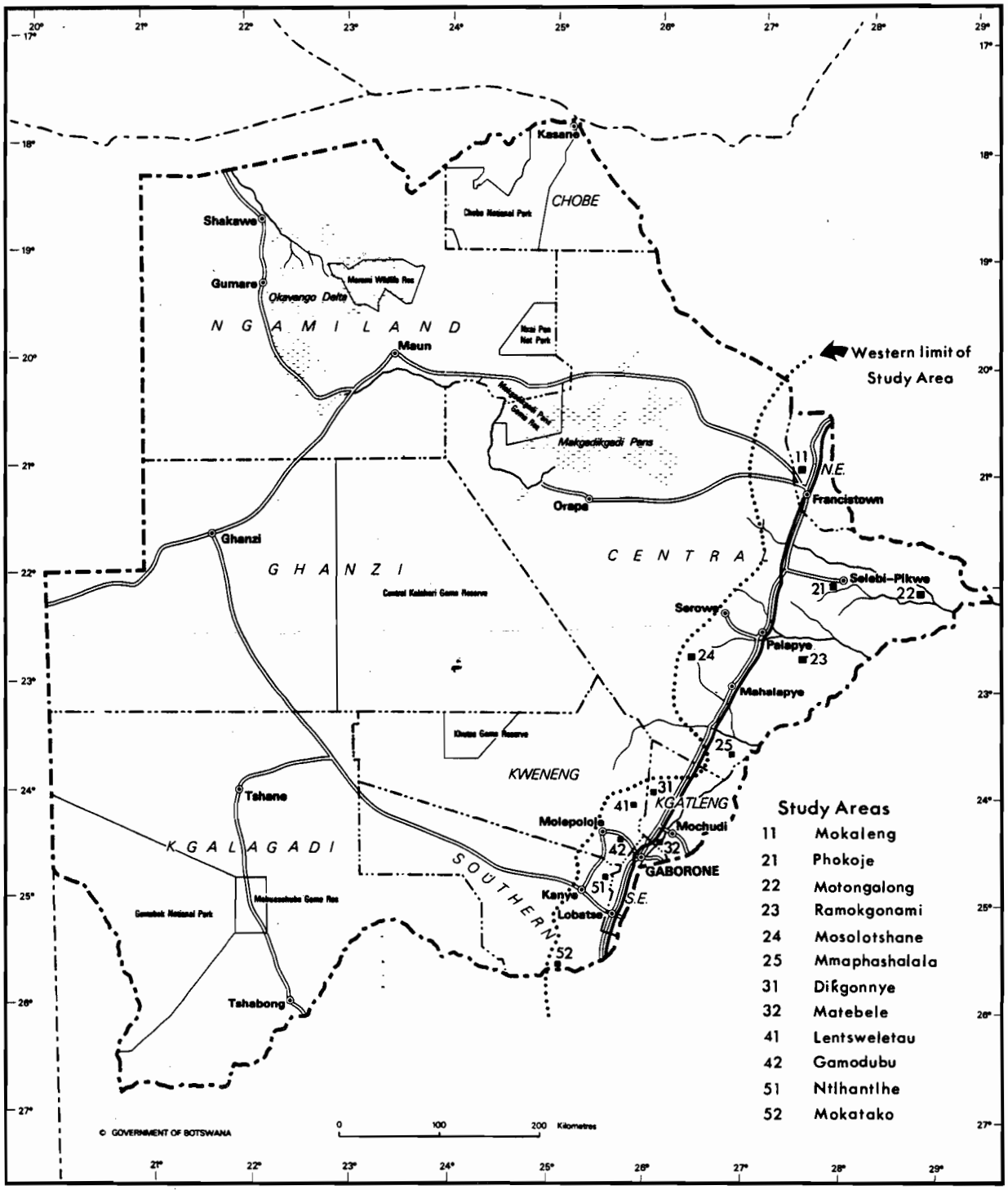

Figure 1 Water Point Survey Study Area

fluctuates seasonally but is trending upward annually. Overall water resources, particularly ground water, appear to be adequate; the principal problem is getting water at the time and place where cattle need it. Farmers try to meet at least the minimal water requirements of their herds by moving from place to place, by changing water points from month to month, and by constructing new water points. Their strategy is to obtain the most reliable, inexpensive, and convenient supply of water they can to give to the cattle for which they are responsible.

"Reliable" means a source of water available in sufficient supply through as many months of the year as possible. A reliable water point gives some protection during severe drought as well as reducing the need to change water points seasonally even in "normal" rainfall years. "Inexpensive" water is water which is the lowest-cost alternative available to a farmer for meeting his cattle's needs. The cost concept is comprehensive, including payment of watering fees in cash, in cattle, in labor, and in other goods and services which flow in the exchange relationships of the extended family. "Convenient" means a water point close to where the farmer wishes to keep his cattle.

The keeper of cattle in eastern Botswana typically does not move his cattle great distances. Thus he must make a strategic choice of water supply from a finite, local, and fairly small population of water points--about 40 to 60. In making this choice he will evaluate the available water points in terms of their relative reliability, cost, and convenience. His choice would be simple if he could find a water point which is at the same time very reliable, costless, and extremely convenient. This is unlikely. A borehole may be reliable and perhaps convenient, but

probably very costly. A dam may be unreliable, some distance away, but costless. The decision the farmer makes thus suggests the importance he places on each of these three selection criteria.

It is the thesis of this paper that farmers do choose the most reliable, inexpensive, and convenient source of water among the alternatives open to them.

Choosing the best available water supply, however, does not necessarily mean, in the eastern communal area, that cattle will get enough water to bring out their best performance. Economic productivity of beef cattle is a function of reproductive performance, calf growth, calf mortality, and carcass merit. The first three of these factors can be measured by "weight of wiener calf per cow per year"--a standard of growth in the sense of animal body weight gain over a stated period of time.[3] The Animal Production Research Unit (APRU) of the Ministry of Agriculture recommends a package of practices which farmers can use to achieve this growth.[4] A principal part of this package is a water point or water points which can provide a continuous supply of water freely available to cattle at all times.[5] This standard of water supply is not reached by any farmer who responded to the questionnaires of the Water Points Survey.

The farmer's cattle watering goal is a quantity at or somewhat above

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[3]Animal Production Research Unit, Livestock and Range Research in Botswana--1978 (Gaborone: Ministry of Agriculture, 1978), pp. 20-24.

[4]Ibid., p. 18.

[5]Animal Production Research Unit, Beef Production and Range Management in Botswana (Gaborone: Ministry of Agriculture, 1980), p. 12.

the minimum subsistence requirements of his herd, but short of the APRU ideal. This is mostly a frank recognition of constraints in local water supply, but partly a lack of appreciation of performance gains attainable through an abundant supply of water. Furthermore, growth to the farmer is the increase in numbers of animals in his herd, not individual bodyweight gain, which he sees as the result of weather and local grazing pressure. Clearly, getting enough water for cattle is a prime concern of farmers, but the meaning of "what is enough" is very flexible.

Throughout the rest of this paper, the target quantity of water for cattle is the APRU ideal of that quantity consumed by cattle when water is freely and continuously available to them. This is useful for planning purposes though it should be recognized that to provide the APRU ideal quantity of water to every cattle holder in the eastern communal area would require enormous amounts of public and private investment, and basic changes in current animal husbandry practices. Investment in water resources development should continue to be directed toward developing a secure water supply "floor" first, with free and continuous supply a secondary goal. Cattle in the eastern communal area will continue to consume a quantity of water below that of the APRU ideal for some time to come. However, with good planning, the geographical and temporal distributions of water can be improved.

Cattle Holders: The Survey Respondents

Farmers in 358 randomly selected households in 12 communities responded to questionnaires and personal interviews about their water use practices and problems. Of this group, 246 had cattle and answered ques-

tions in the first round of the cattle owners' survey in November 1979. The second round, conducted in March 1980, collected information from 239 respondents. (Seven farmers from the first round could not be reached again.) Survey respondents provided information on cattle numbers and husbandry practices as well as changes in herd size and structure through births, deaths, sales, trades, etc., which took place during 1979 and the first quarter of 1980. Cattle numbers were broken down by type of animal (bull, cow, ox, etc.) and by type of holding (owned and kept, mafisa'd,[6] in, borrowed in, mafisa'd out, and loaned or hired out). The first three types of holding constitute the respondent's "management herd," i.e., the cattle for which he must provide water on a week to week basis. Mafisa'd out and loaned or hired out animals, on the other hand, are the watering responsibility of someone else. Therefore, in examining watering practices, only animals in the respondent's management herd have been considered.

Another set of questions in the second round of the cattle owners' survey asked the respondents to recall where they had kept their cattle and which water points they had used in each of the 15 months back to January 1979. These questions were asked about the managed herd or herds, and any groups of animals separated for use at another location during the period. Thus the 239 second round respondents had 239 "main herds," plus 32 "subherds" consisting of 20 groups of animals separated for draft use, 8 groups containing both draft and milch animals, and 4 groups of milch

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[6]"Mafisa" is the long-term loaning of animals. The mafisa holder gets the right to the milk and draft power of these animals in exchange for looking after them.

cows only. In the rest of the paper, "herd" by itself will refer to both main and subherds. The 271 herds are the basis of information on cattle holder watering strategies which are presented in the following sections.

Every survey of cattle owners must consider the problem of misreporting of cattle numbers, particularly when the enumerators are associated with an arm of government. Certain measures to ensure accuracy were followed by the Water Points Survey: enumerator visits to kraals with the respondent, cross-checks built into the questionnaires, and examination of cattle crush[7] reports. The purposes of the Water Points Survey were also explained and discussed in a succession of kgotla[8] meetings in each of the communities. Enumerators lived in the communities for eight to nine months, and over this time were able to establish a rapport and a sense of trust with their respondents. Supervisors visited the communities nearly every week and also met many of the respondents. Therefore these cattle numbers are felt to be reasonably accurate and sufficient for the purposes of the present analysis.

A note on terminology: All cattle numbers are expressed in terms of "livestock units" (LSU) to provide a common denominator for comparisons. The LSU definition is a slightly simplified form of the definition used by the APRU, shown in Table 1.

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[7]A "crush" is a government-maintained holding pen and chute in which cattle can be immobilized for inoculations and tick treatments.

[8]The "kgotla" is an institution of local government presided over by a tribal authority. Physically, it is a place in the community for village meetings and the proceedings of the tribal court.

Table 1

APRU Definition of a Livestock Unit[9]

1.0 LSU =	one mature animal with a live mass of 450 kg. = one cow plus calf = stock older than 24 months
0.5 LSU =	one male or female animal between the ages of 12 and 24 months
0 LSU =	one calf

There were no facilities for weighing each of the 5,700-odd cattle reported by respondents in the cattle owners' survey. Reliable field techniques for age determination also do not exist. Therefore the Water Points Survey interpreted the APRU definitions as shown in Table 2.

Table 2

Livestock Unit Definition Adopted by the Water Points Survey

Type	Age	LSU Equivalent
"bull," "ox," or "cow"	over 24 months	1.0
"heifer" or "tolly"	12 to 24 months	0.5
"calf"	up to 12 months	0

Water Point Survey enumerators could not examine every reported animal, so it was necessary to rely on the respondents' designations of the types of animals they had.

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[9]Ibid., p. 81.

Water Point Types and Categories

The Water Points Survey identified ten physically distinct types of water point. These are defined in Appendix A, and this terminology is used throughout the paper.

The Survey also classified water points by management type. Broadly speaking, "management" is the exercise of human control from the time of siting and construction of man-made water points or first use of natural water points through their service life until they are abandoned. The siting and construction phase of man-made water points usually involves several agencies of district and central governments (Land Boards, district Land Use Planning and Advisory Groups, tribal authorities, the ministries of Local Government and Lands, Mineral Resources and Water Affairs, and Agriculture) as well as private individuals, farmers' groups, and private contractors or drillers. Costs of water point construction are discussed in Part III of this paper.

The much longer water point operational phase involves a somewhat different set of actors who own, manage, or own and manage water points. Ownership and management require running the facility itself, maintaining the facility, and revenue collection (if any). Ownership and management also imply control of access to the water point. The water points which appeared in the Survey were classified into five management types:

1. Agencies of the central or district governments ("government"), which may own dams and hafir-dams, or own and manage boreholes.

2. Private individuals, who own and manage every physical type of man-made water point.

3. Farmers' groups, which manage hafir-dams, or farmer "syndicates" which own and manage boreholes.

4. Whole communities taken as a group ("communal"), which may

manage every man-made physical type.

5. Natural water points--rivers, pans, and springs.

Both managerial and physical characteristics of a water point condition its availability for use by cattle holders.

Cross-classification of water point management and physical types produced 16 management-physical type categories each of which contains one or more examples reported in the cattle owners' survey.

PART I. CATTLE HOLDER WATERING STRATEGIES

Location and Movement of Cattle

In the short run, farmers can either move their cattle, or change water points as they attempt to meet their herds' water requirements. Most survey respondents kept their cattle permanently in one place, with seasonal movements to the lands[10] for plowing. Table 3 shows how first round respondents characterized the type of area where they were keeping their cattle in November 1979. Over two-thirds of the main herds were in mixed lands and cattle post[11] areas or in a village. Less than 20% were at a cattle post, and only 11% were at the lands. The right-hand column lists the communities where the given area type was of first or second importance. Four of the seven communities in which mixed lands and cattle post areas are the dominant location for cattle keeping are themselves

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[10] The "lands" are areas of fenced fields where farmers carry on arable agriculture. Sorghum, maize, millet, watermelon, and sweet reed are important crops.

[11] A "cattle post" is a place where cattle are kept which is surrounded by unrestricted open range.

Table 3

Location of Herds & Area Type Importance
By Community: November 1979

Area Type	Number of Main Herds	Percent of all Main Herds	Communities Where Given Area Type is of First or Second Importance
Mixed Lands	112	45.5	First: Phokoje, Motongolong, Ramokgonami, Mosolotshane, Dikgonnye, Lentsweletau, Gamodubu Second: Mokatako
Village	56	22.8	First: Makaleng, Matebele, Mokatako Second: Ramokgonami, Mosolotshane, Mmaphashalala, Ntlhantlhe
Cattle Post	43	17.5	First: Mmaphashalala Second: Makaleng, Phokoje, Ramokgonami, Dikgonnye
Lands	27	11.0	First: Ntlhantlhe Second: Motongolong, Ramokgonami, Lentsweletau, Mokatako
Mixed Village and Lands	6	2.4	First: None Second: Gamodubu
Mixed Village, Lands and Cattle Post*	2	0.8	First: None Second: Gamodubu

*This area type was reported in only two instances in Gamodubu and is not considered further.

lands areas. However, even farmers in Ramokgonami, Mosolotshane, and Lentsweletau--large, old, established villages--are finding it expedient to operate in the "fringe" between traditional lands and cattle post areas. Relatively few farmers in the Survey were keeping cattle in areas they recognized as "cattle post" areas.

Table 4 presents the mean and the range of answers respondents gave when asked for the year they started keeping cattle in their present location. In this and other questions a large majority of respondents appeared confident they knew the exact year. A few replied that the family cattle were established at the place before they were born and therefore they did not know the year. The year of known kraal[12] establishment thus ranged from 1909 to 1979, with the mean falling in 1965. This indicates that once a farmer finds a place for his kraal, he keeps it there. The kraal is the "home base" for his animals throughout the year, except perhaps in years of unusually low rainfall.

Both the number of cattle and the number of cattle holders in the eastern communal area have increased, particularly in the last decade. One-half of the respondents set up their kraals in the years following 1969 as the area recovered from the severe drought of the middle 1960s. The mean year of kraal establishment in each different type of area suggests a definite pattern of land use change. Kraals in currently recognized cattle post areas of the 12 communities were on average started in 1958. Kraals in what are now mixed lands and cattle post areas followed, with a mean year of establishment falling in 1964. Mixed village and

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[12]A "kraal" is a fenced enclosure for keeping cattle.

FIGURE 2
NUMBERS OF HERDS KEPT IN AREAS OF DIFFERENT TYPES : 15 MONTHS

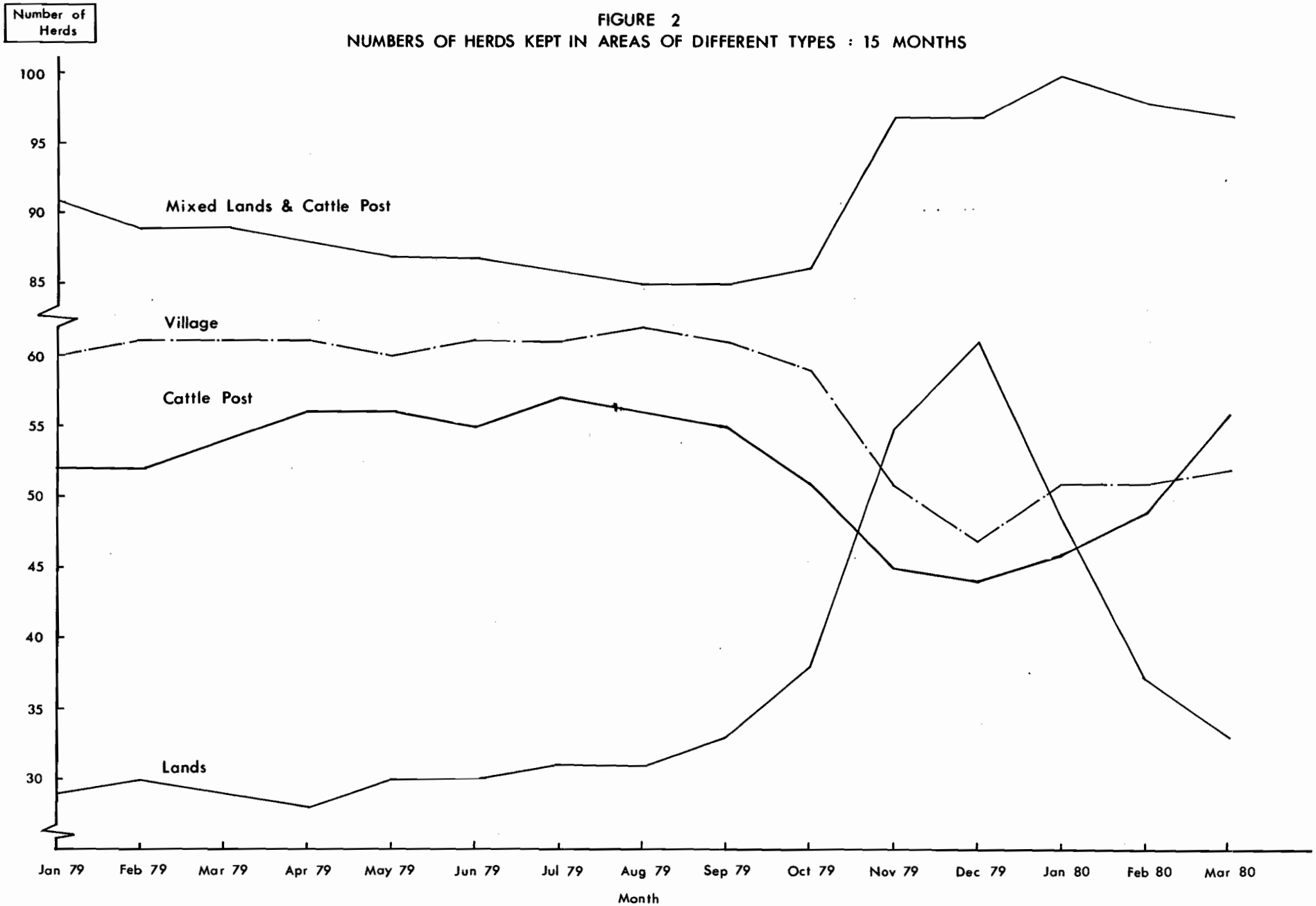

FIGURE 3

TOTAL NUMBER OF WATER POINTS IN OPERATION, CATTLE USING THEM, AND LITERS OF WATER DEMANDED

January 1979 to March 1980

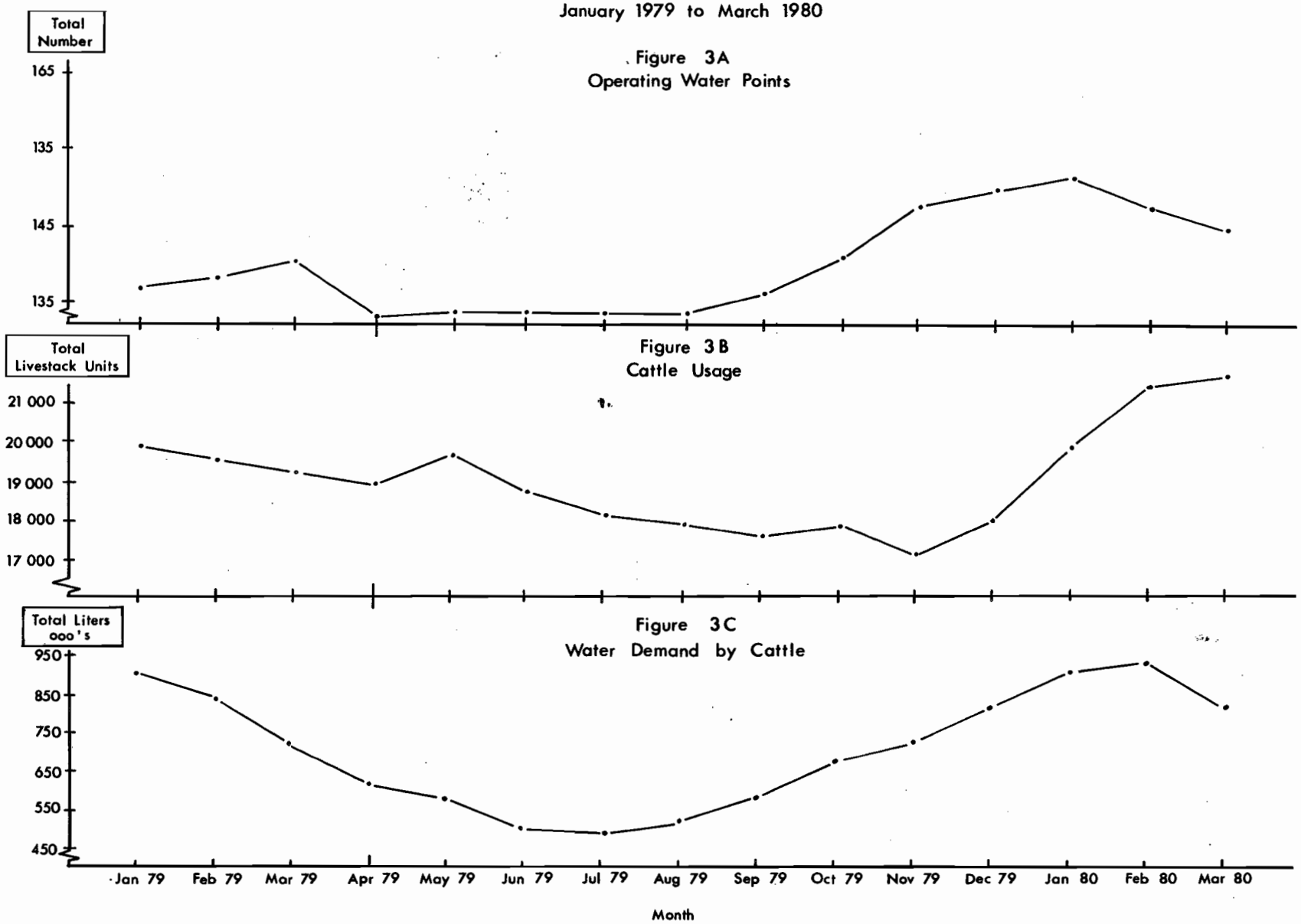

Table 4

Year Respondents Started Keeping Cattle in Present Location

Community	Year* Mean	Year* Range	No. Respondents Answering "Born and found them there"	No. Respondents Answering "Don't know"
All Communities	1965	1909-1979	6	27
Makaleng	1967	1934-1978	0	1
Phokoje	1973	1947-1979	0	0
Motongolong	1963	1935-1979	0	0
Ramokgonami	1970	1950-1979	0	0
Mosolotshane	1964	1909-1978	2	0
Mmaphashalala	1961	1946-1976	0	0
Dikgonnye	1962	1948-1978	0	6
Matebele	1972	1966-1976	1	4
Lentsweletau	1962	1913-1979	1	2
Gamodubu	1958	1918-1979	0	0
Ntlhantlhe	1966	1929-1979	0	1
Mokatako	1960	1931-1974	2	13

*There were 246 respondents to this question. Mean and range were calculated for respondents who gave a date. Inclusion of respondents who answered "born and found them there" would push the mean date back in those villages.

lands areas have a mean of 1965, followed by kraals in villages and in lands, both with means of 1966. It appears that farmers who began to acquire cattle had neither the large numbers nor the resources to set up cattle posts, so they kept their animals closer to their lands or their homes in the village.

Table 5 adds more to the locational picture. It presents the reasons most frequently given for keeping cattle at a particular place.

The dominant reasons for maintaining cattle at a location can be summarized as convenience and necessity--nearness to lands on the one hand, and lack of labor and alternative locations on the other. Enough grass and water rank next.

Table 5

Reasons Respondents Kept Cattle at a Particular Place

Number of Respondents	Reasons Given*
63	Convenient for plowing
56	No other place to keep cattle
34	No labor available except owner's
32	Enough grass
28	Avoid crop damage disputes
26	Enough water
19	Can keep cattle at family's cattle post

*Remaining responses were specific to individual circumstances and could not be categorized.

Figure 2 is a graph showing the numbers of herds present in four different types of area month by month from January 1979 to March 1980. It expands on the static picture presented in Table 3 and confirms the view presented earlier: most herds are kept in mixed lands and cattle post areas, and there is relatively little shifting of herds except for movement to the lands for plowing. A sharp buildup of herds in the lands and mixed lands and cattle post areas began in September-October 1979, in parallel with a shift of herds out of the cattle posts and villages,

as farmers prepared to take advantage of the spring rains. Half the respondents had begun to plow by the third week of November; by the second week in January, half had finished plowing, and herds were being shifted back out of the lands. Table 6 shows the number of main and subherds moved to a different area over the 15 months, together with the reason for the shift. Movement to get nearer to water is given as a reason by only two respondents in August 1979. Nearly all subsequent reasons for movement relate either to plowing or to avoiding disputes about crop damage by cattle.

Table 6

Number of Herds Moved and Reasons Given: January 1979-March 1980

Month	No. of Main Herds Moved	Principal Reasons Given for Moving	No. of Sub-herds Moved	Principal Reasons Given for Moving
Jan 79	0	--	0	--
Feb 79	0	--	0	--
Mar 79	0	--	0	--
Apr 79	0	--	0	--
May 79	1	Lack of herding labor	0	--
Jun 79	0	--	0	--
Jul 79	0	--	0	--
Aug 79	2	Take cattle closer to water	0	--
Sep 79	5	Going to lands to plow	0	--
Sep 79	1	Take cattle closer to grass	-	--
Oct 79	12	Going to lands to plow	0	--
Nov 79	3	Going to lands to plow	0	--
Nov 79	1	Avoid crop damage disputes	-	--
Nov 79	1	Hard prevent scattering	-	--
Dec 79	8	Left lands after plowing	7	Left lands after plowing
Dec 79	4	Avoid crop damage disputes	1	Avoid crop damage disputes
Dec 79	1	Going to lands to plow	-	--
Jan 80	4	Left lands after plowing	5	Left lands after plowing
Jan 80	2	Avoid crop damage disputes	2	Avoid crop damage disputes
--	-	--	1	Take cattle closer to water
Feb 80	1	Left lands after plowing	3	Left lands after plowing
Feb 80	1	Avoid crop damage disputes	-	--
Mar 80	3	Going to lands to plow	2	--
Mar 80	2	Left lands after plowing	2	Left lands after plowing

Choice of Water Points

The previous section established that respondents do not generally move their animals as a strategy for ensuring their water supply. This section looks at strategies of changing water points to achieve the same goal.

The 239 main herds and 32 subherds in this study met their water requirements at 249 water points during the 15 months between January 1979 and March 1980. This amounted to 2,204 water point use-months. (Subherds were away from their main herds only a few months out of the 15.) Table 7 shows the size of the mean herd and the number of water points used by survey respondents in each community by management-physical type category for the one year period from April 1979 to March 1980. These 12 months were selected out of the total 15 to show the annual cycle of use and to avoid overemphasizing the rainy season.

All physical types were not used in all 12 communities. Respondents used rivers and boreholes in 11 communities, open wells in 9, hafirs in 8, and pans in 7. Sand river wells were used in 6 communities, dams and seep wells in 5, hafir-dams in 3, and springs in 2. There are also striking differences among the different communities in the number of management-physical water point categories available: Ramokgonami respondents used 29 water points in ten categories while Matebele respondents used only 5 water points in three categories. Respondents in the "typical" community used 21 water points in seven management-physical type categories to meet their cattle watering needs.

In each community respondents used some water points more heavily

Table 7

Number of Water Points Respondents Used for Cattle, By Type: April 1979-March 1980

Community	Mean Size Of Farmers' Managed Herds (LSU)	Private					Natural		
		Open Wells	Bore-Holes	Seep Wells	Sand River Wells	Hafirs	Rivers	Pans	Springs
Makaleng	12.0	1	-	4	3	-	2	-	-
Phokoje	24.0	8	4*	1	2	-	1	6	1
Motongolong	41.4	10	1	-	-	-	2	4	1
Ramokgonami	22.7	1	2	13	1	1	1	6	-
Mosolotshane	25.2	3	1	-	2	4	2	6	-
Mmaphashalala	46.6	4	7#	-	-	-	-	10	-
Dikgonnye	24.0	6	1	-	-	3	1	-	-
Matebele	9.7	-	1	-	-	-	3	-	-
Lentsweletau	16.6	5	1	-	-	3	3	6	-
Gamodubu	12.1	7	3[c]	8	2	3	2	-	-
Ntlhantlhe	20.6	-	-	1	18	4	10	-	-
Mokatako	22.1	-	-	-	-	-	1	2	-
Total Water Points in Each Category		45	21	27	28	18	28	40	2

*Includes 3 equipped open wells.

#Includes 4 equipped open wells.

cIncludes 1 equipped open well.

Table 7 (cont.)

Number of Water Points Respondents Used for Cattle,
By Type: April 1979-March 1980

Community	Mean Size Of Farmers' Managed Herds (LSU	Communal					Govern-ment	Group/ Syndicate	
		Dams	Hafirs/ Road Pits	Bore-Holes	Open Wells	Hafir-Dams	Bore-Holes	Bore-Holes	Hafir-Dams
Makaleng	12.0	-	1	1	-	1	2	-	-
Phokoje	24.0	1	8	-	-	-	-	-	-
Motongolong	41.4	-	-	-	-	-	1	-	-
Ramokgonami	22.7	1	-	-	-	1	-	-	2
Mosolotshane	25.2	-	1	-	-	-	1	-	-
Mmaphashalala	46.6	-	-	-	1	-	1	-	-
Dikgonnye	24.0	2	-	-	-	-	-	5	-
Matebele	9.7	1	-	-	-	-	-	-	-
Lentsweletau	16.6	-	1	-	-	-	2	-	-
Gamodubu	12.1	-	1	-	-	-	1	-	1
Ntlhantlhe	20.6	-	-	-	-	-	-	-	-
Mokatako	22.1	1	-	-	-	-	-	2	-
Total Water Points in Each Category		6	12	1	1	2	8	7	3

than others. Table 8 shows the distribution of each community's[13] cattle over the water points used by Survey respondents for the same 12-month period shown in Table 7. It indicates the relative importance of each category of water point for the particular community. Cattle usage in Makaleng is the most evenly distributed over the available water point categories, while Mokatako, with its heavy dependence on the Molopo River, is the most concentrated, with Ntlhantlhe not far behind. The wide range in water point availability and usage among the 12 surveyed communities is evident from these two tables.

The tables present the set of cattle watering opportunities, and how farmers chose to make use of those opportunities. Choice results from the interaction between farmers' judgments on the relative reliability, cost, and convenience of water supplied from the different categories of water point and the availability of water from those water points. Farmers' perceptions and water availability are really two sides of the same coin: the set of water points in a particular community posess certain attributes, and farmers assess these attributes in terms of their own needs and resources and choose their water points accordingly. In the short run they select the water points which they can use to best meet their needs; in the longer run they may try to change the attributes of local water points or add new ones in order to better meet their needs.

Tables 9A, 9B, and 9C give some insight into the factors which influence the farmer's short-run choice. Table 9A contains the frequency

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[13]Appendix B describes in detail the derivation of community usage rates and their distribution over time.

Table 8

Percent of Total Annual LSU—Water Point Months Spent at Different Categories of Water Point

Community	Private					Natural		
	Open Wells	Bore-Holes	Seep Wells	Sand River Wells	Hafirs	Rivers	Pans	Springs
Makaleng	1.2	--	22.6	14.8	--	22.7	--	--
Phokoje	31.4	19.2	0.6	5.8	--	4.6	10.0	2.0
Motongolong	34.9	31.3	--	--	--	3.0	3.3	26.4
Ramokgonami	16.2	3.5	47.2	1.8	0.4	2.9	14.5	--
Mosolotshane	45.4	4.7	--	7.0	4.6	2.8	8.2	--
Mmaphashalala	16.6	55.0	--	--	--	--	7.8	--
Dikgonnye	14.4	8.6	--	--	1.2	2.8	--	--
Matebele	--	1.7	--	--	--	58.8	--	--
Lentsweletau	11.9	2.7	--	--	5.7	13.6	28.7	--
Gamodubu	24.4	10.4	39.2	2.5	4.7	9.8	--	--
Ntlhantlhe	--	--	0.4	21.7	1.9	76.0	--	--
Mokatako	--	--	--	--	--	87.0	2.6	--

Table 8 (cont.)

Percent of Total Annual LSU—Water Point Months Spent at Different Categories of Water Point

Community	Communal					Government	Group/ Syndicate		Total Percent
	Dams	Hafirs/ Road Pits	Bore-holes	Open Wells	Hafir-dams	Bore-holes	Bore-holes	Hafir Dams	
Makaleng	--	1.6	12.8	--	1.9	22.4	--	--	100.0
Phokoje	3.9	22.5	--	--	--	--	--	--	100.0
Motongolong	--	--	--	--	--	1.1	--	--	100.0
Ramokgonami	3.5	--	--	--	0.6	--	--	9.4	100.0
Mosolotshane	--	2.1	--	--	--	25.2	--	--	100.0
Mmphashalala	--	--	--	2.2	--	18.4	--	--	100.0
Dikgonnye	28.0	--	--	--	--	--	45.0	--	100.0
Matebele	39.5	--	--	--	--	--	--	--	100.0
Lentsweletau	--	0.3	--	--	--	37.1	--	--	100.0
Gamodubu	--	1.3	--	--	--	7.5	--	0.2	100.0
Ntlhantlhe	--	--	--	--	--	--	--	--	100.0
Mokatako	8.4	--	--	--	--	--	2.0	--	100.0

of different types of reasons farmers gave for leaving their current water point for another one, month by month. Table 9B shows the frequency of different types of responses farmers gave to explain why they chose a particular new water point in the following month. The total number of responses given for leaving a water point in one month does not exactly equal the total number of responses for using a new water point in the next month because respondents sometimes left two or three water points for one water point, or vice versa. Table 9C shows the actual responses farmers gave, arranged under the categories used in Tables 9A and B.

In Table 9A, reasons for leaving a water point have been categorized as "push" factors, i.e. those reasons which cause a farmer to leave his water point, and "pull" factors, where the attraction of another water point is the dominant consideration. Any cattle movement unrelated to dissatisfaction with the water point, e.g., necessary movement to the lands for plowing, is shown separately. The last column in the table gives total responses under each category, seasonally adjusted for the 12-month period April 1979 to March 1980. Over the year, "push" factors accounted for 43.5% of the reasons for leaving a water point while "pull" factors were more important in 38.5% of the shifts to another water point. Cattle movement was the major consideration in 18.0% of the changes of water point. Nearly one-third of all changes to another water point were caused by the current water point going dry.

There are two peak periods of change from water points to other water points: at the end of the rainy season in March, spreading over into April and May as surface catchment water points go progressively dry, and in September-October, when spring rains begin to fill ephemeral

Table 9A

Reasons Given for Leaving a Water Point: January 1979-March 1980

Category of Response		Jan 1979	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan 1980	Feb	Mar	12 mos. Apr 79-Mar 80
Push Factors:																	
Water point	No.	5	11	43	17	26	7	1	2	5	1	1	8	11	6	8	93
went dry	%	100.0	84.6	87.8	81.0	89.7	58.3	50.0	15.4	12.8	2.6	3.4	14.8	39.3	33.3	72.7	31.6
Push Factors:																	
Other	No.		1			1			6	9	8	2	5	2	2		35
	%		7.7			3.4			46.2	23.1	21.1	6.9	9.3	7.1	11.1		11.9
Pull Factors:																	
Lower cost	No.			2	1					2	7	11	9		1	2	33
	%			4.1	4.8					5.1	18.4	37.9	16.7		5.6	18.2	11.2
Pull Factors:																	
Greater	No.				3	1	2	1	1	16	15	10	17	4	1		71
Convenience	%				14.3	3.4	16.7	50.0	7.7	41.0	39.5	34.5	31.5	14.3	5.6		24.1
Pull Factors:																	
Other	No.		1			1	3		2	2	1						9
	%		7.7			3.4	25.0		15.4	5.1	2.6						3.2
Cattle	No.			4					2	5	6	5	15	11	8	1	53
Movement	%			8.2					15.4	12.8	15.8	17.2	27.8	39.3	44.4	9.1	18.0
Total	No.	5	13	49	21	29	12	2	13	39	38	29	54	28	18	11	294
	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 9B

Reasons Given for Starting to Use a New Water Point: January 1979-March 1980

Category of Response		Jan 1979	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan 1980	Feb	Mar	12 mos. Apr 79-Mar 80
Reliability																	
	No.	126	1	5	14	15	25	9	5	8	17	21	13	25	9	4	165
	%	43.8	16.7	55.6	93.3	88.2	92.6	81.8	71.4	61.5	27.9	28.4	30.2	49.0	42.9	66.7	47.7
Lower Cost																	
	No.	52	3	3		1	1		2	3	7	19	20	13	6		172
	%	18.1	50.0	33.3		5.9	3.7		28.6	23.1	11.5	25.7	46.5	25.5	28.6		20.8
Greater Convenience	No.	73	2				1			2	36	27	9	12	6	1	94
	%	25.3	33.3				3.7			15.4	59.0	36.5	20.9	23.5	28.6	16.7	27.2
Water Point Owner or connected to owner or management	No.	37		1	1	1		2			1	7	1	1		1	15
	%	12.8		11.1	6.7	5.9		18.2			1.6	9.5	2.3	2.0		16.7	4.3
Total																	
	No.	288	6	9	15	17	27	11	7	13	61	74	43	51	21	6	346
	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 9C

Actual Farmer Responses Categorized in Tables 9A and 9C*

Table 9A		
Category		Response
"Push" Factors	Went dry:	Water point became dry.
	Other:	River flooded sand river well. Water point was damaged or broke down. Wanted to avoid disputes about crop damage. Owner told me to stop using his water point. Too much work to desilt the water point. Too much work to get water from the well.
"Pull" Factors	Lower cost:	Payment for water was too high. Rain has filled another water point and this is cheaper to use. Too many other cattle were coming there for water.
	Greater Convenience:	Water point was too far from my village/lands/cattle post. Water point was too far from grazing. Rain has filled another water point which is closer to where I want to keep my cattle.
	Other:	My borehole/other water point was repaired. My water point has filled with enough water. Another water point has cleaner water.
Cattle Movement		Went to lands for plowing. Left lands after plowing. Returned to village/cattle post. Cattle are now watering themselves. Wanted cattle closer to my job.

*Responses listed in order of decreasing frequency.

Table 9C (cont.)

Actual Farmer Responses Categorized in Tables 9A and B*

Table 9B

Category	Response
Reliability	Water point has enough water. Nearest reliable water point. Only water point in area which has enough water. Water point is in working order. Water point is used only during the dry season. Previous water point went dry.
Lower cost	Payment for water was not too high/was free. Water point does not require labor to maintain it, only cash payments. Easy to water your cattle with your own labor. Not many other cattle come there for water. Cattle can water themselves.
Greater Convenience	Water point is close to village/lands/cattle post/ good grazing. Water point is close to village and has clean water.
Water Point Owner or connected to owner or management	Own the water point. Am a member of the borehole syndicate. Water point owner is friend/relative. Hold mafisa cattle from the water point owner.

* Responses listed in order of decreasing frequency.

sources. The relative importance of different types of reasons for leaving water points varies with the season. "Push" factors, particularly the water point going dry, dominate from January to September, after which convenience becomes the most important consideration, continuing thus more or less through December. The "push" factors reassert themselves from January onward. The cost of water is the most important reason only in November, and then only marginally more than convenience. As the number of water points offering free water increases in the October-

December period, farmers can shift their emphasis from merely finding any water for cattle to using water points closer to their kraal, which may also be less expensive. They can also lessen their use of wells, which require a lot of labor to water herds of any size. During this period, too, farmers begin moving their herds to the lands in anticipation of plowing. This also requires a change of water points.

Cattle holders leaving one water point must choose a new one. Table 9B categorizes the reasons farmers gave for choosing a new water point under the four headings of reliability, lower cost, greater convenience, and ownership relation. Reliability has two connotations: a water point that meets the needs of the moment and that offers water security over the near future. It accounts for 47.7% of the seasonally adjusted total responses. Greater convenience is next, with 27.2% of the responses, followed by cost at 20.8%. As in Table 9A, the relative importance of reasons changes with the season, water supply reliability being paramount through the dry fall and winter months. Convenience is most important in October and November, and cost considerations were mentioned more frequently in December. Reliability comes to the fore again in January and succeeding months.

The evidence in Tables 9A through 9C supports the proposition that cattle holders shift from water points to other water points on the basis of their assessment of relative reliability, cost, and convenience. Reliability of water supply is the most important consideration. If the responses classed as "push" factors in Table 9A are added to those classed under reliability in Table 9B, they account for 45.6% of all seasonally adjusted responses. During the spring and early summer months of October-

December, the basic water need can easily be met from a large number and variety of water points. At this time convenience and cost emerge as considerations. Seasonally adjusted total responses under these two headings from both tables are 25.7% and 16.0% respectively.

The next three sections examine reliability, cost, and convenience in more detail.

Reliability

Reliability of water supply is the bottom line; it dominates considerations of cost and convenience; cattle must have water. In terms of physical type it appears that water points fall into three reliability groups: I. Pans, dams, hafirs, and hafir-dams are the least reliable. Of 106 surface catchment water points monitored by the Survey, only 22% had water at the date of monitoring. II. Rivers and sand river wells complement each other, and together they are reasonably reliable. III. Boreholes, seep wells, and open wells are quite reliable. Springs are infrequently found, but the two used by respondents were quite reliable.

One measure of reliability is the size of the average herd using water points in each of these groups. Holders of larger herds use the more reliable water points because (a) it is difficult to move large numbers of cattle, continually redistributing them over a succession of unreliable sources, and (b) large holders have influence and money to ensure access to more reliable water points. The average herd size observed at water points in each of the reliability groups in fact increased with reliability of water supply: Group I--15.9 LSU, Group II--20.0 LSU, Group III--23.9 LSU, and springs--26.7 LSU.

Cost

The cost of water to be discussed here is the cost as seen by cattle holders. The cost concept used is a broad one. It includes the farmer's time and effort to get water directly, water payments in cash, cattle, materials, and other services, and his use of his social position within family and community. The farmer commits these resources to obtain at least the minimum amount of water his cattle need. Table 10 arranges the 10 physical types of water point in ascending order of required resource commitment, based on their technical and social characteristics.

--Springs, pans, and rivers require little effort from the farmer to water his cattle. Usually the cattle go by themselves and drink as often and as much as they want. These three types are open to anyone who cares to use them.

--Hafir-dams are essentially dams on flatter terrain with lower water-holding capacity (see Appendix A). All the dams which respondents used were built by the government before Independence and are usually not fenced and therefore are open to all. They almost belong with springs, pans, and rivers in terms of required resource commitment. Hafir-dams are of more recent government construction (see Part III) and access is limited by a group of farmers who maintain a fence. Animals are taken into the reservoir area in groups to water.

--Sand river wells, hafirs, and seep wells, in addition to cattle herding and fencing, require the farmer's labor to lift water to where his animals can reach it. Original construction (for sand river wells, an annual task) and periodic cleaning and deepening also require resources.

These water points are nearly always privately owned, and access is limited to the owner, his family, and possibly some friends. A few respondents reported paying for water from these sources.

--Open wells differ from the previous group by requiring much more labor to lift water up within reach of cattle. Their initial construction is also much more protracted and costly. Though cleaning and deepening is less frequently needed, it is quite laborious and risky when it does get done. Construction also requires formal sanction by various governmental agencies, whereas the water points in the previous group require only informal local agreement. Nearly all open wells are privately owned, and access is limited to the owner, his family and friends, and others who either pay in cash or in kind (labor, cattle).

--Boreholes and open wells equipped with pump and engine demand the most resources. In addition to herding and fencing they require a pumper and the cash to pay for diesel, oil, repairs, and replacement parts. Initial drilling and equipping are relatively very expensive, as are occasional repairs and rehabilitation of the structure. The technology depends on equipment and energy source, which must come from outside the community. Construction requires negotiations with a specialized technician--the driller--as well as approval by government agencies. Boreholes and equipped wells are owned by government, by syndicates of farmers, and by private persons. Access is limited to those who can pay, either in cash or in kind (diesel).

As costs increase from water point type to water point type, the concept of the "group" becomes more important as a means of controlling access and covering cost. As defined here, a group may consist of a

Table 10

Resources Required for Water Points of Different Physical Types

Water Point Physical Types	I. Springs Pans Rivers	II. Dams Hafir-dams	III. Sand River Wells Hafirs Seep Wells	IV. Open Wells	V. Boreholes Equipped Open Wells
	Increasing Level of Resource Commitment				
Resources committed: Labor, cash, cattle, materials, influence	Negligible	1. herding to water 2. thorn bush fencing	1. herding to water 2. thorn bush fencing 3. labor to lift water a short distance to trough 4. construcution 5. cleaning and deepening	1. herding to water 2. sometimes thorn bush fencing 3. labor to lift water a long distance to trough 4. construction 5. cleaning and deepening	1. herding to water 2. thorn bush or wire fencing 3. pumper labor or wages 4. diesel, oil, and parts 5. drilling and equipping 6. structural repairs and rehabilitation

cattle holder, his family, and friends, and be centered on a private water point, or it may contain the members of several families and their friends and relatives and be connected to a communal, group, or syndicated water point. A cattle holder may not own a water point, but be within such a group. The costs associated with a water point are spread out over the group, and may involve a complex and continuing set of exchanges reaching well beyond just the supply of water. Cost-sharing behavior was reported for water point physical types from hafir-dams to boreholes and equipped open wells.

Cattle holders outside such a group buy water, as do all farmers when using government boreholes. Water sales are conducted under a formal fee structure.[14] Fees are expressed either in terms of in-kind payments per herd per year or multiple years, or in terms of cash payments per herd or per animal per day, month, or year. Water purchasing occurs at the same set of water point physical types as cost-sharing, though it is most important with open wells, boreholes, and equipped open wells.

This distinction between cost-sharing and water purchasing is not a polar one. A cattle holder's share of the costs may be connected to the size of his herd using the water point;[15] a holder may pay less than the amount dictated by the formal fee structure if he has some kind of personal relationship with the water point owner.

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[14] Water fees are discussed further in Appendix C.

[15] This works both ways. In at least two instances, a syndicate member with a very large herd paid less than his share of costs because other members hesitated to challenge him.

It should now be clear why gathering accurate and complete data on the cost of water to cattle holders is difficult. Three-quarters of the respondents did not own a water point. They used open access water points, shared the costs of water points with others, or purchased water. Table 11 shows the cost of water to these "nonowners."[16] The closer the cost-sharing relationship, the more difficult it was to pin down exact costs of cattle watering by non-water point owners. Thus Table 11 picks up all costs from water sales and some cost-sharing expenditures.

Columns three through six in the table show the number of water transactions involving cash, cattle, labor, and materials (primarily diesel). Cash and cattle are a rough index of the number of transactions which involved water selling; labor and materials indicate the amount of cost-sharing. There was almost no water purchasing in Phokoje, Motongolong, or Ntlhantlhe;in these communities nearly all respondents were either related to or friends of water point owners, or owned their own water points. Nonowners in Matebele and Mokatako used mostly natural sources, and in the case of the former, purchased water at the one private borehole only when there was no other choice. Buying water was most common in Makaleng, Mosolotshane, and Lentsweletau. Most respondents in Ramokgonami and Mmaphashalala shared the costs of water, while those in Dikgonnye and Gamodubu both bought water and participated in cost-sharing arrangements.

The remainder of Table 11 presents mean expenditures on water per livestock unit per month. Each respondent's total reported expenditure

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[16]Costs to water point owners are dealt with in Part III.

Table 11

Cost of Water for Nonowners of Water Points

Community	Number of Nonowners/Total number of respondents	Number of Transactions Involving:				Mean Expenditure per Livestock Unit-Month* (pula)					
		Cash	Cattle	Labor	Materials	Private Open Wells	Private Seep Wells	Private Bore-holes	Govt. Bore-holes	Syndicate Bore-holes	Group Hafir-Dams
Makaleng	19/19	13	0	0	0	0	M (2)	--	0.79 (4)	0.64** (6)	0#
Phokoje	25/27	3	0	0	1	0.08 (2)	0	0.01 (1)	--	--	--
Motongolong	12/21	0	0	1	0	0.01 (1)	--	0	M (1)	--	--
Ramokogonami	15/21	5	0	14	6	0.01 (1)	0.04 (8)	0.22 (2)	--	--	0.06 (3)
Mosolotshane	16/19	6	3	0	0	0.11 (5)	--	0	0.23 (4)	--	--
Mmaphashalala	9/16	4	0	0	7	0	--	0.27 (10)	0@	--	--
Dikgonnye	22/26	18	3	4	1	0.20 (6)	--	0.77 (6)	--	0.22 (10)	--
Matebele	8/8	2	0	0	0	--	--	1.07 (2)	--	--	--
Lentsweletau	16/18	17	1	1	0	0.38 (3)	--	0.51 (1)	0.28 (13)	--	--

* "M" indicates information is missing. The number in parentheses is the number of payments on which the mean is based.

** Actually a communal borehole. # Actually a communal hafir-dam.

@ Quarantine camp borehole at Dibete.

Table 11 (cont.)

Cost of Water for Nonowners of Water Points

Community	Number of Nonowners/Total number of respondents	Number of Transactions Involving:				Mean Expenditure per Livestock Unit-Month (pula)					
		Cash	Cattle	Labor	Materials	Private Open Wells	Private Seep Wells	Private Bore-holes	Govt. Bore-holes	Syndicate Bore-holes	Group Hafir-Dams
Gamodubu	18/23	12	0	15	0	0.15 (5)	0.14 (6)	0.37 (6)	0.56 (1)	--	0.08 (1)
Ntlhantlhe	1/18	0	0	0	0	--	0	--	--	--	--
Mokatako	23/23	2	0	0	1	--	--	--	--	0.09 (3)	--
All Communities	184/239	82	7	35	16	0.13 (23)	0.09 (14)	0.32 (28)	0.47 (23)	0.32 (19)	0.07 (4)

was divided by the size of his herd in November 1979 times the number of months he used the water point. Noncash payments were assigned a cash-equivalent value as follows: Cattle were valued at the average sale price prevailing in each community in the first quarter of 1980 for the particular kind of animal. Labor was assigned an opportunity cost equal to the government-mandated minimum wage of P 2.10 per day.[17] Diesel was valued at P 0.50 per liter; other materials were valued at their going market price. Thus expenditures on water range from P 0.01 to P 1.07 per LSU-month, with an overall mean of P 0.23. Water points in order of increasing expenditure are: group hafir-dams, private seep wells, private open wells, private and syndicate boreholes, and government boreholes. The expenditures computed for Makaleng are unexpectedly high, probably because of underreporting of herd size. With these values removed, expenditures at private and government boreholes are about the same, and syndicate boreholes are somewhat below this.

Several conclusions can be drawn from these data. First, monthly expenditure on cattle watering in the 12 communities is generally well under one pula per LSU. Second, respondents in fact paid more for water from the more resource-demanding types of water point. Third, there are considerable differences in water expenditure from community to community in part because of the quite different mix of water point types available in each place.

Convenience

Convenience is the third factor cattle holders consider when choosing

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[17] One pula (P) = U.S.$1.28.

a water point, i.e. how far they will have to take their cattle to get water. Respondents were asked for the distance in terms of time to herd cattle from their kraal to each water point they used. Their subjective answers were categorized as:

Code	Distance
1	Less than 10 minutes
2	10-30 minutes
3	Up to 45 minutes
4	About an hour
5	More than an hour
6	More than two hours

Code 4 responses were measured on the 1:50,000 water point census maps prepared by the Water Points Survey for each of the 12 communities. On average, an hour of time represents 4 kilometers of distance over flat terrain.

Table 12 displays values of an index of kraal-water point distance broken down by community and by water point physical type. The index is the mean of the code values which correspond to the responses given for a particular type of water point. Cattle holders in Ntlhantlhe are closest to water, reaching it within 10 minutes. Cattle holders in Dikgonnye are the furthest; it takes them nearly an hour to get to their water point. Not surprisingly, kraals are closest to hafirs, pans, rivers, and sand river wells. These water points either influenced the original siting of the kraal, or were easily constructed thereafter. They also demand the fewest resources from the farmer to use. Kraals are somewhat further from open and seep wells, hafir-dams, and springs, either because these water

Table 12

Index of Kraal-Water Point Distances by Physical Type of Water Point

Community	Each Community: Number used	Each Community: Mean	Dams	Hafir-Dams	Hafirs	Rivers	Pans	Bore-holes	Open Wells	Sand River Wells	Seep Wells	Springs
Makaleng	15	3.6	--	2.7	6.0	3.3	--	3.2	2.0	4.6	5.0	--
Phokoje	32	2.9	2.0	--	2.4	6.0	2.0	1.7	3.9	6.0	3.0	4.0
Motongolong	19	2.2	--	--	--	3.5	2.1	2.0	1.7	--	--	3.0
Ramokgonami	29	3.0	3.5	3.4	2.0	3.0	2.3	3.7	3.0	1.0	3.6	--
Moslotshane	20	3.2	--	--	2.6	2.5	3.3	2.8	4.2	2.2	--	--
Mmaphashalala	23	2.7	--	--	--	--	3.3	2.7	1.9	--	--	--
Dikgonnye	18	3.8	4.0	--	1.3	4.8	--	4.0	3.6	--	--	--
Matebele	5	3.1	3.8	--	--	2.4	--	4.0	--	--	--	--
Lentsweletau	21	2.7	--	--	1.8	2.8	1.9	3.2	3.8	--	--	--
Gamodubu	28	2.4	--	3.0	2.3	2.2	--	2.3	2.8	2.0	2.3	--
Ntlhantlhe	33	1.8	--	--	2.0	1.8	--	--	--	1.8	1.0	--
Mokatako	6	2.5	4.4	--	--	2.0	2.8	2.8	--	--	--	--
Each Category Mean		2.8	3.9	3.1	2.3	2.4	2.5	3.2	3.1	2.5	3.1	3.1
Number Used	249		6	5	30	28	40	37	46	28	27	2

points tend to occur in clusters or because there is only a small number of them in the community. The index values broken down for private, government, and syndicate boreholes are 2.9, 3.5, and 3.6 respectively.

The differences in convenience of water indicated in Table 12 are small, and water is, on the average, quite close to kraals. Most cattle holders can reach water within 30 to 45 minutes. However, this is still a far cry from reaching the APRU ideal of a continuous and freely available supply of water for cattle.

PART II. PATTERNS OF WATER POINT USE: JANUARY 1979-MARCH 1980

Part I described the watering strategies of farmers as shown by movement of herds and use of water points. It particularly focused on farmer choice of water points seen against the background of the water supply situation in each community. Part II considers the change in the usage pattern of water point types over time, i.e. the varying importance of different sources of water from January 1979 to March 1980.

The three sections of Figure 3 show the total number of water points in operation, the number of livestock units using them, and the liters of water these stock demanded per day for the period. Figure 3A indicates that the number of water points in use diminishes during dry periods and increases when rains are ample because of the greater availability of surface water sources. Fall and winter show the greatest drop, though numbers were also fewer in the first quarter of 1979, a period of drought, than in the six months from October 1979 onward, a time of relatively abundant rainfall.

Figure 3B refers to the total population of cattle which used these

water points in the 12 communities. It is important to realize that the month to month changes in livestock units represent changes in the size of the aggregate herd using these water points because of entries and exits into and from each respondent's herd from births, deaths, sales, and so forth. The drop in the plotted line does not represent animals shifting to water points other than those included in Figure 3A. The steep rise in livestock units following December 1979 however does reflect calves born in the first quarter of 1979 which entered the heifer-tolly class one year later, and thus got counted in the LSU calculation.

Figure 3C shows the trend in daily water demand by livestock units in Figure 3B at water points included in Figure 3A. Daily water demand is here a function of number of livestock units present, mean temperature, and herd composition community by community for the given month. Broadly speaking, daily water demand is lowest during the winter months when temperatures are lowest and there are few milch cows in the herds. Comsumption rises with the onset of warmer weather and the beginning of the calving period. Adequate cattle watering is most difficult during the winter season when the available water points are the fewest and the water content of the available grasses is the lowest. On the other hand, at the aggregate level, herd numbers are also fewer and water needs per animal are least. However, to the individual cattle holder these things are probably not very evident; he still has to find water for his herd.

Figure 4 displays the seasonal variation in distance between respondents' kraals and the water points they were using. The index of distance is the same as that explained in Part I, i.e., an index value of 4.0 represents a distance of an hour, or roughly 4 kilometers. Predictably,

FIGURE 4

SEASONAL VARIATION IN DISTANCE TO WATER

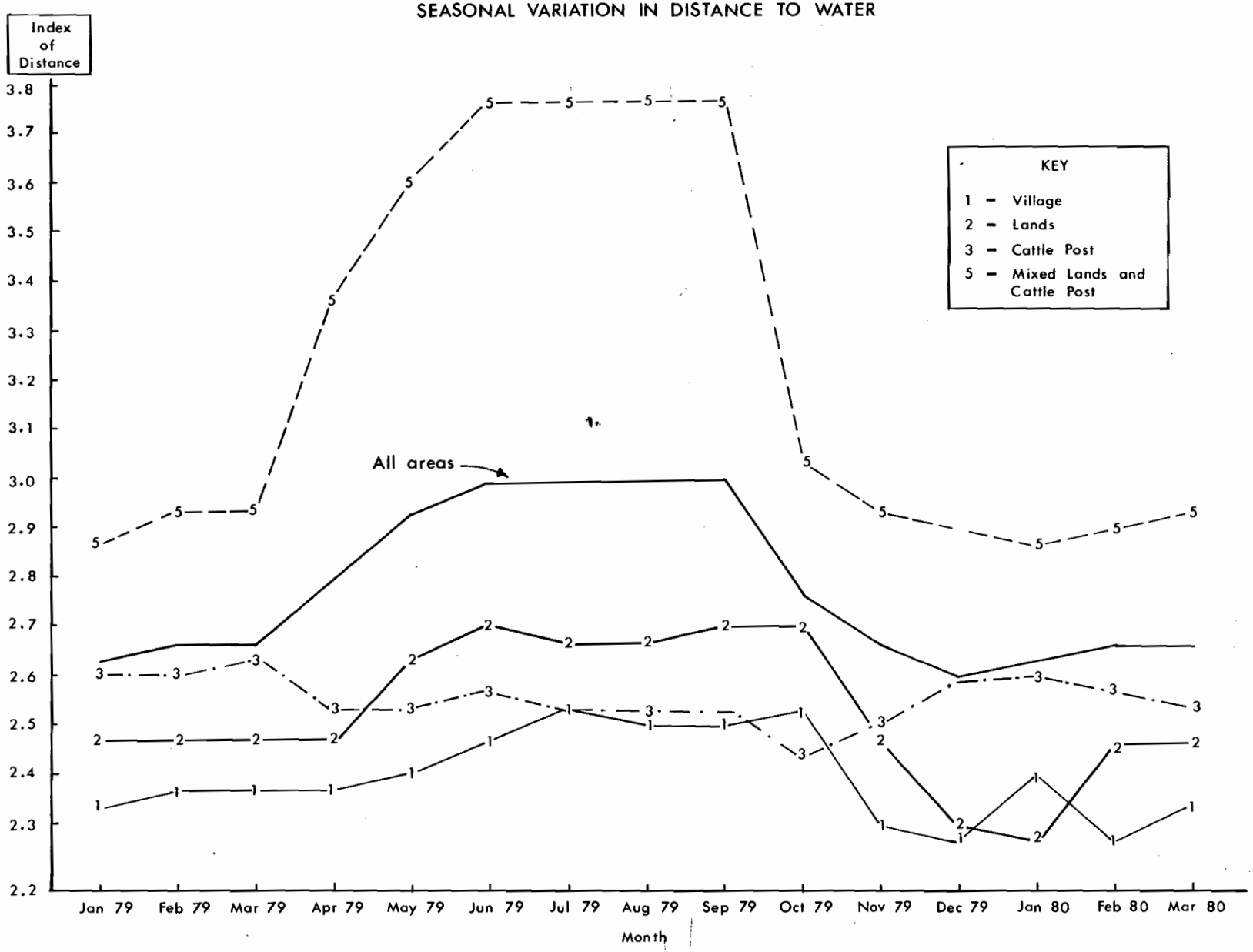
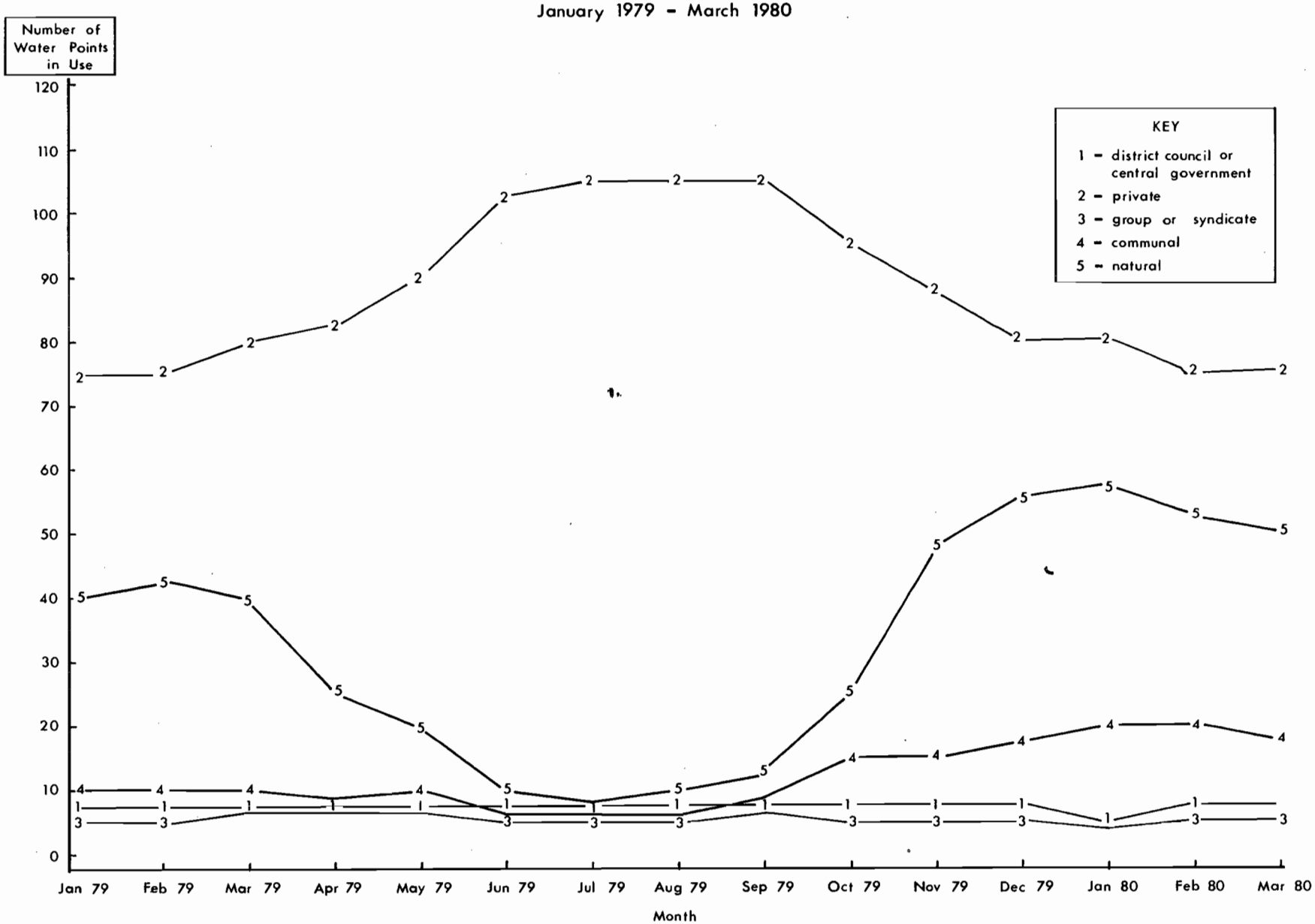


FIGURE 5

NUMBER OF WATER POINTS IN OPERATION, BY MANAGEMENT TYPE

January 1979 - March 1980



the distance to water increases with the beginning of the dry season in April and falls with the beginning of the rains in September-October. This pattern holds for cattle kept in villages and lands and most markedly for cattle kept in mixed lands and cattle post areas. The pattern is somewhat the reverse for stock at cattle posts, probably because cattle return from more distant pans to boreholes nearer the cattle post kraals during the dry season. The short distance to water for lands area cattle during November-January is surprising since adequate water at the lands is considered to be a chronic problem. Figure 4 reaffirms that the lands water problem is at the beginning and end of the plowing season and suggests that the real arable water shortage is in the mixed lands and cattle post areas.

The meaning of Figures 3 and 4 can be summed up simply: In the dry season in the eastern communal area the number of operating water points, the number of cattle, and the amount of water demanded fall; average distance to water increases. Subsequent figures break down the three graphs of Figure 3 by water point management and physical types and by management-physical type categories.

Number of Water Points Used

Figure 5 considers water point usage in terms of number of operating water points in each of the five management types. Here again seasonal patterns are evident, with a shift from natural sources to privately owned and managed water points beginning in March 1979 and a shift back again beginning in September. Government and group or syndicate water points do not show much seasonal shift. Use of communal water points, however, increased somewhat beginning in October. Overall, the importance

of natural water sources and water points in the private sector stands out, with water points of the other management types providing a more low-key but constant supply. Any government plans to regulate or develop water resources will have to take account of these facts.

Figure 6 shows the number of water points of each physical type in operation month by month. Since respondents used only two springs, these have been dropped to improve clarity in this and subsequent figures. Similarly, dams and hafir-dams have been combined since they exhibit a similar pattern. Figure 6 shows the switch from surface to ground water sources with the beginning of the rainy season. Differences between the rainy seasons of 1978-79 and 1979-80 are also apparent, pans, rivers, and hafirs being much more important in the latter than in the former. Open wells, boreholes, and seep wells, all of which are more costly to operate than surface water sources, declined in use in the relatively abundant rainy season of 1979-80.

Number of Cattle Using Water Points

Figure 7 is derived from Figure 3B. It displays livestock unit use, broken down by water point physical types. This is a picture somewhat similar to that in Figure 6, only here the relative importance of the various water point physical types in terms of animal usage becomes apparent. Figure 6 shows numbers of operating water points, whereas Figure 7 reflects the water supply capacity of different water points. Thus open wells are the most important dry season water point in terms of numbers, but boreholes are the most important in terms of cattle served. Seep wells, although fewer in number than open wells, are about equally important for cattle during the late winter. Use of pans, hafirs, and rivers

FIGURE 6
NUMBER OF WATER POINTS IN OPERATION, BY PHYSICAL TYPE
January 1979 – March 1980

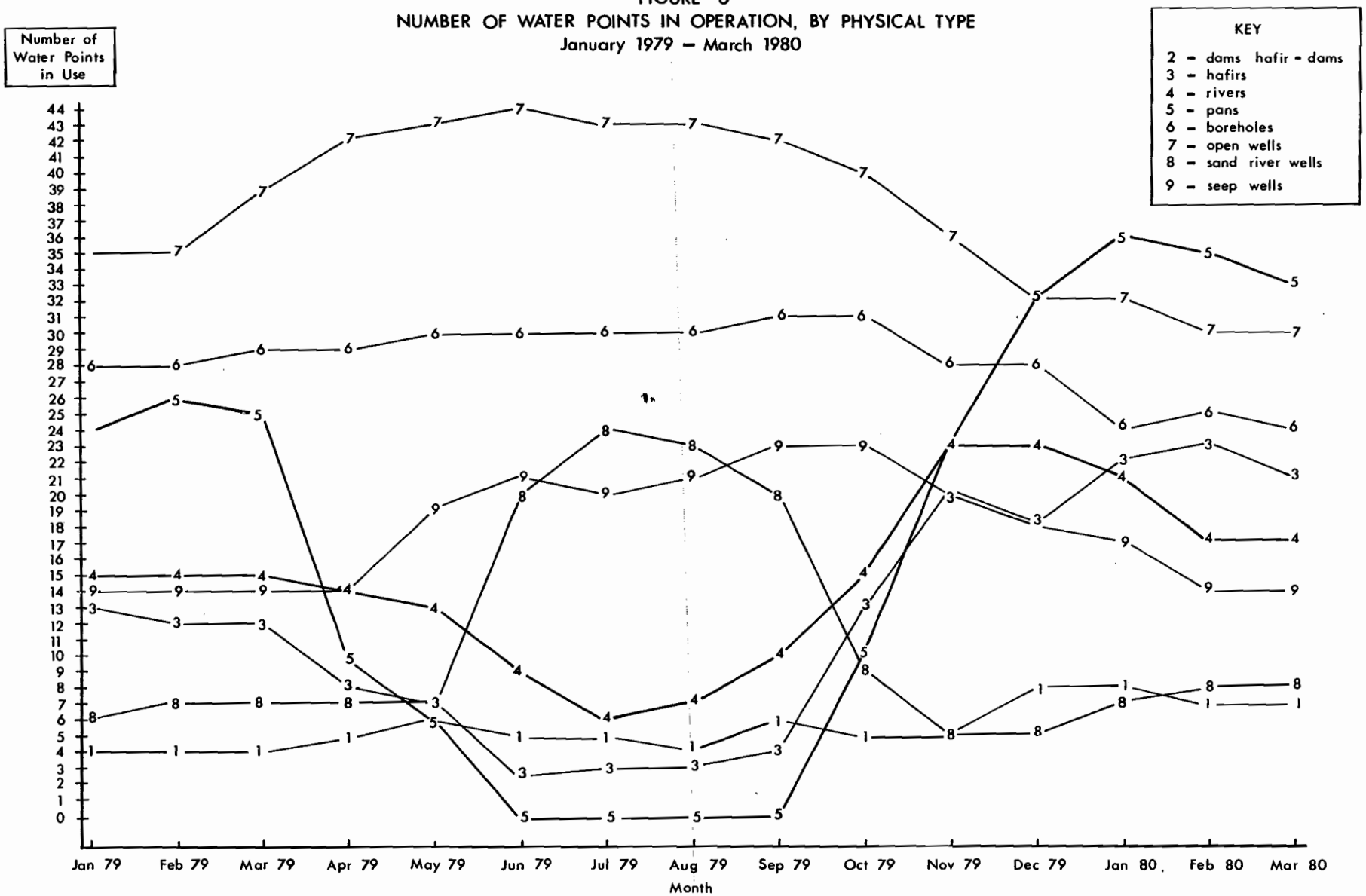


FIGURE 7
NUMBER OF CATTLE (LSU) PRESENT AT WATER POINTS, BY PHYSICAL TYPE
January 1979 – March 1980

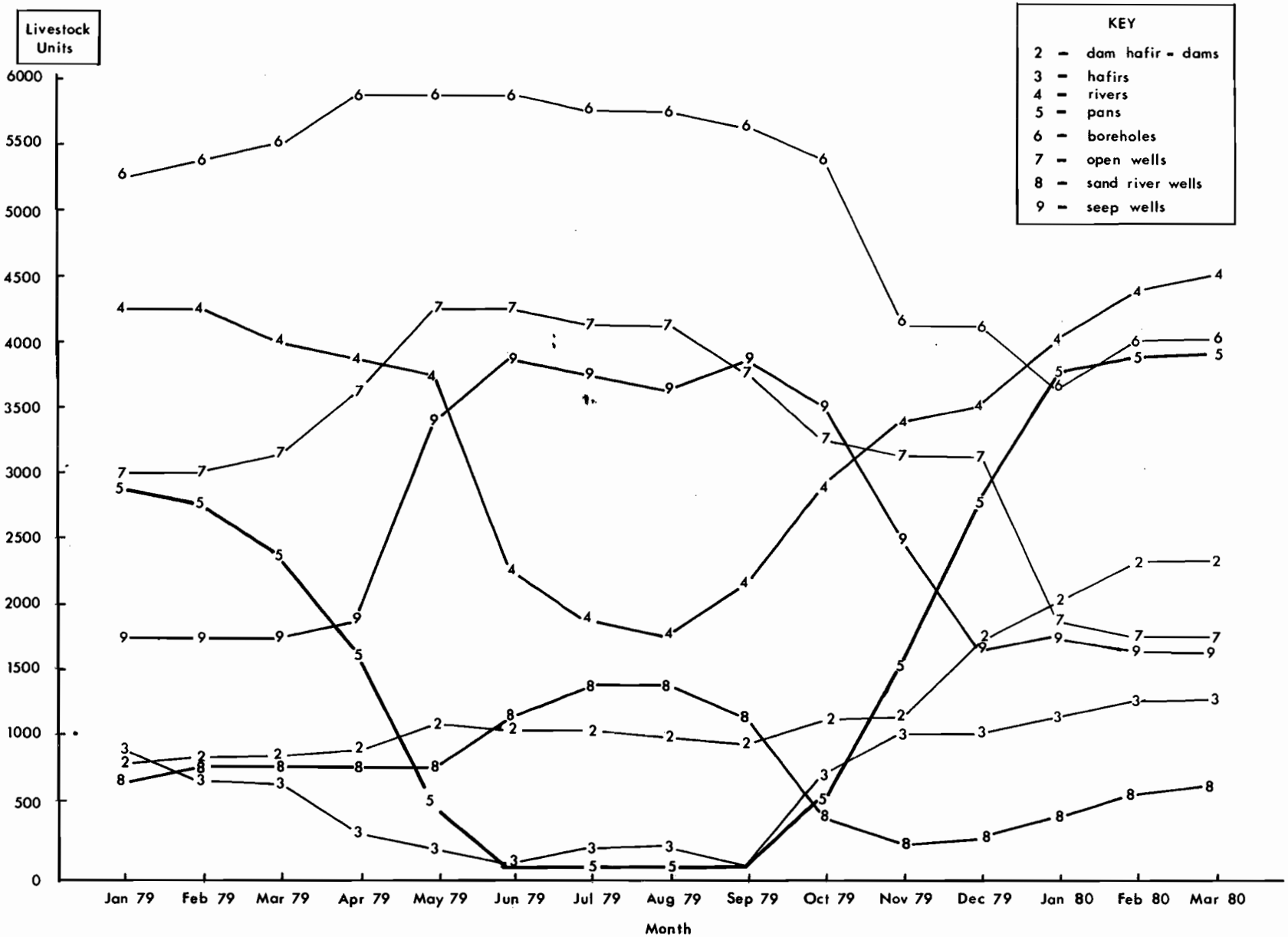


FIGURE 8

NUMBER OF CATTLE (LSU) PRESENT AT WATER POINTS, BY MANAGEMENT PHYSICAL TYPES CATEGORIES

January 1979 - March 198

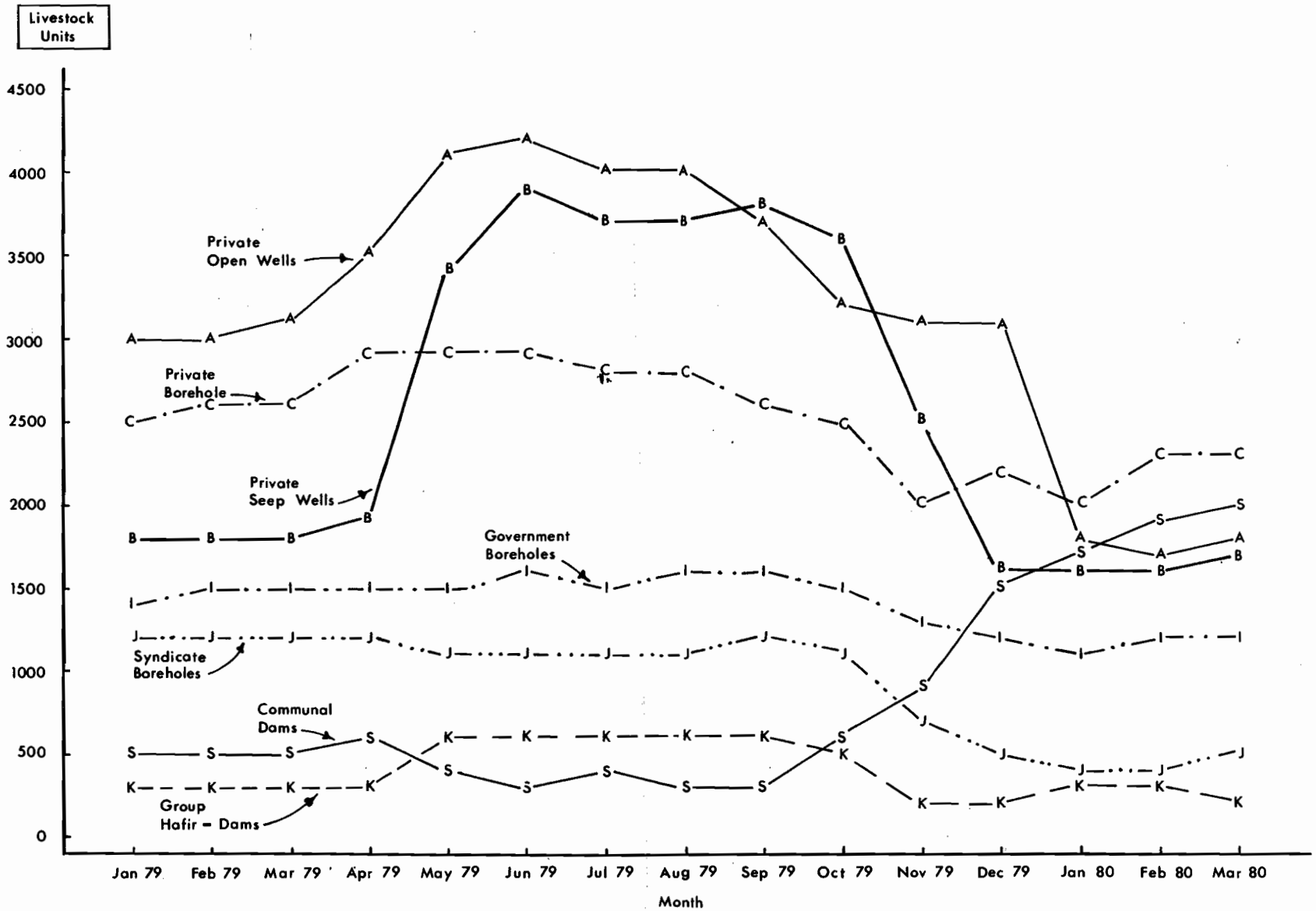
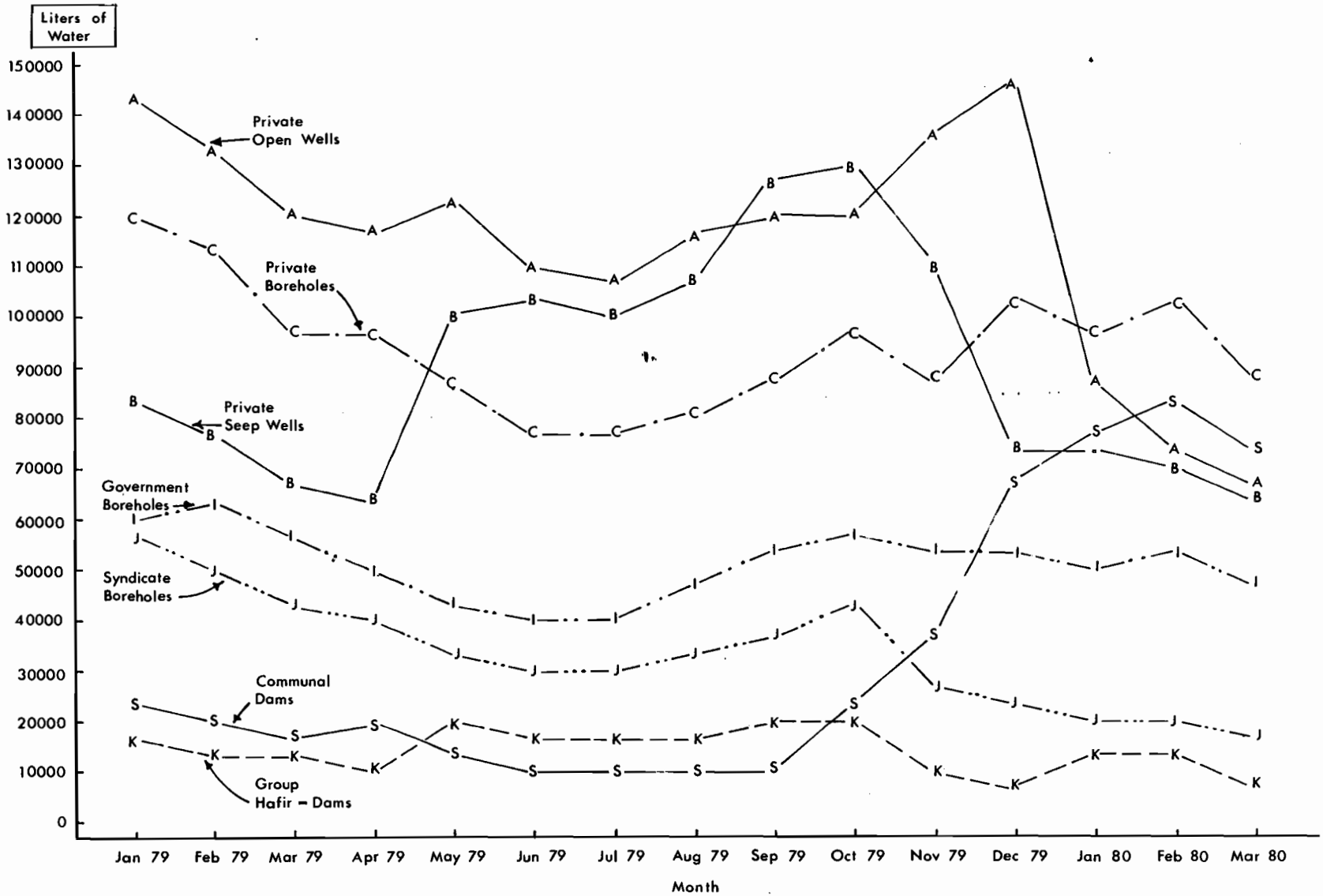


FIGURE 9

DAILY WATER DEMAND BY CATTLE (LSU), BY MANAGEMENT - PHYSICAL TYPE CATEGORIES

January 1979 - March 1980



drops off sharply beginning in May, the last matched by an increase in the use of sand river wells. Dams and hafir-dams continued to provide water to some herds throughout the winter, although this observation is based on only a small number of such structures.

Figure 8 decomposes Figure 7 one step further to show cattle by eight important management-physical type categories. Natural sources and other categories with only a small number of examples have been left out. Private open wells, seep wells, and boreholes are the most important for cattle and exhibit the most marked seasonal fluctuation. Borehole usage under all three types of management falls off with the beginning of the rainy season in October, with syndicate usage dropping the most. The few group hafir-dams in the Survey appear to have had water during the winter of 1979, and may have served as alternative water points for farmers in their areas when other surface sources went dry. Communal dams on the other hand did not yield much water during the winter, but became very popular as an open-access water source when they filled in the 1979-80 rains.

Quantity of Water Demanded by Cattle

Figure 9 is the last of this series. It presents the time use pattern of water points in the eight management-physical type categories of Figure 8, but this time in terms of daily water requirements of cattle. The purpose is to show the amount of water that livestock present at a water point in a particular category would have drunk if they could have had as much as they wished. Of course there is no guarantee that the water point actually supplied this amount. Communal dams probably come closest to meeting unfettered cattle demand, since they are usually

unfenced and unsupervised. Private open wells, however, probably fall shortest of meeting demand because of the considerable labor required to lift water and the shift-by-shift watering of cattle from a small trough. The degree to which actual supply from different categories of water points fell short of demand is a matter of judgment. The importance of the calculations behind Figure 9 though is that they provide an estimate of water point supply capacities. This information will be extremely useful in Part III for deriving the unit cost of water from different types of water points.

Water Point Use Over Time: A Summary View

Survey results presented thus far have concerned the type of area used for cattle-keeping, movement of herds, and patterns of water point use, with frequent references to the 12 communities which provided the data. Table 13 displays a summary of some of this information, arranged by water point types and categories. The listing is in descending order of importance in terms of total use by cattle of water points of each type or category over the year. On this criterion private open wells, rivers, private seep wells, and private boreholes were the most important water points used for cattle in the 12 communities. Pans, government boreholes, sand river wells, communal dams, and syndicate boreholes were of medium importance. Group hafir-dams, communal hafirs, springs, and private hafirs were of least importance.

The second column of Table 13 shows the average size of a herd using water points of different types and categories. Government owned and managed water points (boreholes) attracted cattle holders with the largest herds; communally managed water points served the smallest herds.

Table 13

Summary of Water Point Use Statistics: April 1979-March 1980

Water Point Types	Number of Water Points	Average size of herd at Water Point (LSU)	12-month Total Usage (LSU-months)	Rank in Total Usage (%)
Management Types:				
Privately owned & managed	139	25.1	117,406	1 (51.5)
Natural Sources	70	18.7	60,114	2 (26.4)
Communally managed	22	11.3	18,041	3 (7.9)
Govt. owned & managed	8	27.2	16,932	4 (7.4)
Group/Syn. owned/managed	10	23.8	15,534	5 (6.8)
Physical Types:				
Boreholes	37	32.8	59,538	1 (26.1)
Open wells	46	20.2	38,917	2 (17.1)
Rivers	28	16.4	38,150	3 (16.7)
Seep wells	27	18.8	32,928	4 (14.4)
Pans	40	21.2	18,334	5 (8.0)
Sand river wells	28	23.5	13,085	6 (5.7)
Dams	6	17.5	10,947	7 (4.8)
Hafirs	30	11.3	6,866	8 (3.0)
Hafir-dams	5	13.7	5,632	9 (2.5)
Springs	2	26.8	3,630	10 (1.6)

Table 13 (cont.)

Summary of Water Point Use Statistics: April 1979-March 1980

Water Point Types	Number of Months Herds Used Water Point		Daily Water Demand by Cattle (m^3)		Estimated Annual Supply from Water Point (m^3)
	Mean	S.Deviation	Mean	S.Deviation	
Management Types:					
Privately owned & managed	7.2	3.7	3.87	0.52	848
Natural Sources	5.7	3.4	6.27	0.90	1,091
Communally Managed	5.3	2.3	4.21	1.53	674
Govt. owned & managed	8.8	2.7	7.15	0.86	1,909
Group/Syn. owned/managed	7.3	4.4	7.26	1.77	1,605
Physical Types:					
Boreholes	7.7	3.9	6.17	0.38	1,444
Open wells	8.9	2.8	2.97	0.63	805
Rivers	6.3	3.6	7.88	1.44	1,505
Seep wells	7.8	3.5*	4.95*	0.50	1,173*
Pans	4.1	1.8	3.80	1.40	471
Sand River Wells	4.9	3.0	4.18	3.89	623
Dams	4.7	1.6	9.86	7.25	1,410
Hafirs	4.7	2.2	1.50	0.81	215
Hafir-dams	5.9	4.0	7.02	2.66	1,257
Springs	9.2	3.9	8.73	3.86	2,447

*Provisional value.

Table 13 (cont.)

Summary of Water Point Use Statistics: April 1979-March 1980

Water Point Categories	Number of Water Points	Average Size of Herd at Water Point (LSU)	12-Month Total Usage (LSU-months)	Rank in Total Usage (%)
Private open wells	45	20.5	38,226	1 (16.8)
Rivers	28	16.4	38,150	2 (16.7)
Private seep wells	27	18.8	32,928	3 (14.4)
Private boreholes	21	44.0	30,144	4 (13.2)
Pans	40	21.2	18,344	5 (8.0)
Government boreholes	8	27.2	16,932	6 (7.4)
Private sand river wells	28	23.5	13,085	7 (5.7)
Communal dams	6	17.5	10,947	8 (4.8)
Syndicate boreholes	7	25.2	10,494	9 (4.6)
Group hafir-dams	3	18.3	5,040	10 (2.2)
Communal hafirs	12	7.6	3,843	11 (1.7)
Springs	2	26.8	3,630	12 (1.6)
Private hafirs	18	19.9	3,023	13 (1.3)
Communal boreholes	1	7.7	1,968	14 (0.9)
Communal open wells	1	10.5	691	15 (0.3)
Communal hafir-dams	2	8.0	592	16 (0.3)

Table 13 (cont.)

Summary of Water Point Use Statistics: April 1979-March 1980

Water Point Categories	Number of Months Herds used Water Point		Daily Water Demand by Cattle (m^3)		Estimated Annual Supply from Water Point (m^3)
	Mean	S. Deviation	Mean	S. Deviation	
Private open wells	8.8	2.8	2.97	0.63	793
Rivers	6.3	3.6	7.88	1.44	1,513
Private seep wells	7.8	3.5	4.95*	0.50	1,173*
Private boreholes	7.0	4.3	5.66	0.94	1,189
Pans	4.1	1.8	3.80	1.40	471
Government boreholes	8.8	2.7	7.15	0.86	1,909
Private sand river wells	4.9	3.0	4.18	3.89	623
Communal dams	4.7	1.6	9.86	7.25	1,410
Syndicate boreholes	7.5	4.5	6.63	0.97	1,505
Group hafir-dams	6.6	4.8	11.98	5.60	2,396
Communal hafirs	5.2	1.9	1.53	1.27	240
Springs	9.2	3.9	8.74	3.86	2,447
Private hafirs	3.8	2.5	1.35	0.56	155
Communal boreholes	8.8	2.2	5.52	2.72	1,474
Communal open wells	12.0	0	1.91	0.61	23
Communal hafir-dams	5.0	3.4	1.45	0.75	218

*Provisional value.

Within the private sector the largest herds used boreholes, while smaller herds used open wells, hafirs, and seep wells. Group hafir-dams accommodated herds somewhat smaller than the overall average herd size of 20.5 livestock units.

Table 13 also gives the average number of months which herds spent at water points over the course of the year. Herds used pans about four months, while staying at open wells nearly nine months. Boreholes were used for over seven months; group hafir-dams served their members' cattle for six and a half months. These average use values reflect the net result of farmers' balancing considerations of water point reliability, cost, and convenience in choosing where to water their cattle. They thus represent the aggregate judgment of cattle holders in all 12 communities on the "usability" of each category of water point. That is, these values are the average usefulness of the particular category of water point arising out of the very different water supply choices made in each community. These values measure the time dimension of water supply; this contributes to but in itself is not sufficient for planning the development of local water resources. Spatial implications of water point development and supply capacities are equally important.

The last columns of Table 13 concern water demand by cattle and supply of water from water points. As discussed earlier, water demand is that quantity of water which cattle present at a water point would consume if they had free and continuous access to it. The supply estimates are the product of daily demand times the average number of days (months) cattle used the water point. These estimates approximate the supply capacity of the water point. In the case of open-access water points such

as dams they may be underestimates, i.e., there were not enough cattle present to drink all the water available. In the case of most water points, though, these estimates will be high to the degree that the water needs of cattle present were not satisfied. However, it is felt that the estimates are sufficiently accurate to allow calculation of relative unit costs of water for different water point types.

PART III. COSTS OF WATER POINT CONSTRUCTION, OPERATION, AND MAINTENANCE

Earlier sections of this paper have focused on cattle watering strategies and the operation of water points, particularly from the viewpoint of nonowners. Part III presents information on the cost of constructing water points and the cost to their owners or managers of operating them thereafter. Table 14 displays the agencies, groups, and persons who may play a role in the construction, operation, and maintenance and revenue collection at different physical types of water point. The following discussion deals with dams, boreholes, and open wells in turn.

Dams and Hafir-Dams: Construction

The Ministry of Agriculture's Small Dam Unit: There is a long history of small dam construction in Botswana: dams built by tribal authorities starting in the early years of the century, dams built by the railroad, dams constructed by the Protectorate Government, and dams erected under the Food for Work Program. After Independence, the Ministry of Agriculture took up responsibility for further dam building through its Soil Conservation and Dam Building Unit (SC&DBU). Between 1967 and 1970 the Unit constructed 10 dams in the Moshupa catchment and 12 dams in the

Table 14

Man-Made Water Points in Eastern Communal Area*

Water Point Physical Type	Construction	Operation and Maintenance	Revenue Collection (if any)
Dams and Hafir-Dams	1. MoA Small Dam Unit (SDU)	Farmers' groups	Farmers' groups
	2. Serowe Brigades Dam Building Unit (with SDU oversight)	Farmers' groups	Farmers' groups
	3. Private contractor (with SDU funds and oversight)	Farmers' groups	Farmers' groups
Boreholes	1. Water Affairs	Water Affairs District Council Borehole Repair Service	District Council District Council ----
	2. Large private contractors	Private person Syndicate Borehole Repair Service	Private person Syndicate ----
	3. Small private drillers	Private person Syndicate Borehole Repair Service	Private person Syndicate ----
Open Wells, Sand River Wells, Seep Wells, and Hafirs	1. Private person	Private person Communal	Private person None

* Excluding water points maintained by agencies of the central government other than the Department of Water Affairs.

Bokaa area, as well as a few in Tutume.

In 1974 the reorganized SC&DBU began operations again under a new name, the present Small Dam Unit (SDU) of the Division of Land Utilization. Since 1974 the SDU has constructed or commissioned the construction of 99 dams in the eastern communal area. Table 15 shows their distribution.

Table 15

Location of SDU-Built Dams

Dam Location	Number
Northeast District	8
Central District	
Serowe area	21
Tswapong area	20
Southern part of Kgatleng District	9
Eastern part of Kweneng District	20
Southeast District	10
Eastern part of Southern District	11
Total	99

Mr. H. Mettrick, Chief Agricultural Economist, carried out the last cost analysis of the Ministry's dam-building efforts which he presented in a paper, "Small Dam Construction Pricing Policy" (December 1970). His approach was to "work out on the basis of past experience the total cost for a notional 'average' dam. . . . The annual cost of operating the dam building unit is calculated and compared with the number of dams built in a typical year to arrive at the cost per dam." He

characterized costs as follows (figures in Rand[18]):

Annual depreciation on capital assets	56,663
Annual running costs	130,920
Interest repayment at 8%	26,528
	R 214,111

From his population of 22 dams, Mettrick excluded three: the very large Moshupa village water supply dam with a storage capacity of 609,600 m^3, and two very small dams (28,000 m^3 and 6,400 m^3). Of the remaining 19, storage capacity averaged 65,480 m^3, ranging between 30,800 m^3 and 288,000 m^3. By contrast, the average capacity of the 19 SDU dams for which data are available is 14,442 m^3, with a range of 4,218 m^3 to 48,388 m^3. The typical LUPU[19] dam had four and a half times the storage capacity of a SDU dam. According to Mettrick's calculations, the average construction cost for the 19 LUPU dams was R 8,223. This is equivalent to P 28,150 in today's money.

The present cost analysis deals with the fiscal year running from April 1, 1979, to March 31, 1980. It compares the number of dams completed during this period, the storage capacity created, and the volume of earth moved to the costs directly incurred by the Small Dam Unit. Cost per dam permits comparison with the LUPU dams. Cost per cubic meter of storage capacity and cost per cubic meter of earth moved will be compared with similar costs to the Serowe Brigades Dam Building Unit and a private contractor.

According to staff of the Small Dam Unit, these structures were com-

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[18] 1 Rand = U.S.$1.23.

[19] LUPU (Land Utilization Planning Unit) is the acronym commonly used for SC&DBU dams.

pleted or nearly completed during the fiscal year:

Table 16

SDU Dams Completed in 1979-1980

Number	Name	Completed	Full Storage (1,000 liters)	Earth Moved (m^3)
CE/18	Botepetepe	October 1979	10,000	7,000
C/PA/17	Sesulela	July 1979	6,438	3,438
C/PA/18	Mmamahututu	September 1979	4,888	4,888
C/PA/19	Ratholo	January 1980	4,218	4,218
KW/19	Dikhutlane	August 1979	N.A.	N.A.
KW/20	Sefatlhane East	February 1980	N.A.	N.A.
SO/11	Taupane	February 1980	48,388	6,756
SE/9	Tleberwane	April 1979	N.A.	N.A.
SE/10	Disaneng	75% complete*	N.A.	N.A.
SO/10	Lokgoba	75% complete	14,495	9,023
C/PA/20	Makaipaa	75% complete	N.A.	N.A.

*At the end of the budget year.

N.A. = Not Available.

All but one of the eight completed dams were finished in the middle of or toward the end of the year. That is, the work was substantially accomplished within the limits of the fiscal year. The three nearly completed dams have been included in the year's total, with weights of three-quarters each. By this reckoning, the SDU completed 10.25 dams during the fiscal year.

After examining various full storage averages of the available data (with and without outliers, this year versus all previous years), it was decided to use the average of all 19 dams for which information

was available to fill in the full storage missing values for Table 16. Similarly, earth moved data from 10 dams were averaged to fill in that missing value in the table. These averages are 14,442 m^3 and 6,117 m^3 respectively. With these interpolations, and the weighting of the three dams mentioned earlier, the SDU in fiscal year 1979-80 created approximately 148,000 m^3 of storage capacity by shifting 63,000 m^3 of earth.

Table 17 shows what this work cost. A detailed explanation of the cost calculations is given in Appendix D.

Table 17

Costs of Running the Small Dam Unit--Fiscal Year 1979

Item		Pula	
1. Salaries and subsistence payments for 10 working-years of permanent & pensionable staff			39,602
2. Pensions, at 15% of above salaries			4,867
3. Wages for approximately 75 working-years of Industrial Class Staff			93,204
4. Heavy equipment:	Interest and Depreciation	47,536	
	Fuel and Maintenance	142,947	
		190,483	190,483
5. Other Plant and equipment	Depreciation	620	
	Interest	1,616	
		2,236	2,236
6. Machinery and vehicle running costs			2,739
7. Traveling and transport			4,662
8. Maintenance of buildings and equipment; static plant			3,131
9. Clothing and uniforms			397

10. Water development equipment (watering troughs)	8,425
11. Fencing materials	8,418
	P 358,164

In addition to building eight dams, and nearly completing three more, the Small Dam Unit repaired six other dams in FY 1979-80. This work is treated as the equivalent of constructing two more dams. Thus for purposes of the cost calculation, the SDU did work amounting to the construction of 12.25 dams. This leads to a cost of P. 29,238 per dam, P. 2.02 per cubic meter of storage capacity created, and P. 4.78 per cubic meter of earth moved. The cost per dam compares favorably with the LUPU cost of P. 28,150 until it is recalled that the LUPU dams had four and a half times the storage capacity of a SDU dam.

There are several apparent reasons for the low productivity reflected in these cost figures. These center on the use of heavy equipment, whose cost makes up 53% of the SDU expenditure:

1. The machinery may be underutilized in the sense that the present group of machines has more capacity and sophistication than are required by the size and design of the hafir-dams they are currently engaged in building. Evidence to support this view is that the original SC&DBU machinery was used to build larger and (reportedly) more elaborate dams than its direct descendants--the SDU machinery--is doing at present.

2. Because of the versatile nature of the SDU's machinery, other government departments requisition it at short notice and use it for prolonged periods of time. This plays havoc with planning as well as with

actual construction.

3. The average age of SDU key equipment--613 scrapers and bulldozers--is nine years. Aging equipment means more frequent breakdowns.

4. When breakdowns occur, it may take weeks to obtain the necessary parts and get them to the construction site together with a mechanic capable of making the repairs.

5. The failure of one key piece of equipment often immobilizes all the other pieces in that unit because of the complementary nature of the work. The great distance between units prevents the exchange of equipment and the continuation of work in such circumstances.

6. The SDU wage bill is higher than would be found in the private sector both because Industrial Class laborers are paid even when they are idle and because the machinery operators have attained a high hourly rate through seniority. Also, since wages are only issued at Gaborone, a SDU officer must specially travel to all the work sites monthly with the money.

The Serowe Brigades Dam Building Unit: The Brigades' Dam Building Unit works under contract to the Ministry of Agriculture, and has constructed nine hafir-dams in the Serowe area since 1976. The Ministry paid for the first dams at the rate of P 0.90/m^3 of earth moved.[20] This was subsequently raised to P 1.25/m^3. Whatever the other benefits arising from its work, the Dam Building Unit was not a financial success. Appendix 9 in its most recent report[21] tells the story:

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[20]Figures supplied by the Small Dam Unit.

[21]Wauter vd Wall Bake, "Dam Building Programme '79-'82--Work Document," Serowe Brigades Development Trust, Serowe, December 1979.

	1976	1977	1978	1979
Return on Capital Employed	-52%	14%	-18%	N.A.
Net Profit Ratio	- 8%	18.5%	-52.7%	-82.3%

It appears that past payment rates were too low. However, the connection between rates received per cubic meter of earth moved and the overall financial performance of the Unit is not clear in the report just cited.

The bulk of the report lays out a new program to build 24 dams over the three years 1979/80 to 1981/82. The investment required to carry out this program is P 119,405, with an average equipment service life of nine years.[22] Using a capital recovery factor at 12% interest, the annual capital cost is P 22,410. The report assumes that eight dams can be completed each year. The past experience of the Dam Building Unit, however, suggests that a more likely number is two. This makes the capital cost per dam P 11,205. Recurrent costs of construction are estimated at P 13,500 per dam, for a projected total of P 24,705 per completed structure. Eleven of these dams had preliminary designs done,[23] which if representative call for an average storage capacity of 38,013 m^3, and 8,682 m^3 as the average amount of earth moved. To compare cost per dam it is necessary to adjust the DBU's dam size (taken as 8,682 m^3 of earth moved) down to that of the

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[22]Ibid., pp. 58-59, and Appendix 11, pp. 1-2, lay out the total capital and construction cost figures. Interest costs excluded by Wall Bake have been added; 12% is the current bank lending rate to private firms.

[23]The preliminary designs from which these average figures were calculated are currently being reworked by the Small Dam Unit. In the absence of new values for storage capacity and earth moved, the old ones are being used. Taken as an average, the new values are not likely to be substantially different from the old.

SDU "average" dam (6,117 m^3). The derived costs for the Brigades Dam Building Unit would thus be P. 17,406 per dam, P. 0.65 per m^3 of storage capacity created, and P. 2.85 per m^3 of earth moved.

A Private Contractor: These cost figures are for a onetime effort by a private contracting firm to construct a hafir-dam involving the positioning of 6,117 m^3 of earth to create a full storage capacity of 14,442 m^3 of water.[24] These are the same "average dam" values used in the Small Dam Unit cost calculations.

Timetable:

1. Site location, assessment, and preparation of drawings		4 days
2. Layout and establishment, including transport of workers and equipment to the site		4 days
3. Earthmoving (6,117 m^3)		10 days
4. Shaping and trimming		2 days
5. Fencing (250 meters)		3 days
6. Cleaning up		2 days
	Total	25 days

[24] Information on machinery, labor, rates, and capacities was supplied by J. Newton, Lekanya Engineering Services, Francistown.

Table 18

Dam Construction Costs for a Private Contractor

Item			Pula
1. Personnel			
Engineer, 6 working-days (P 2,000/mo.)		570	
Foreman, 8 working-days (P 1,500/mo.)		570	
Mechanic, 13 working-days (P 10/day)		130	
Chargehand, 20 working-days (P 8/day)		160	
Laborers, 68 working-days (P 0.26/hour)		141	
	Subtotal	1,571	1,571
2. Equipment			
(1) D-7 bulldozer (commercial rate of P 55/hr. includes fuel and operator) for 11 8-hour days		4,840	
(1) 14F grader (P 35/hr., as above) for 2 8-hour days		560	
(1) 4 x 2 5-ton truck (P 0.41/km, C.T.O. rate) for 600 kms		246	
(1) 4 x 4 1 1/2 ton truck (P 0.30/km, C.T.O. rate) for 900 kms		270	
Two lowbed truck round trips, each 600 kms, to deliver and retrieve D-7 bulldozer at P 4.00/km loaded and 60% of this (i.e., P 2.40 on empty return		3,840	
One round trip for grader, 600 kms, 15 hours, at P 25/hr. (C.T.O. rate)		375	
	Subtotal	10,131	10,131
3. Materials			
250 meters of 6-foot security fence, with one gate, at P 4.00/meter		1,000	1,000
4. Other			
10% contingency allowance		1,270	
20% contractor's mark-up (calculated on the above, excluding dozer and grader commercial hire amounts which already have built-in mark-ups)		1,714	
	Subtotal	2,984	2,984
			P 15,686

Using the private contractor in this example, the costs would be P 15,686 per dam, P 1.09 per m^3 of storage capacity created, and P 2.56 per m^3 of

earth moved.

The results of all the cost calculations are summarized in Table 19.

Table 19

Summary of Dam Construction Costs

Builder	Costs in Pula per: Dam	m^3 storage capacity	m^3 earth moved	Annual Capital Cost per Dam (P)
Ministry of Agriculture--Small Dam Unit	29,238	2.02	4.78	4,293
Serowe Brigades--Dam Building Unit	17,406	0.65	2.85	2,556
Private Contractor	15,686	1.09	2.56	2,303

The rightmost column in the table shows the annual capital cost of a dam of the same size constructed by each of the three builders. These values assume a dam service life of 15 years and an interest rate of 12%. Estimates of dam lifetime are conjectural; some structures might continue to provide some water indefinitely if when they are silted up the material is sand. Earlier dam costing exercises used estimates varying between 10 and 25 years.[25] Given the relatively small size of the SDU dams, 15 years seems like a reasonable lifetime. The interest rate chosen approxi-

[25] See, for example, H. Mettrick, "Small Dam Construction Pricing Policy," Ministry of Agriculture memorandum, December 17, 1970; S. H. Youthed, "Stockwatering and Grazing Control," Ministry of Agriculture, n.d.; and R. H. Slade, "Small Dam Construction--Water Costs," Ministry of Development Planning, under cover of memo dated May 30, 1969.

mates the current prime lending rate by banks to large enterprises in the private sector and represents the opportunity cost of capital. The annual capital cost is thus repayment of principle plus interest on the remaining unpaid balance, spread out over the lifetime of the dam.

These results deserve careful scrutiny of all the steps and assumptions by which they were derived. In particular it should be remembered that (1) the Small Dam Unit figures are based on actual expenditures during the fiscal year 1979-80, whereas the cost estimates for the other two builders refer to expected costs in calendar 1980; (2) the cost figures for the Small Dam Unit and the Dam Building Unit are possibly more comprehensive than those presented for the private contractor. On the other hand, (3) the private contractor has a large entry for costs of moving equipment to and from the site, an expense which is not explicitly taken into account for the other two builders. If these transport costs are halved for the contractor, his cost per dam becomes P 16,579, storage capacity created is P 0.94 per m^3, and earth moved is P 2.22 per m^3.

The Small Dam Unit expended over one and a half times as much to move a cubic meter of earth as would a private contractor; the Brigades unit would require about 10% more than the contractor. Of course, the purpose of moving the earth is to create storage capacity for water. The cost per unit of capacity created is the important figure when planning water resources development.

It is useful to distinguish between machinery efficiency and hydraulic efficiency when considering how to reduce costs of water from SDU dams.[26] Better sequencing of construction work and reduced idle and down

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[26]This distinction was suggested by Gil Levine, Water Points Survey water resources engineer.

time would increase the amount of earth the existing SDU machinery could move in a year. For example, if the number of dams completed in a year could be increased from a little over 10 to 15, cost per cubic meter of earth moved would fall to P 3.90, and cost per unit of storage capacity would be P 1.65. Hydraulic efficiency gains are a question of improved dam siting, design, and construction. The Small Dam Unit conducts or oversees the construction of all stock-watering dams in the eastern communal area. If the Unit could also put more of its resources into planning dams, then the amount of storage created per unit of earth moved could increase, and the cost per unit of water supply capacity would fall even further than with just machinery efficiency gains.

Dams and Hafir-Dams: Operation and Maintenance

Dams and hafir-dams owners and managers spend very little on operation and maintenance of their water points. Of the eight structures for which this kind of cost information is in hand, two (privately owned) employ caretakers who receive annual wages of approximately P 100 to maintain the structure and control access. For the other six, the only cost is that of the time of the owners or group members which is devoted to building or repairing the fence. A rough estimate for group-managed dams would be 10 men x 4 hours/day x 6 days/year, at an opportunity cost equal to the minimum wage of P 0.26/hour, i.e., P 62.40, or say P 65 per hafir-dam per year.

Poor maintenance, or more broadly speaking, poor management, shortens the service life of the structure by permitting relatively higher rates of reservoir siltation and erosion of the dam well. Certain design changes, introduced at the time of construction may lengthen service

life, e.g., a small hafir silt-trap upstream of the main structure,[27] a field stone-paved ramp for cattle into the reservoir, fencing which restricts cattle access to the water to small sequential groups,[28] flatter slopes on the dam walls, and rip-rap covering on the wall.[29] Since higher levels of maintenance may not be forthcoming from most dam and hafir-dam users, there is a distinct possibility that any increased cost of construction through design improvements will be more than matched by the (discounted) benefits of longer service life.

Boreholes: Construction

The construction of a ready-to-operate borehole usually happens in two stages: (1) siting, drilling, installation of casing, and pump testing, and (2) equipping the drilled hole with pump, engine, reservoir, and associated fittings.

Government Drilling

Government cost figures for the first stage come from two sources: a paper entitled "Review of Rural Water Prices" produced by C. E. W. Simkins of the Ministry of Mineral Resources and Water Affairs in early 1975, and a paper entitled "Drilling Costs" by P. Spray of the same Mini-

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[27] Some farmers use small silt-traps to protect their hafirs; this silt-trap would be for larger structures, and would require fairly frequent cleaning during the rainy season.

[28] Design changes suggested by George Classen, ALDEP Consultant on water supply in lands areas, May 1980.

[29] See Gil Levine, "Observations of Botswana Water Points," Water Points Survey, February 1, 1980, pp. 5-6.

stry, done in 1978. The categories in each paper have been slightly reorganized to make their cost figures comparable in terms of Pula per borehole. Simkins's total cost estimates have been inflated to March 1980. Spray's figures were mostly based on 1980/81 Recurrent Budget Estimates and therefore have not been inflated.

Table 20

Government Borehole Drilling Costs
(Pula per hole)

Item	Schramm Rig		Percussion Rig	
	Simkins (P)	Spray (P)	Simkins (P)	Spray IP)
Siting	89	--	89	--
Vehicles for siting	--	60	--	60
Depreciation on rig	416	710	1,024	400
Depreciation on vehicles	--	480	--	660
Industrial Class Staff	52	770	871	1,920
Drill Foremen	53	180	884	643
Permanent & pensionable staff and other staff not included above	--	390	--	223
Bit consumption	127	--	205	--
Foam, bits, maintenance	--	2,400	--	3,360
Fuel for rigs	86	1,730	722	480
Lubricants	22	--	181	--
Fuel for pump test rigs	--	230	--	230
Pump test (12 hours at P 6.00 per hour)	96	--	96	--
Casing	182	--	182	--
Casing and screens	--	780	--	780
Vehicles excluding depreciation	119	910	89	1,770
Transport for administrative staff	61	--	138	--
Other recurrent costs	--	520	--	520
Totals	1,303	9,160	4,481	11,046

The Simkin totals have been brought up to March 1980 using (in the absence of anything more appropriate) the Botswana Cost of Living Index.[30]

Table 21

Comparative Borehole Drilling Costs
(Inflated to March 1980)

	Schramm Rig		Percussion Rig	
Basis of Comparison	Simkins (P)	Spray (P)	Simkins (P)	Spray (P)
Cost per hole (from above)	1,303	9,160	4,481	11,046
Cost per hole (inflated)	2,605	as above	8,959	as above
Cost per successful hole (inflated)*	4,570	15,267	15,718	18,410
Cost per meter**	23.47	82.52	80.71	99.51

*Simkins: 57% success rate, based on D.G.S. experience in 1973; Spray: 60% success rate.

**Assuming, with Simkins, an average borehole depth of 110 meters.

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[30] Central Statistics Office, Ministry of Finance and Development Planning, Statistical Bulletin, vol. 4, no. 4, December 1979. The March 1979 to March 1980 CPI percentage increase is courtesy of Michael Pepper, C.S.O.

Rate of Increase in Consumer Price Index

Year Ended March	Percent
1975	12.2
1976	12.6
1977	13.7
1978	10.0
1979	8.7
1980	16.4

The two papers agree that percussion rigs are more costly than Schramm rigs, and there is some agreement on the cost of the percussion rig. The greatest discrepancy is between the two cost estimates for the Schramm rig. Simkins's low estimate may be a result of the relatively small amount of experience with Schramms existing at the time he wrote.

Private Sector Drilling

Small private drillers in Kgatleng and Southern districts are charging P 30-32 per meter drilled, including casing.[31] The pumping test is an additional flat rate of P 90 per hole. The driller and his (private) client agree on the site and split the cost of a dry hole. Assuming a 50% success rate, the cost of a successful hole of average depth (110 meters) ready to be equipped ranges between P 6,600 and P 7,040. Large contractors in the private sector are charging P 9-10,000 per hole complete with casing. Their advantage is a better hole faster finished. With a 60% success rate, this amounts to P 15,833 per successful hole.

Equipping

The costs of the second stage of borehole construction--equipping -- can be illustrated by the experience of the Animal Production Research Unit, which equipped a borehole at its Makhi II ranch in November 1979.[32] The borehole is 116 meters deep.

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[31]Drilling charges for western Ngwaketse provided by B. Addy, Division of Land Utilization. Information on the small private drilling sector provided by Mr. Rampa of Pilane, Kgatleng District.

[32]Detailed expenditures on the Makhi II borehole were furnished by T. Rennie, APRU.

Table 22

Central Government Borehole Equipping Costs:
APRU Makhi II Ranch

Item	Pula
Provided through Water Affairs:	
Mono pump and discharge head	276
Lister 6/1 engine with pulley, cooling tank and stand, belts	1,099
Pumphouse	365
Fittings and fixtures	447
Procured from private firms:	
Reservoir	1,346
Piping	1,133
One watering trough	50
Cement, paint, tools, other materials	1,382
Labor and installation charges	909
Total	7,007

Another example of recent borehole equipping costs comes from the North East District Council Water Maintenance Unit, which equipped a borehole at Makaleng in 1979.[33]

[33] P. N. Dijeng, Chief Technical Assistant (Water), North East District Council, provided, via L. Fortmann, the expenditure data on the Makaleng borehole.

Table 23

North East District Council Borehole Equipping Costs: Makaleng

Item	Pula
MRTS Mono pump and pump element	405
Lister SW1 air-cooled engine with pulley, cooling system, and belts	2,131
Pumphouse	450
Fittings and fixtures	35
Two 2,000 gallon water tanks	514
Piping	538
One watering trough	73
Cement and other materials	121
50 working-days labor	277
Total	4,544

The Makhi II borehole costs also included P 877 for 38 pipes of the rising main; this item was omitted from Table 22 to facilitate comparisons.

The cost of drilling and equipping a borehole is a function of its depth, yield, location, anticipated water supply requirements, and the agency doing the work, which is to say that the cost varies widely. Table 24 summarizes the costs of borehole drilling and equipping. The annual capital cost of drilling assumes that the hole will be usable for 35 years; equipment lifetime is set at 20 years, following the

O'Sullivan report.[34] The interest rate is 12% in both cases.

Table 24

Summary of Borehole Construction Costs

	Total Cost (P)	Annual Capital Cost per Borehole (P)
Drilling:		
Government* --Schramm	15,267	1,867
--Percussion	18,410	2,252
Large private contractor	15,833	1,937
Small driller	7,040	861
Equipping:		
Makhi II borehole	7,007	938
Makaleng borehole	4,544	608

*P. Spray, cost per successful hole.

Boreholes: Operation and Maintenance

These costs are even more difficult to pin down than those of borehole construction. Average annual repair and maintenance costs to owners of all boreholes looked after by the Borehole Repair Service are currently on the order of P 535. This figure was derived from the calculations done by P. Spray in his paper, "The Annual Cost of the BPMS and its implication

[34] T. P. O'Sullivan and Partners, Borehole Preventative Maintenance Study, draft final report, London and Gaborone, February 1975, Table V.4.1.

for Fees," Ministry of Mineral Resources and Water Affairs (n.d.), inflated to March 1980. Information from nine boreholes in the Water Points Survey shows their owners spent an average of P 310 on repairs and maintenance in calendar 1979.

Costs of borehole operation include pumper's wages, diesel, and lubricating oil. Information from 13 boreholes in the Water Points Survey[35] reveals their owners spent an average of P 522 on diesel and oil. Five of these boreholes had pumpers, whose annual wage payment averaged about P 400.

Open Wells: Construction and Maintenance

With the exception of a recent initiative in Ngamiland, the Government of Botswana has no program which constructs or encourages the construction of open wells. However, this is one of the most common and reliable forms of water point found in eastern communal areas. An open well has several advantages: its construction emphasizes relatively unskilled labor over sophisticated heavy machinery; it can provide reasonable volumes of clean water the year round; it is easy to control cattle access to open well water; and the well can be upgraded in stages by the addition of a hand-pump, then an engine as the owner accumulates funds. There are also some disadvantages: open wells are somewhat dangerous to construct; with no raised lip or rim dirt, animals and people can fall in; it is a lot of work to water cattle from the typical open well equipped with roller, chain, and bucket.

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[35] Operating costs for Bodungwane syndicate borehole came out of the work of P. Peters on syndicate boreholes in Kgatleng.

Costing open well construction is difficult because wells are infrequently dug these days in the eastern communal area. The newest well in the Water Points Survey was finished in 1976; most were built during the 1920s and 1930s; some date back to World War I. Several reasons are offered for the lack of new construction: a lack of time and interest in the long-drawn-out and casual labor on wells as it used to be done; for those that have money to invest, a much greater interest in borehole construction; the Land Board requirement that water points must be eight kilometers apart; and stringent government regulations on the handling and transport of dynamite. An accurate evaluation of costs will depend on how a new effort at open well construction is organized. Open well siting and rock blasting are two construction phases where government help could be critical.

Eleven open wells measured by the Water Points Survey showed an average depth of 16.1 meters, with a range of 7.2 to 27.0 meters. The ground water table is fairly close to the surface in many parts of the eastern communal area, and it is assumed that new open wells would be of about the same depth. With an average construction diameter of 1.5 meters, the typical new open well would require the removal of a core of earth and rock amounting to 28.5 m^3. Current private sector rates for excavation are P 5 per m^3 and for blasting, P 15 per m^3.[36] It is assumed that half of the material would have to be blasted, and all would have to be excavated. In addition, concrete might be used in place of the traditional timbering

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[36]Estimates supplied by J. Newton, Lekanya Engineering Services, Francistown.

to better protect the top of the well.[37] Table 25 shows the cost of open well construction for an individual relying on the private sector. The annual capital cost presumes a service life of 30 years for the hole and the concrete collar, ten years for the piping and water trough, and two to five years for the remaining items.

Table 25

Open Well Construction Costs

Item	Total Cost (P)
Earth removal to depth of average open well	
Blasting at P 15/m^3	215
Excavation at P 5/m^3	142
Installation of concrete rings to protect top of well	114
Roller, bucket, and chain	85
Piping and water trough	115
Thorn fencing	10
Total Cost	681
Annual Capital Cost	108

Open Wells: Operation

Open well operating costs consist of the value of the labor of those

[37] G. A. Classen, "Consultant's Report on Small Scale Rural Water Supplies," Ministry of Agriculture, Gaborone, May 1980. The cost of the installation of the concrete rings in Table 25 is Classen's estimate, p. 60.

engaged in drawing water. Most well users draw for themselves and their family. Some older men brag of watering 200 head of cattle a day from a roller-equipped open well, which must represent some upper limit on effort. Water Points Survey respondents used open wells 8.8 months of the year and watered on average 85 livestock units a day. The labor of two men working daily at this task valued at the minimum wage amounts to an open well operating cost of P 1,120 per year. Unlike all other water points, open wells are very labor-intensive; labor accounts for over 90% of total annual costs. The unit cost of water is thus very sensitive to assumptions about the amount of labor required to operate an open well.

The Unit Cost of Water at Dams, Boreholes, and Open Wells

Many different pieces of information developed earlier in this paper are brought together in Table 26, which shows the unit cost of water at different categories of dams, boreholes, and open wells. The leftmost column lists eight different ways of constructing one of these water points, from SDU dams to private sector open wells. The next three columns display annual costs of these water points. Borehole annual recurrent costs are composed of repair and maintenance, diesel and oil consumed, and the wages of a pumper. For repair and maintenance the Borehole Repair Service estimate of P 535 was used for government boreholes, while the Water Points Survey value of P 310 was assigned to private boreholes. The mean of these values was used for syndicate boreholes. The diesel and oil charges of P 522 were allocated to private boreholes and prorated upward for syndicate and government boreholes which on the average pumped more water.

The next columns of the table show the management presumed to prevail over the water points constructed by the agencies in the first column.

Table 26

Unit Cost of Water at Different Water Points--12% Interest Rate

Water Point Builder	Annual Capital Cost (P)	Annual Recurrent Cost (P)	Total Annual Cost (P)	Estimated Annual Supply from Water Point: Water Point Category	Estimated Annual Supply from Water Point: Amount m^3	Annual Cost per Cubic Meter of Water Supplied (P)
Dams						
MoA Small Dam Unit	4,293	65	4,358	Group Hafir-Dam	2,396	1.82
Brigades Dam Building Unit	2,556	65	2,621	Group Hafir-Dam	2,396	1.09
Private Contractor	2,303	65	2,368	Group Hafir-Dam	2,396	0.99
Boreholes						
Water Affairs--Schramm	2,640	1,773	4,413	Government Borehole	1,909	2.31
Water Affairs--Percussion	3,025	1,773	4,798	Government Borehole	1,909	2.51
Large Private Contractor	2,710	1,773	4,483	Government Borehole	1,909	2.35
		1,486	4,196	Syndicated Borehole	1,505	2.79
		1,232	3,942	Private Borehole	1,189	3.32
Small Private Driller	1,634	1,486	3,120	Syndicate Borehole	1,505	2.07
		1,232	2,866	Private Borehole	1,189	2.41
Open Wells						
Private Sector	108	1,120	1,228	Private Open Well	793	1.55

The Small Dam Unit specifically builds hafir-dams for groups of farmers, as do the Brigades and the private contractor under SDU direction. Water Affairs-built boreholes are for government. It is assumed that large private contractors may build boreholes for the government, syndicates, or private individuals, but the small driller is unlikely to get a government contract at present. Up until recently, open wells have been constructed and operated entirely within the private sector. The annual supply of water from water points was derived earlier in this paper (see Table 13) and refers to the period April 1979-March 1980. Thus the unit cost of water presented in the last column is the cost of water presumed used by cattle in the 12 surveyed communities in 1979-80 at current costs of water point construction, operation, and maintenance.

These unit costs are sensitive to (a) the number of livestock units using a particular category of water point and hence the water assumed to be supplied by it, and (b) the assumed cost of capital, or the interest rate. Based on random selection of respondents within each of the 12 surveyed communities, it was possible to derive the total number of cattle using a water point and not just the respondents' animals.[38] The volume of water supplied by a water point is based on this number, with the assumption that cattle could drink as much as they wished from the water point. This is not always the case, as discussed earlier, so the water supply estimates are if anything high. Therefore the unit costs above somewhat underestimate the true values.

The proper selection of interest rates in project evaluation has

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[38]Appendix B gives details on the procedure used.

generated an enormous literature in the field of economics. However, the general practice is to use a low interest rate for publicly funded projects and the market rate of interest for private projects. Unit costs in Table 26 were all calculated with an interest rate of 12%; Table 27 shows unit costs with assumed interest rates of 8, 4, and 2%. Dams are most sensitive to changes in the assumed interest rate since over 90% of their total annual cost is the cost of capital. Boreholes are of medium sensitivity, with 50-60% of their annual cost made up of capital. Open wells are least sensitive, since less than 10% of their annual cost is based on capital costs.

This paper contains enough information on costs and their derivation that the reader can alter any of the assumptions he wishes to produce his own estimates. The final table in Part III displays unit costs of water pulled out of the previous two tables, assuming a 2% interest rate for government-financed projects and a 12% rate for all other projects. Under these assumptions a group hafir-dam built by a private contractor is the lowest cost water point at P 0.54 per cubic meter; a privately owned borehole drilled by a large private contractor is the most expensive water point, providing water at a cost of P 3.32 per cubic meter. The average unit cost of water from all the listed water points is P 1.69. As a group, boreholes supply the most expensive water, having an (unweighted) mean cost of P 2.14. The cost of water from hafir-dams is about one-third this amount. Water costs more at open wells than at hafir-dams chiefly because of the labor involved in lifting it up to ground level.

The cost of water for cattle in the 12 surveyed communities is higher than it need be. Overall cost savings appear to be possible through

Table 27

Unit Cost of Water at Different Interest Rates

Water Point Builder	Owner/Manager	Unit Cost (P) of Water at Assumed Interest Rates of: 8%	4%	2%
MoA Small Dam Unit	Group Hafir-Dam	1.45	1.12	0.98
Brigades Dam Building Unit	Group Hafir-Dam	0.88	0.68	0.59
Private Contractor	Group Hafir-Dam	0.76	0.62	0.54
Water Affairs--Schramm Rig	Government Borehole	1.92	1.58	1.43
Water Affairs--Percussion Rig	Government Borehole	2.06	1.67	1.50
Large Private Contractor	Government Borehole	1.95	1.60	1.45
Large Private Contractor	Syndicate Borehole	2.28	1.83	1.64
Large Private Contractor	Private Borehole	2.67	2.10	1.86
Small Private Driller	Syndicate Borehole	1.78	1.52	1.41
Small Private Driller	Private Borehole	2.03	1.71	1.57
Private Sector	Private Open Well	1.52	1.49	1.48

Table 28

The Unit Cost of Water for Cattle

Water Point Builder	Owner/Manager	Annual Cost per Cubic Meter of Water (P)
MoA Small Dam Unit	Group Hafir-Dam	0.98
Brigades Dam Building Unit	Group Hafir-Dam	0.59
Private Contractor	Group Hafir-Dam	0.54
Water Affairs--Schramm Rig	Government Borehole	1.43
Water Affairs--Percussion Rig	Government Borehole	1.50
Large Private Contractor	Government Borehole	1.45
Large Private Contractor	Syndicate Borehole	2.79
Large Private Contractor	Private Borehole	3.32
Small Private Driller	Syndicate Borehole	2.07
Small Private Driller	Private Borehole	2.41
Open Wells--Private Sector	Private Open Well	1.55

improved dam siting, design, and construction, better borehole maintenance, and open well water lifting techniques which improve the efficiency of hand labor.[39] On the other hand, relative cost differences among different physical types of water point are inherent in the different water supply technologies. Surface water supplies will always fluctuate more than water from underground; ground water will nearly always require an energy source to get it to cattle; ground water lifting structures are more costly to construct per unit of water supplied, therefore they are

[39]For specific recommendations, see, respectively, Gil Levine, T. P. O'Sullivan, and G. A. Classen, op cit.

less numerous and are at greater distances from farmers' kraals. Thus the water resources planner finds himself in a position remarkably similar to that of the cattle holder, i.e., balancing reliability, cost, and convenience of water supply in the context of a local water use system. The difference is the planner's job is explicitly to take a longer run view and consider how best to develop the water resources of an area.

SUMMARY AND CONCLUSIONS

This paper has presented an analysis of the water use strategies of cattle holders in the 12 communities of Botswana's eastern communal area which were studied intensively by the Water Points Survey during 1979-80. It is maintained that farmers choose the most reliable, inexpensive, and convenient sources of water among the alternatives available to them within their locality.

The introduction sets the scene. Cattle consume over 85% of the water annually used in the eastern communal area, but they still are not able to get enough to meet APRU recommendations of a continuous and freely available supply required for optimal bodyweight growth. However, it is suggested that water development efforts should first be directed to improving water security, with continuous and freely available supply a secondary goal. The remainder of the introduction describes the survey procedures, explains the meaning of "livestock unit" used in the analysis, and classifies all water points by physical and management types, and a cross-classification, the management-physical type category.

Part I examines water use from the viewpoint of the cattle holder. In the short run, farmers can either move their cattle or change water

points as they attempt to meet their herds' water requirements. Most farmers keep their cattle permanently at one place, except for seasonal movements to the lands for plowing, and change water points to satisfy their cattle's water needs. Over the course of a year, most farmers use between two and three water points. On average there are 54 water points within normal range of their kraals, though this number varies widely among the 12 surveyed communities from 14 to over 100.

In choosing his water points the farmer balances the relative reliability, cost, and convenience of water available from the different categories of water point. During much of the year he gives most weight to reliability--the assurance of enough water now and in the immediate future. However, during the spring and early summer (October-December), when rainfall fills many surface catchment water points, convenience becomes a more important consideration. Convenience means the distance between the farmer's kraal and the water point he is using; distance dropped from 45 minutes during June, July, August, and September to 30 minutes during December and January. Two-thirds of the Survey respondents did not own their own water point and had to pay for water they used from boreholes, equipped open wells, private open wells and seep wells, and group hafir-dams. Still, cost in the sense of outlays of cash, cattle, labor and materials to pay for water was the least important of the three considerations in choosing a water point. Water payments ranged from P 0.01 to P 1.07 per livestock unit-month, with a mean of P 0.23.

Part II focuses on the water points respondents used and shows their pattern of use over time. The usage pattern is described in terms of (a) changes in the number of operating water points of different types, (b)

changes in distance to water, broken down by types of area in which respondents were keeping their cattle, (c) changes in the distribution of cattle over water points of different types and categories, and (d) changes in daily water demand by cattle at different categories of man-made water points. These changes are shown graphically in Figures 3 to 9.

The total number of operating water points dropped 9% from March to May-June 1979; it rose 26% between August 1979 and January 1980, reflecting a more abundant rainy season. Fifty-six percent of all water points were privately owned and managed. The major seasonal shift was from natural sources to these water points and back again. The number of operating open wells and seep wells increased during the winter dry season and fell off again with the rains because of the considerable labor these water points, especially open wells, require. The number of operating boreholes maintained a constant level from March until October 1979 when it too fell. Of the man-made surface catchment water points, the number of operating hafirs used for cattle watering rose the most dramatically in the spring and summer of 1979-80.

Distance to water increased most in mixed lands and cattle post areas in the winter of 1979; it decreased slightly in cattle post areas as cattle left pans for boreholes and open wells situated closer to their kraals. Among all area types, cattle were closest to water in the lands in January 1980.

Changes in the distribution of cattle over water points exhibit a similar seasonal pattern to changes in the number of operating water points: ground water tapping water points dominate surface water catchment water points during the dry season. However, in this case the relative

importance of the various water point physical types in terms of animal usage becomes apparent. Open wells are the most numerous dry season water point but boreholes serve more cattle. The fall in cattle usage of boreholes, open wells, and seep wells in the November to March period is dramatic, but matched by an equally steep rise in use of rivers, pans, dams, and hafir-dams.

Changes in daily water demand by cattle have been analyzed by management-physical type categories of water point. Cattle demand for water is the quantity an animal would drink if water were continuously and freely available to him. This condition did not usually prevail in the 12 communities except at open-access natural sources and unfenced dams; to this degree the water demand values are overestimates of water actually consumed. Water demand is a function of the number of cattle using a water point, the mean monthly temperature, and the composition of the community herd. Overall cattle numbers and mean temperature both fall in the winter months, and herd composition shifts toward less water demanding types of animals (i.e., fewer cows in calf). Therefore overall water demand is less in the winter months, though it is concentrated on fewer water points. Private open wells and seep wells had the greatest demand for water from May to November 1979; most of the remaining demand over the same period was met by private, government, and syndicate boreholes (in that order).

Part III shifts from a concern with current water point use practice and patterns to consider the costs of constructing new water points, specifically dams and hafir-dams, boreholes, and open wells. Costs of construction are detailed for the Ministry of Agriculture's Small Dam Unit, the Serowe Brigades Dam Building Unit, a private contractor (dams

and hafir-dams), the Ministry of Mineral Resources and Water Affairs Department of Water Affairs, a large private contractor, and a small private driller (borehole), and the private sector (open wells). Costs of operation and maintenance are also discussed.

The analysis concludes with estimates of the pula cost per cubic meter of water supplied from newly constructed group hafir-dams, government, syndicate, and private boreholes, and private open wells. As a group, boreholes supply the most expensive water at an average cost of P 2.14 per cubic meter. Hafir-dams are the least expensive at P 0.79 per cubic meter. Open wells cost P 1.55 per cubic meter of water, largely because of the high labor component in operating costs.

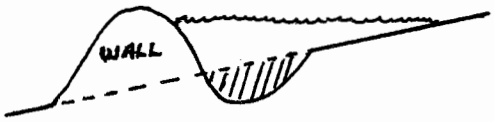
The water supply situation for cattle holders in the eastern communal area varies enormously from place to place and at the same place over time. Farmers are faced with a whole set of decisions on cattle watering; this set constitutes a very large fraction of their total herd management effort. In choosing where to water their cattle farmers give most weight to reliability of supply, but also take distance to water and cost of water (including their own labor) into account. The first goal of water resources development should be to stabilize water supply in a locality over the course of the year. The second goal should be to increase overall supply both to raise per capita consumption of existing stock and to provide for the anticipated growth in stock numbers.

In carrying out such a program the first need is for information on local water resources. This permits setting priorities on which areas to work in first and also suggests the proper mix of new water points which will best complement those already in place. A very simple local survey

combined with kgotla meetings should be able to provide the required information. The results of the Water Points Survey provide the background within which to interpret this information and plan water development. Work is currently in progress on such applications and more general water planning methodologies for the eastern communal area of Botswana.

Appendix A: Definitions of Water Point Physical Types

1. Dam:

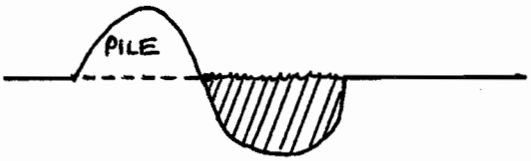


In a dam, the dam wall holds back the water, and more than half of the water at full storage lies above the ground level that existed before the dam was built. (Setswana: tamo, letamo, letlamo; Sekhalanga: damu).

2. Hafir-dam

In a hafir-dam, the dam wall holds back the water, but less than half of the water at full storage lies above the ground level that existed before the hafir-dam was built. (Setswana: tamo e nnye, mahuti, letlamo, letangwana).

3. Hafir:



In a hafir the wall is just a convenient place to put the soil taken out of the hole. It does not hold back standing water. All of the water at full storage lies below ground level in a hole or pit. (Setswana: letamole lennye, letamo, lekidi, letlamo, letangwana, tamo e nnye, tangwana).

//// = Water lying below the original ground level (shown by dashed lines).

4. River: A seasonal or perennial flow of water along a defined water course. A linear rather than a point source of water. (Setswana: molapo, noka).

5. Pan: A low spot or depression in which water seasonally collects. (Setswana: mogobe, letsha, letlodi).

6. Borehole: A machine-drilled, small diameter hole of variable depth, often lined with casing pipe. An engine and pump, or a hand-pump is required for obtaining water. (Setswana: sediba se se dirisaleng engine, motobetso, mokhenyembule, sediba, sediba sa engine, sediba se se thunthunyetswang, dipompo; Sebirwa: gwege; Sekhalanga: borabora).

7. Open Well: A shaft deeper than it is wide, the top portion of which is lined with logs to prevent cave-ins. It is commonly equipped with a roller, chain, and bucket. Some owners have installed a hand-pump or an engine and pump. (Setswana: sediba se se epilweng, petse, sediba, sediba se se tiraesewang, sediba se se epilweng sa terai, sediba sa petse).

8. Sand River Well: A shallow well penetrating to ground water in sand rivers. It is reconstructed after every rainy season which causes water to flow over the surface of the sand. Water is obtained with a bucket. (Setswana: sediba se se epilweng mo molapong, sediba se se mo nokeng, sedibana se se tswelang se epilwe fa nokeng).

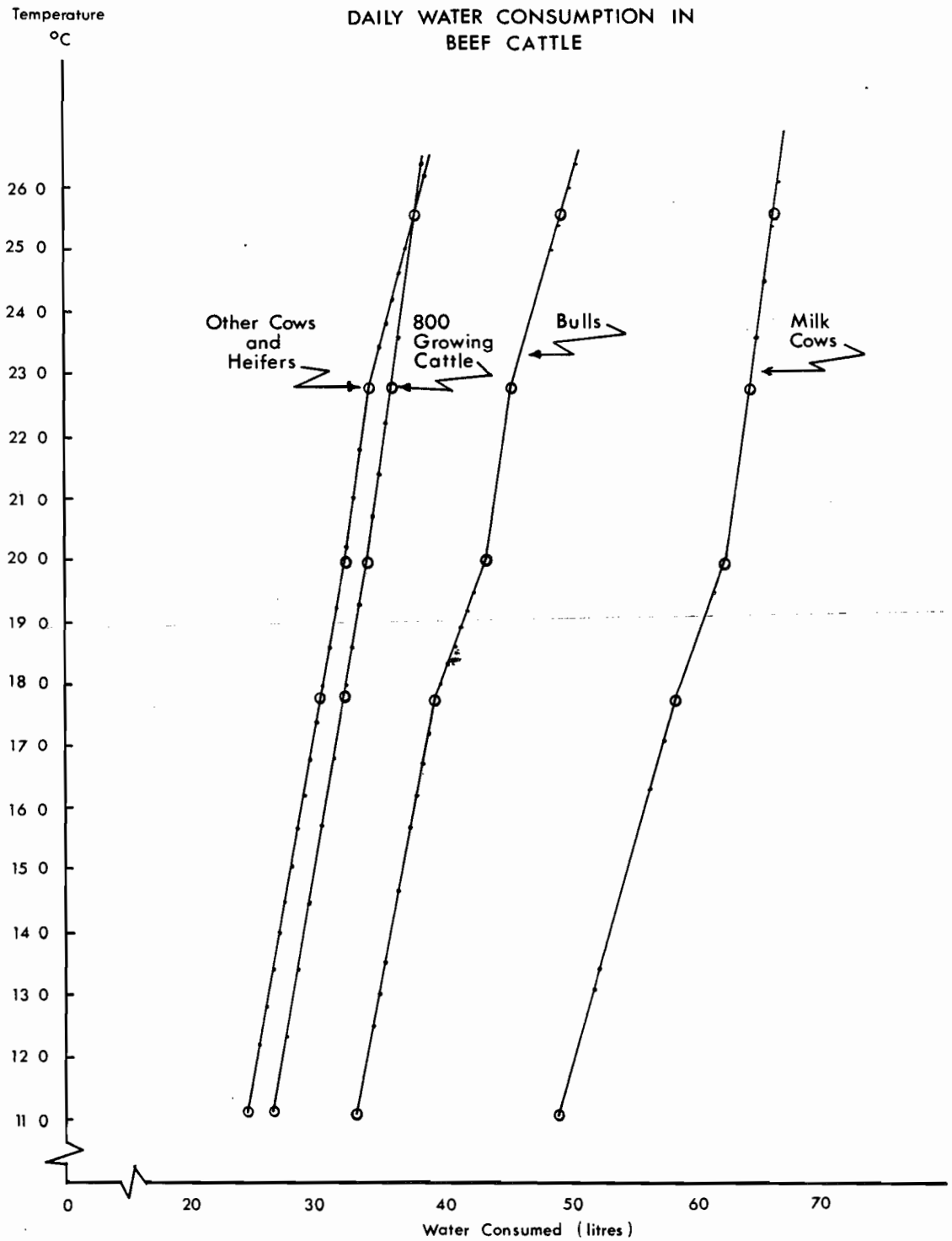
9. Seep Well or Pit: A pit often wider than it is deep, unlined in the top portion, and tapping groundwater which lies above an impervious layer. Water is obtained with a bucket. During the rainy season a large seep

well may function as a haffir. (Setswana: se se epilweng, sediba, petse, madutledi, sediba se se fato lotsweng gore metsi atswe ka diatla, lehoti, motswedi, morokwana).

10. Spring: A spontaneous flow of water out of the ground. The volume typically varies with the season. (Setswana: mosenyana, motswedi, molatswana, madutledi).

FIGURE B1

RELATION BETWEEN TEMPERATURE AND DAILY WATER CONSUMPTION IN BEEF CATTLE



Appendix B: Derivation of Livestock Units and Liters of Water per Water Point

The field data came from the two rounds of the Water Points Survey which were directed to cattle owners in the 12 communities. The data consist of:

a. Numbers of cattle owned or held and managed and owned but not managed by type (bulls, cows, etc.) and by location as of November 1979.

b. Calf births, deaths, and total breeding stock, which permitted calculation of the effective calving percentage for each herd. About 5% of the cases had missing values for births and deaths; village means were substituted.

c. Annual distribution of calf births.

d. All other entries into each herd from purchases, trades-in, dowry, gift, inheritance, and mafisa-in.

e. All exits from each herd from sales, trades-out, dowry, gift, mafisa-out, payment of wages, fees, and fines, home slaughter, natural death, and disappearance.

f. Composition of each team used to plough in the 1979-80 season in terms of type of animal and ownership.

g. Monthly information for each of the farmer's herds and subherds over the period January 1979 to March 1980 on where it was being kept, which water points were being used, and distance (in terms of time) from the kraal to each water point.

h. Water point census maps and key.

The derivation proceeded in stages from these data:

Step I

Farmer herds and subherds consisting of animals they owned, mafisa'd in, or borrowed and managed on a month-to-month basis were the starting point in this analysis. Of the total number of water point use-months, farmers' first herds account for 94%, and subherds within first herds another 4%. The remaining 2% were farmers' second herds. These were dropped from the analysis because of their small share in total usage and because second herds were often found far away from the actual water use survey areas.

The size of each farmer's herd and subherd in terms of numbers and composition was determined for each of the 15 months from January 1979 to March 1980. This step had three aspects: allocation of entries and exits into each first herd over the 15-month period, accounting for calves born January to March 1979 which entered the heifer and tolly classification 12 months later, and shifting draft and milking animals from first herd to subherds at the designated times.

Entry-exit allocation over time proceeded on the principle that any reported herd entry or exit had an equal probability of occurring in any of the 15 months, except sales and deaths. These two latter categories make up the bulk of herd inventory changes and were assigned the probability distributions given in Table B.1.

Since date-of-sale data were not collected, the cattle sales distribution is the average monthly throughput at the Botswana Meat Commission (BMC) originating from cooperatives, 1972-1979.[1] Cooperative sales are

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[1]Iain MacDonald, A Handbook of Livestock Statistics: Botswana, section 5 (draft, 1980).

Table B.1

Assumed Distribution of Cattle Sales and Deaths

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
*Cattle Sales (%)	8.5	11.3	9.2	11.4	10.9	12.3	10.4	9.7	6.1	2.6	4.1	3.5
*Cattle Deaths (%)	4.0	4.0	4.0	4.0	4.0	8.0	8.0	18.0	23.0	15.0	4.0	4.0

*Percent of annual total. Series were adjusted for the 15-month time period. Percents add to 100.0.

sales from the original communal area producers and reflect the behavior of farmers very much like those in the Survey sample. Indeed, 72% of the Survey farmers' sales were to the BMC, and of this number, 65.2% reached the Commission via the cooperative network. Therefore the cooperative sales distribution is the best approximation to the sales behavior of farmers in the Survey.

No similar source of information on time-distribution of deaths was readily available. The above distribution reflects judgments based on examination of rainfall patterns, readings of village case studies, and personal experience.

The results of entry-exit allocations produced a size and structure for each first herd for each of the 15 months. It was then possible to apply herd-specific effective calving percentages and calf birth distributions to the breeding stocks present in January, February, and March 1979 to estimate the numbers of calves which would enter the heifer and tolly categories 12 months later. This is necessary because the formula for expressing a herd in terms of livestock units (LSU's) ignores calves

but counts heifers and tollies at 0.5 LSU each. These additional animals must be taken account of in expressing January, February, and March 1980 herds in LSU's. That is, these animals were present in the herds in 1979 as calves, but were recognized as part of the herd in 1980 in terms of livestock units.

The third aspect of Step I was determining LSU values for the subherds. These subherds represent removal of some animals from the farmer's first herd for use at another location, most often for milking or plowing at the lands. It was important to recognize these subdivisions because the subherds frequently use a different set of water points during the months they are away from the first herds.

In the end, Step I produced a livestock unit value for every herd and subherd for every month between January 1979 and March 1980.

Step II

Monthly livestock unit values were matched with the water points each farmer reported using in that month. Most farmers used only one water point in a given month and therefore the total LSU value of the herd was assigned to that water point. However, in 9.7% of the user-months farmers used two water points, and in an additional 2.5% of the user-months farmers used three or more water points. In these cases the LSU value of the farmer's herd was divided up among all the water points he used in that month. If the water points were equidistant from the farmer's kraal, then the LSU value was apportioned equally. If the water points were not equidistant, then the LSU value was allocated according to a geometric decay function. At this level of information it is assumed that, other things being equal, in a situation of using two or more water points,

the more distant water point gets used less.

After completing these allocations, Livestock Units were summed for each water point for each month it was in use. The unit of analysis has now become the water point-month.

Step III

The next step was to jump from sample herds to the area herd in each of the 12 in order to get an accurate idea of total cattle usage of water points within each area. Since sample herds were randomly selected, and the total number of farmer-households within each area was known, the total cattle population of each area (C_p) is a simple function of survey area sample herd size (C_s), number of cattle-holding households in the sample (H_s), and total number of cattle-holding households in the area (H_p):

$$C_p = (C_s \cdot H_p) / H_s$$

Area total herd sizes can then be used to estimate water point usage by the cattle population (W_p), using the LSU utilization figures per water point-month (W_s) obtained in Step II above. However, this would assume that all area cattle used just the water points used by sample farmers and no others. This is not the case. W_p was therefore weighted by the ratio of the number of water points of given physical type used by sample farmers (N_s) to the total number of water points of that physical type in the area (N_p).

$$W_p = [(C_p \cdot W_s) / C_s] \cdot (N_s / N_p)$$

The weighting procedure prevents overestimation of water point cattle populations. It also assumes that the otherwise overestimated fraction of the particular water point cattle population properly belongs at another water point of the same physical type. On a month-to-month basis

this does not seem to be an unrealistic assumption.

Values appearing in the first equation are shown in Table B.2. The second equation was used with values for 67 different combinations of the 12 survey areas and the physical types of water point found in each place. It yielded LSU values for the population of cattle using each water point each month from January 1979 to March 1980.

Step IV

The final step is to convert the population Livestock Units presumed present at each water point each month to liters of water consumed each day of that month. The conversion is carried out by expressing liters of water consumed as a function of mean monthly temperature and the composition of the survey area herd in that month. That is, cattle drink more when it is hot. Milch cows drink more than other cows and heifers. Hence herd water consumption will be highest when it is hottest and cows are calving, i.e., during the months of November, December, and January.

The assumption underlying this approach is that cattle are always able to drink as much as they wish, whenever they wish, at the particular water point. This assumption may be true when cattle have unrestricted access to natural water points such as rivers, pans, and springs. However, in the majority of cases the daily water intake of cattle is restricted in timing, and during especially water-short periods, in quantity as well. Therefore, these water consumption estimates represent the amount of water which should be produced by the water point for optimal growth of the cattle population using it. This estimate is more useful for planning

Table B.2

Cattle Holders and Cattle Held: Survey Sample and Population Estimates

Survey Area	Cattle-Holding Households (sample)	Cattle-Holding Households (population)	Total Cattle Held (LSU) (sample)	Total Cattle Held (LSU) (population)
Makaleng	20	122	239	1,458
Phokoje	27	86	649	2,067
Motongolong	20	28*	828	1,175
Ramokgonami	22	322	500	7,318
Mosolotshane	22	86	555	2,170
Mmaphashalala	16	66	746	3,077
Dikgonnye	27	82	649	1,971
Matebele	8	21	78	205
Lentsweletau	18	153	299	2,542
Gamodubu	23	109	278	1,317
Ntlhantlhe	18	90	372	1,860
Mokatako	23	100*	509	2,213

*Based on best estimates of total number of occupied dwelling units.

purposes than the actual consumption of water in a particular year would be. Ready availability of adequate water is one of the basic features of the "reasonably acceptable" standard of beef cattle management recommended by the Ministry of Agriculture's Animal Production Research Unit.[2]

Since no studies of cattle daily water intake have been carried out in Botswana, data developed in the United States on the temperature-water intake relationship were used.[3] These are graphed in Figure B.1 for the four classes of cattle which correspond to animal types reported in the field surveys. Calves are excluded; tollies and oxen fall in the graphed category "800# Growing Cattle." The four classes are thus components of the livestock unit calculation formula and therefore the relationship is between mean daily temperature and daily water consumption in liters per LSU. Table B.3 shows interpolated values over the range of temperatures found within the survey area.

Table B.4 shows temperature data for five points within the Water Points Survey study area. These were computed from mean monthly maxima and minima based on records for the 19-29 years preceding 1962.[4] Each of the 12 survey areas is assigned to the nearest temperature recording station.

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[2]Ministry of Agriculture, Animal Production Research Unit, Livestock and Range Research in Botswana--1978, pp. 18 ff.

[3]D. G. Fox and O. E. Olson, "Water Requirements for Beef Cattle," Fact Sheet #1090, Cornell Beef Production Reference Manual, Animal Science Department, Cornell University, Ithaca, N.Y., 1979.

[4]M. G. Bawden and A. R. Stobbs, The Land Resources of Eastern Bechuanaland (Surrey, England: Department of Technical Cooperation, Directorate of Overseas Surveys, 1963), Appendix II, Table B, "Mean Temperature in Degrees Centigrade--Monthly Values."

Table B.3

Temperature Ranges for One-Liter Increments of Water Consumption by Beef Cattle

Milch Cows		Other Cows and Heifers		Bulls		800# Growing Cattle	
°C	Liters	°C	Liters	°C	Liters	°C	Liters
26.1	66	26.2	38	26.4	50	26.4	38
25.4	65	25.2	37	25.6	49	25.2	37
22.8	64	24.6	36	25.0	48	23.6	36
21.4	63	23.8	35	24.2	47	22.2	35
20.0	62	23.0	34	23.5	46	20.7	34
19.5	61	21.8	33	22.8	45	19.3	33
18.9	60	20.2	32	21.4	44	18.0	32
18.3	59	19.2	31	20.0	43	16.8	31
17.8	58	18.0	30	19.5	42	15.7	30
17.1	57	16.8	29	18.9	41	14.5	29
16.3	56	15.7	28	18.3	40	13.4	28
15.5	55	14.5	27	17.8	39	12.3	27
14.9	54	13.4	26	16.7	38	11.1	--
14.2	53	12.2	25	15.7	37	--	--
13.4	52	11.1	--	14.7	36	--	--
12.7	51	--	--	13.7	35	--	--
12.0	50	--	--	13.5	34	--	--
11.3		--	--	12.5	33	--	--
				11.4			

Table B.4

Mean Monthly Temperatures (°C.)

Recording Stations and Survey Areas	J	F	M	A	M	J	J	A	S	O	N	D
Francistown Makaleng Phokoje Motongolang	26.0	25.3	23.7	21.0	16.5	13.1	13.1	15.8	20.1	24.2	25.3	25.9
Palapye Ramokgonamu	25.2	22.0	23.1	19.9	16.2	13.2	12.8	15.5	19.8	23.3	24.8	25.1
Mahalapye Mosoltshane Mmaphashalala	25.3	24.7	23.0	20.4	16.4	13.2	13.1	16.1	20.2	23.9	24.7	25.2
Gaborone Dikgonnye Matebele Lentsweletau Gamodubu	25.1	24.6	22.8	19.6	15.2	12.1	12.0	14.7	18.9	22.9	23.9	24.6
Ranye Ntlhantlhe Mokatako	23.6	22.6	21.1	18.4	15.4	12.4	12.3	14.8	18.3	22.0	22.2	23.4

The data in Tables B.3 and B.4 were used to construct tables of daily water intake by month by class of animal for each of the five groups of survey areas. Month-by-month changes in relative proportions of each animal class in each survey area herd were then used to produce the weighted average daily LSU water consumption per month for each survey area. This set of values was combined with the values for LSUs present at each water point each month to convert them to liters of water consumed at each water point each month.

Appendix C: Water Use Fees Charged in Eastern Botswana

The following list contains data gathered by the Water Points Survey on water use fees charged at a sample of 78 dams, hafir-dams, hafirs, boreholes, and open wells in the communal areas of eastern Botswana. Privately owned water points, primarily hafirs, which serve only the owner's needs have been excluded. Certain terms are used in the list:

"beast"	=	a single adult bovine
"smallstock"	=	a single adult or juvenile goat or sheep
"hhd."	=	household
"drum"	=	a 200 liter steel drum
"hand-pumped"	=	appears in the name of a borehole so equipped; all other boreholes operate with an engine and pump
"equipped"	=	appears in the name of an open well equipped with an engine and pump; all other open wells feature a reel, chain, and bucket
"*"	=	dams constructed by the Small Dam Unit

Respondents stated fees in terms of (1) in-kind payments per herd per year or multiple years, or (2) in terms of cash payments per herd or per animal per day, month, or year. In most cases the level of payment per herd did not vary with herd size. In the following paragraphs the plethora of fee structures have been partially consolidated: cash per household per year or cash per drum for domestic water, and cash per animal per year for smallstock and cattle.

A warning: These formally stated fee structures do not mean that these amounts were actually collected from every water user during the

last one or two years. Actual fees collected often vary with the relationship between payer and payee and the urgency with which funds are needed to keep the water point operating.

Dams, Hafir-Dams, and Hafirs

Of the 36 dams, hafir-dams, and hafirs for which fee data will be found in the list, 22 (61%) charge no fees (though three of these require group members to contribute labor), and ten (28%) have some kind of payment for water. Information is still being compiled on the other four.

Of the ten with water payments, three involve users sharing the costs of construction, or contributing labor to main the fence or to desilt, one involves payment with cattle (one heifer or tolly per two years of use), and the remaining six have cash payments.

Domestic--25t/drum (N = 1) and an average of P 2.55/household/year, ranging from P 1.00 to P 6.00 ($N \doteq 4$). Nongroup members at group-managed water points pay the most for domestic water in this sample.

Smallstock--1t/4 smallstock/day (nonmembers at one group-managed hafir-dam).

Cattle--72t/beast/year (members at one group-managed hafir-dam) P 3.65/beast/year (nonmembers at one group-managed hafir-dam).

Some group-managed water points exclude nonmembers altogether; others appear to achieve the same result by charging relatively high prices.

Boreholes

All the owners of the 19 boreholes examined charge fees. Three of these boreholes supply water exclusively for domestic use, while the rest meet a mixture of demands for water for smallstock, cattle, and domestic

needs.

Domestic--P 5.25/household/year on average, ranging from P 1.00 to P 12.00 (N = 6). Water by the drum averages 27t, with a range of 5t to 50t (N = 5).

Smallstock--2 head of smallstock/herd/year (N = 1); 50t/herd/year (N = 1); and cash payments which average 97t/smallstock/year (range 25t to P 2.40, N = 8).

Cattle--1 heifer/herd/year (N = 1), 1 beast/herd/2 years (N = 1); an average of P 35/herd/year (N = 3); per capita cash payment which averages P 3.85/beast/year, with a range of 60t to P 7.20 (N = 15). These calculations exclude one Council borehole at Mosolotshane where cattle watering is being discouraged with a fee equivalent to P 18.25/beast/year.

Open Wells

Six owners among the 25 owners of open wells in the sample do not charge fees, and of the remaining 19, six share costs among users, and 13 charge fees:

Domestic--P 1.00/household/year (N = 1), with one hand-pump equipped open well having an annual charge of P 6.00. Water by the drum averages 23t (N = 5).

Smallstock--1 goat/herd/year (N = 1); P 1.20/smallstock/year (N = 1).

Cattle--1 heifer/herd/4 years, 1 beast/herd/6 years, 1 heifer or tolly/herds larger than 90-100 head/2 years, 2 beasts/herds larger than 100 head/year, 1 beast/herds smaller than 100 head/year, 1 heifer or tolly/herd/2 years, 1 beast/herd/2 years; P 15.00/herds less than 90-100 head/year (N = 1 for all the preceding). Cash payments average P 2.76/beast/year, ranging from P 2.40 to P 3.60 (N = 4).

Comment

It appears that fees for domestic water are highest at boreholes, followed by dams and hafir-dams, and then by open wells. This is true for payments both by the household and by the drum. The fee ranking for smallstock is unclear. Cattle watering fees are highest at boreholes, followed by open wells, and then dams and hafir-dams.

Study Area Code	Management Code	WPS No.	Name	Fees Charged
			DAMS, HAFIR-DAMS, AND HAFIRS	
11	4	101	Regimental Dam	None
11	1	301	Bosudi Hafir	None
11	4	302	Toteng Hafir	None
21	2	101	Sinombe's Dam	None
21	1		Mambo Hafir	None
23	3	201	Lekurwana Hafir Dam*	None, nonmembers excluded
23	3	202	Radithota (Gwaikelwa) Hafir-Dam	None, nonmembers excluded
23	3	203	Dinokana Hafir-Dam*	Members: None, nonmembers domestic use only: 25t/drum (limit 1 drum per day) 50t/month (buckets only)
23	3	204	Sekerepa Hafir-Dam*	Members: Domestic P 1.20/hhd./year, cattle 72t/beast/year plus contributed labor Nonmembers: Domestic P 2.00/hhd./year, smallstock 1t/4 head/day, cattle 1t/beast/day
23	4	101	Igole (Ipelegeng) Dam	None
23	2	206	Orabile's Hafir-Dam	Users help with desilting and fence maintenance
24	2	101	Dennison's Dam	Fence maintenance
24	2	301	Phalapye Hafir	1 heifer or tolly/2 years; larger herd owners pay with larger heifers or tollies

Study Area Code	Management Code	WPS No.	Name	Fees Charged
25	4	101	Ipelegeng Dam	None
31	4	101	Dikgonnye Dam	None
31	4	102	Matsimola Dam	None
31	3	301	K. Rakgati's Group Hafir	None, 5 members each paid P 100 to construct the hafir
32	4	101	Kgalapitse Dam	None
32	3	201	Belabela Hafir Dam*	P 6.00 membership fee, nonmembers excluded
32	4	102	Three Kopi Dam	None
41	3	201	Galetlokwane Hafir-Dam*	None
41	3	200	Segomotlaba Hafir-Dam*	None
41	3	202	Letswatswe Hafir-Dam*	None
41	3	203	Digwagweng Hafir-Dam*	None
41	4	204	Medie (Ipelegeng) Hafir-Dam	None
41	3	205	Ngotshwale Hafir-Dam*	None
41	3	206	Mannyelanong Hafir-Dam*	None
42	3		Mmamohiko Hafir-Dam*	None
42	3	201	Motloletsetshega Hafir-Dam*	All uses: P 1.00/hhd./year
42	3		Manokwe Hafir-Dam*	All uses: P 1.00/hhd./year
42	3		Rapalana Hafir-Dam*	
51	3		Mehane Hafir-Dam*	
51	3		Magotlhwane Hafir-Dam*	
51	3		Mmamonkge Hafir-Dam*	
52	4	100	Molete (International) Dam	None
52	2	202	Marojane Hafir-Dam	Domestic: P 1.00/hhd./year
			BOREHOLES	
11	4	601	Makaleng (Salty) Bh.	Regular users: 60t/beast/year Occasional users: P 2.00/year
11	1	603	Botalaote Bh.	20t/beast/month
11	1	604	Mambo Bh.	20t/beast/month
22	2	601	L. Tombale's Bh.	P 1.00/hhd/month for domestic use, smallstock, and calves
23	2	601	J. Jobere's Hand-pumped Bh.	Domestic: 50t/hhd./month; smallstock: 1 smallstock/6 mos.

Study Area Code	Management Code	WPS No.	Name	Fees Charged
				Draft oxen: P 2.00 for season, Cattle 1 heifer/year, or P 50.00/year
23	2	602	M. Seshaba's Hand-pumped Bh.	1 beast/2 years
24	1	601	Council Bh.	5t/beast/day
25	2	601	R. Tselayabone's Bh.	Domestic: 50t/hhd./month Smallstock: 50t/year, Cattle: P 42.00/year
25	1	602	Council Bh.	5t/drum
31	3	601	Diphage (Mmamakgoro) Bh.	Members: P 5.00/year + assessments Nonmembers: 20t/drum, 30t/beast/month, 10t/smallstock/month
31	2	602	Gabosianelwe's Bh.	10t/smallstock/month 50t/beast/month 25t/calf/month
32	2	601	Motlhatlhedi's Bh.	20t/smallstock/month 40t/beast/month
41	1	601	Council Bh.	5t/smallstock/month 20t/beast/month 5t/calf/month
42	1	601	Motlatlawe's Bh.	Domestic: P 3.00/hhd./year Smallstock: 50t/smallstock/year Cattle: P 2.00/beast/year; 50t/calf/year
52	3	601	Gakikana Bh.	Members: P 30.00 one time subscription, 30t/beast/year Nonmembers: Domestic 40t/drum (harvest season only), 5t/bucket, 15t/beast/month, 7 smallstock counted as 1 beast
52	3	602	Freestaat Bh.	Members: P 10-20/year Nonmembers: Domestic 20t/drum, 60t/beast/month including calves, donkeys, 7 smallstock count as 1 beast

Study Area Code	Management Code	WPS No.	Name	Fees Charged
52	2	605	K. Makgola's Bh.	Domestic: P 3.00/ hhd./month. Cattle: 50t/beast/ month
52	2	607	K. Lesogo's Bh.	Domestic: 10t/bucket 50t/drum. Cattle: 50t/beast/month, 5t/smallstock/month; 1 heifer/hhd./year for all the above
52	2	608	Tlatsana's Bh.	Domestic: P 1.00/hhd. /year
			OPEN WELLS	
21	2	701	R. Leposo's Open Well-1	None
21	2	702	R. Leposo's Open Well-2	None
22	2	701	J. Phepsi's Open Well	None
22	2	702	M. Moroba's Open Well	None
22	2	703	P. Sekwababe's Open Well	None
22	2	704	L. Tombale's Open Well	None
24	2	701	Mapuba Open Well	1 heifer/4 years, or 1 beast/6 years
24	2	702	Sehako Open Well	Smallstock: 1 goat/ year Herds over 90-100 beasts: 1 heifer or tolly/2 years Herds under 90-100 beasts: approx. P 15/year
24	2	703	Shakge (West) Open Well	Herds over 100 beasts: 2 beasts/ year Herds under 100 beasts: 1 beast/ year
25	4	701	B. Sekgoma's Open Well	None
25	2	702	G. Mmape's Open Well	None. Shared with 2 neighbors
25	2	790	C. Maje's Equipped Open Well	6 users shared costs of P 363 last year
25	2	791	M. Maduelele's Open Well	3 users share costs of diesel and oil
31	2	703	D. Mokoke's Open Well	1 heifer or tolly/ 2 years

Study Area Code	Manage-ment Code	WPS No.	Name	Fees Charged
31	2	709	Haanyane's Hand-pumped Open Well	Domestic: 50t/month (bucket only) Cattle: 35t/beast /month
41	2	790	Mokokong's Equipped Open Well	Domestic: 30t/drum, 30t/month (bucket only) Smallstock: 10t/ smallstock/month Donkeys: 20t/donkey/ month Cattle: 40t/beast/ month, 15t/calf/ month
41	2	703	Badisang's Open Well	20t/drum, 20t/beast /month
41	2	704	Bothata's Open Well	25t/drum, 1 beast/ 2 years
41	2	705	Rabanyana's Open Well	30t/beast/month
41	2	706	Mosimanyanamotho's Open Well	20t/drum, 30t/beast /month
41	2	708	Chebage's Open Well	30t/beast/month
41	2	791	Motswakhumo's Open Well	20t/drum
52	2	795	Tlatsana's Open Well	Domestic: P 1.00/ hhd./year

Key to Study Area and Management Codes

11 = Makaleng, North East District
21 = Phokoje, lands area for Mmadinare, Central District
22 = Motongolong, lands area for Bobonong, Central District
23 = Ramokgonami, Tswapong Valley, Central District
24 = Mosolotshane, Northwest of Shoshong, Central District
25 = Mmaphashalala, East of Mookane, Central District
31 = Dikgonnye, lands-cattle post area for Mochudi, Northwest Kgatleng District
32 = Matebele, near Oodi, Kgatleng District
41 = Lentsweletau, Kweneng District
42 = Gamodubu, lands area for Molepolole, Kweneng District
51 = Ntlhantlhe, Southern District
52 = Mokatako, Southern District

1 = district council or central government
2 = private
3 = group or syndicate
4 = communal

Appendix D: Derivation of SDU Costs in FY 1979

Notes for Table 17 in text:

Item 1: There are 11 P & P staff members in the SDU. Of these, 10 spent all or portions of their time on managing dam construction. Actual salaries and subsistence received by the 10 were furnished by the SDU and appear in Table C-1 along with their weights. Time spent in overseeing Brigades dam work, meeting with dam groups, dealing with the Water Appropriations Board, etc., has been explicitly excluded.

Item 2: Pensions are calculated at 15% of the total salary attributable to dam work.

Item 3: Actual aggregate expenditure. This includes overtime payments. The figure was supplied by the SDU.

Item 4: Table D-2 shows the item-by-item disposition of heavy equipment during the fiscal year. Up until the end of 1979, this equipment was divided among four units located in Serowe, Tswapong, Kweneng, and South East. It is now being consolidated into two units in Kweneng and Southern Districts. This information comes from personal recollections of senior SDU staff.

Table D-3 is the immediate source of the Interest and Depreciation and the Fuel and Maintenance figures in Table 17 in the text. Interest and depreciation represent the cost of ownership, and this applies whether the machine is in use, idle, or under repair. The column "Hrs./Yr." shows the number of hours each type of equipment may be used during a year. The next column to the right shows hourly rates for interest and depreciation used

by C.T.O. in mid-June 1979. The product of hours per year that the machinery is not loaned out and the hourly rates gives total interest and depreciation for the equipment.

Similarly, the product of "Hours Worked for SDU" and "Fuel & Maintenance Costs/Hr." is the total expenditure on each piece of equipment to make it run and build dams. "Hours Worked for SDU," again, is the product of the percentage of total working days "Available for Work" (Table D-2) and "Life Expectancy, Hrs./Yr." (Table D-3).

Item 5: Table D-4 shows the line items under this heading, and actual expenditures. The service life for each item is derived from the SDU Project Memorandum (AG 09), estimates by Mettrick, and personal judgment.

Items 6 to 11: These line items and expenditures were provided by the SDU. Fifty percent of total expenditure on total "traveling and transport" has been attributed to dam construction. An additional item, machinery, in the amount of P 175,472, was excluded from these calculations because the equipment arrived too late in the fiscal year to contribute noticeably to dam completions.

Table D-1

SDU Professional Staff

Person	Salary* (P)	Subsistence (P)	% Time Spent on Dam Construction	Total Amount Attributable to Dam Construction (P)
1	4,992	1,827	60	4,091
2	4,200	182	60	2,629
3	3,720	418	94	3,890
4	3,920	59	100	3,979
5	3,420	2,325	100	5,745
6	3,420	2,322	100	5,742
7	3,960	147	100	4,107
8	4,200	427	100	4,627
9	1,920	614	40	1,014
10	2,740	30	100	2,770
11	1,008	0	100	1,008
	34,080			39,602

*Total salary attributable to dam work = P 32,448.

Table D-2

Heavy Equipment Usage in FY 1979-80
(Working Days*)

Equipment	Loaned Out	Under repair	Lack of Complementary Equipment	Available for Work	Total Working Days
Unit 1					
613 Scraper	125 (50%)	53 (21%)	0	72 (29%)	250 (100%)
D-6 Bulldozer	125 (50%)	21 (8%)	53 (21%)	51 (21%)	250 (100%)
D-4 Bulldozer with Scraper	0	20 (8%)	0	230 (92%)	250 (100%)
Unit 3					
613 Scraper	0	17 (7%)	0	233 (93%)	250 (100%)
D-6 Bulldozer	0	16 (6%)	0	234 (94%)	250 (100%)
D-4 Bulldozer with Scraper	198 (79%)	0	0	52 (21%)	250 (100%)
Unit 2					
D-5 Bulldozer	43 (17%)	11 (4%)	0	196 (78%)	250 (100%)
Five (5) Tractors with Scrapers	215 (17%)	0	55 (4%)	980 (78%)	1250 (100%)
Unit 4					
D-5 Bulldozer	0	145 (58%)	0	105 (42%)	250 (100%)
Five (5) Tractors with Scrapers	0	0	315 (25%)	935 (75%)	1250 (100%)
TOTAL DAYS	706	283	423	3088	4500
Percentage of total available machine time**	16%	6%	9%	69%	100%

* Estimates may vary ± 5 working days.

**18 machines x 250 working days in FY 1979-80 = 4,500 potential working days.

Table D-3

Heavy Equipment Costs in FY 1979-80

Item	Life Expectancy Year	Life Expectancy Hrs./Yr.	Interest + Depreciation per hour	Total (P)	Hours Worked for SDU	Fuel & Maintenance Costs/Hr.	Total (P)
Unit 1							
613 Scraper	10[1]	900[2]	11.20[3]	5,040	261	19.80[3]	5,168
D-6 Bulldozer	9[4]	900[2]	0[5]	0	189	17.37[3]	3,283
D-4 Bulldozer	9[4]	900[2]	0[5]	0	828	12.16[7]	10,068
Scraper for D-4							
Unit 2							
D-5 Bulldozer	9[4]	900[2]	8.19[6]	6,118	702	14.76[6]	10,362
(5) MF-188 Tractor	5[2]	1200[4]	1.15[3]	5,727	4,680	5.85[3]	27,378
Scrapers for MFs							
Unit 3							
613 Scraper	10[1]	900[2]	11.20[3]	10,080	837	19.80[3]	16,573
D-6 Bulldozer	9[4]	900[2]	0[5]	0	846	17.37[3]	14,695
D-4 Bulldozer	9[4]	900[2]	0[5]	0	189	12.16[7]	2,298
Scraper for D-4							
Unit 4							
D-5 Bulldozer	9[4]	900[2]	8.19[6]	7,371	378	14.76[6]	5,579
(5) MF-188 Tractors	5[5]	1200[4]	1.15[3]	6,900	4,500	5.85[3]	26,325
Scrapers for MFs							
Other Equipment							
(3) MF-165 Tractors	5[2]	1200[2]	1.00[3]	3,600	3,105[8]	4.50[3]	13,973
MF-285 Tractor	5[2]	1200[4]	2.25[3]	2,700	828	8.75[3]	7,245
				P 47,536			P 142,947

Notes to Table D-3, Heavy Equipment Costs in FY 1979-80

1. Estimate from Small Dam Unit.

2. Estimate from N. C. Schultz, Senior Engineer (Maintenance), Roads Department.

3. Figures are from Central Transport Organization, "Vehicle/ Plant Operating Cost (Excluding Driver)," 12 June 1979.

4. Figures are from Kampsax International A/S, "Highway Maintenance Study--Final Report," vol. 1, Ministry of Works and Communications, May 1978, plate 9-05 and p. 130.

5. Fully depreciated.

6. 85% of the C.T.O. figure for the D-6 bulldozer.

7. 70% of the C.T.O. figure for the D-6 bulldozer.

8 Overall machine average availability was 68%, so this figure was used to calculate hours worked for "Other Equipment."

Table D-4

Other Plant and Equipment

Item	Expenditure[1] in FY 1979	Service Life (Years)	Annual[2] Depreciation	Annual[3] Interest Cost	Total
Buildings	1,182.03	15	78.80	89.83	168.63
Furniture and Office Equipment	1,179.69	10	117.97	92.01	209.99
Field Radios	317.85	8	39.73	25.27	65.00
Technical Equipment	336.68	5	67.34	28.28	95.62
Field Vehicle Equipment	931.38	3	310.46	85.69	396.15
Camping Equipment	2,302.39	3	767.46	211.82	979.28
Equipment and Tools	1,170.91	5	234.18	87.12	331.30
			1,615.94	620.02	2,235.97

1. Figures provided by Small Dam Unit.
2. Straight line.
3. Calculated with the formula: $I = \frac{rA}{2} \left[\frac{t+1}{t}\right] + Sr$

Where I = annual interest cost, A = amount of investment to be amortized, t = total service life, r = interest rate (here 12%), and S = salvage value (here set at 10% of original cost.) This formula was suggested by J. Litschauer, Division of Planning and Statistics, Ministry of Agriculture.

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