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END OF TOUR REPORT

CONSERVATION ENGINEER

JANUARY 1978 TO FEBRUARY 1980.

Submitted to
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By

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END OF TOUR REPORT

L.F. SCHERER

CONSERVATION ENGINEER

JANUARY 1978 TO FEBRUARY 1980

INTRODUCTION:

The position of Conservation Engineer in the Conservation Division, Ministry of Agriculture was included in the USAID Land and Water Resources Development Project which was implemented in 1974. The position of Conservation Engineer was filled by the incumbent on October 6, 1975. The 2 year contract ended on October 6, 1977, but was extended for three months to allow further contract negotiations. The present contract began January 6, 1978 and ends on February 6, 1980.

The primary need for an engineer in the Conservation Division was to properly design and construct grassed waterways, terraces, diversions and rock structures. An engineer had been provided for the Thaba Bosiu Conservation Division but all of his time was needed to initiate the conservation design and construction for that project. Design and construction supervision of conservation measures for the Conservation Division had previously been done by the planning and operations sections but there were no personnel with the training or the time to properly carry out the needed work.

ACKNOWLEDGMENT:

It has been a pleasure to work with the contracting agency, The International Institute of Education for the past two years. Mr. Clifford Barnett III, has always been most helpful in trying to fulfill our requests.

I am grateful to the U.S. Government and AID for their funding of the conservation project in Lesotho which gave me the opportunity to work on programs that I consider essential to the future viability of agriculture in Third World Countries.

Many thanks are due to Mr. H. Cooper and Mr. R. Mochebelele for allowing me to work on problems that sometimes held little prospect of any immediate profit.

The SARCCUS Group have been a great help in keeping the problems in perspective and often leading to valuable information for the resolution of investigations.

Special thanks to Dr. duPasani of the R.S.A. Agrometeorological Group for his directing me to the information on rainfall that was available in Ficksburg, and to the people at Potchefstroom that so willingly copied and forwarded the available records.

The people in the Meteorology Section of The Ministry of Water, Energy and Mines have also been most cooperative in allowing us to use their records.

The LASA Group have been most helpful in offering advice and the use of their library.

The efforts of Mr. Robert Flannery in getting me involved in the Universal Soil Loss Equation are most appreciated.

Last but certainly not the least are all the employees of the Conservation Division who have been very helpful in gathering data, offering their advice, etc.

ACCOMPLISHMENTS:

Training was given to 2 counterpart Conservation Engineers, drafting room personnel, IVS Volunteer engineers, conservation assistants (surveying, design) B.S. returnees from U.S.A., a diploma Engineer and CCPP personnel (surveying, planimetering) details are given in Section 2.1 under DUTIES.

To facilitate the proper DESIGN of conservation structural measures many publications were put out under the supervision of the Conservation Engineer. They included waterway design, runoff calculation, USLE for Lesotho, Basic Surveying (Don Miller SCS Nebraska), Using the Planimeter, Design Procedures (Mike Nyquist), standards and specifications for conservation structural measures, and Rock Structure Design See Section 2.3A under DUTIES.

Designs were made for grassed waterways, diversions, terraces, dams, irrigation systems, structures, and fish ponds. Much of this design work was done by engineers working under the supervision of the Conservation Engineer. See Section 2.3 under DUTIES.

In an effort to find a more suitable method of terrace spacing, estimate the quantity of soil erosion under existing and future conditions, determine

the best crop rotation for erosion control and determine which steep slopes could be farmed and how, a great deal of time and effort was spent in arriving at the various factors to use for the Universal Soil Loss Equation, (USLE) as it applies to Lesotho. This effort has been worthwhile since it has refuted some long held beliefs and presents a quantitative method of evaluating the soil erosion for various soils, crops, slopes and regions. See the discussion under Duties, Section 2.3B.

To properly design the waterways, diversions and structures called for in a conservation program, knowledge of rainfall parameters is very necessary. The incumbent began analyzing the available rainfall records during the first contract and this has continued during the present contract period. See Section 2.3E under Duties. The above mentioned rainfall analysis should help to substantially reduce the cost of conservation structural measures.

Many jobs of a consultive nature were undertaken for divisions other than Conservation and Ministries other than Agriculture. See Item 2.7 under Duties.

RECOMMENDATIONS:

1. In some of the job descriptions and recommendations by some people the qualifications for Conservation Engineers included the alternative that the person could be either an agricultural engineer or a civil engineer. I would strongly recommend an agricultural engineer over a civil engineer for the following reasons:

   Ordinarily agricultural engineers will have a farm background or an interest in agriculture whereas a person going for a civil engineering degree would likely have a city background and an initial interest in building roads, railroads, bridges, dams and etc., instead of agriculturally oriented structures. The basic college training received by agricultural and civil engineers is the same but the third and fourth year courses diverge with the agricultural engineers getting subjects directed toward agriculture and the civil naturally toward civil works.

2. There should be close cooperation between the planning and engineering sections during the planning process and the engineering section should be given the opportunity to make a detail revue of the conservation plans before they are finalized. This would hopefully el-

iminate most of the revising that has occasionally been necessary in the past.

3. There should be at least one design engineer, one construction engineer and a Diploma engineer at Maseru with the necessary supporting staff and one Diploma or B.S. Engineer North and one South. The engineers for North and South should be based in Maseru until such time as a satisfactory administrative and support set up can be created in the North and South regions. The workload for the engineering staff has increased greatly in the last 4 years and whether it increases in the future will depend on the nature the conservation program takes in the next few years. A large amount of the day to day engineering work such as routine design, construction inspection and training can be done by conservationists in the field if they have the time and there is sufficient engineering time to properly train them.

4. Our existing program of training the field personnel to do the routine surveying should continue. Again depending on the engineering workload there should be a diploma engineer in Maseru in charge of the surveying country wide, with a surveyor North and one South. If we could have surveyors and engineers stationed North and South it would greatly reduce the amount of travel expense and increase the quality of engineering and surveying. With the staff stationed at Maseru as at present there is not sufficient time to travel to each of the projects and do the surveying and construction inspection that should be done. This naturally detracts from both the quality and quantity of work that is done in the field.

5. In light of the engineering consulting services rendered and the fact that we now have engineers in BASP and farm machinery as well as conservation, it might be advisable at some future date to create an engineering post under the DPS(T) to handle the consultive type work and oversee the engineering work Ministry wide.

6. With the number of engineers now employed by the Lesotho Government it would be wise to set up a procedure for examination, licensing and/or registering engineers. The main purpose of this is to protect the public and the government from engineers designing unsafe structures. It also gives the engineer a better standing in the community

and a forum from which to address items of concern to the engineering community.

7. A training plan should be set up for each employee in the drafting room to improve their skills and increase their productivity. This should be done in collaboration with the head of the drafting room.

8. The planimetering booklet should be revised to include other methods of area measurement, and clarify the planimetering instructions.

9. The Conservation Division should be very cautious about putting grassed waterways in an area unless they are convinced that there is a strong chief and he will be able to control the grazing in the waterways. In addition the Conservation Division should use every means at its disposal to promote nationwide grazing management since overgrazing has so many detrimental effects on soil and water conservation (Section 2.3B4).

10. The depth of flow in terraces should be recomputed and recommendations made for design depths. (Section

11. The engineering design and constructions booklet should be revised as soon as possible.

12. Rehabilitation should be strongly considered for all new terracing projects. (Section 2.3D4)

13. We should buy one "Bob Cat" front end loader to try in terrace rehabilitation.

14. The Engineering standards and specifications for all practices should be revised.

15. We should cooperate with LASA on the soil moisture estimator program and when it is operational, evaluate its potential as a runoff estimator.

16. We should emphasize moisture conservation practices, especially crop residue management in our plans.

17. The possibility of furrowing maize when cultivating, should be explored. This would get more water into the soil and reduce erosion.

18. We should instrument more catchments for yield data.

19. Planning, Soils and Engineering should be involved in the planning and design of all buildings put up by the Operations Section.

20. The publication USLE For Lesotho should be revised as soon as possible. The Planning Section should assist by revising the "C" factor calculations.

21. We should be on the lookout for sites and opportunities to build small dams near and preferably above villages. These dams could be used by individuals or groups within the village to irrigate their gardens. This could be especially beneficial during dry years and to families who may not have any farm land.

DUTIES:

1. As Head of the Engineering Section the Conservation Engineer is responsible for cooperation and coordination with the other sections in carrying out the conservation program. This coordination and cooperation has been accomplished with few exceptions. Some of the exceptions were due to a lack of understanding of the job description of the heads of sections. This problem was partially cleared up by the rewriting of the job descriptions.

2. OTHER DUTIES

2.1 TRAINING

2.1A COUNTERPART TRAINING

Counterpart training began when Mr. Mochebelele returned from Nebraska with an M.S. in Agricultural Engineering. When Mr. Mochebelele was co-opted to be the counterpart C.C.O., Mr. Mochochoko who returned from Nebraska with a B.S. in Agricultural Engineering was put in the position of counterpart Conservation Engineer. Mr. Mochochoko has a good academic background and now needs only a few years on the job experience to be a well qualified Conservation Engineer. This on the job experience with a qualified Conservation Engineer as an advisor will enable him to be more firm in dealing with people (yet diplomatic), better acquainted with the alternatives that can be used in different situations and more confident of his ability. The ordinary design work for conservation is easily handled but the unusual and particularly consultive type assignments require some experience and background to arrive at the best solution.

2.1B DRAFTING ROOM

The incumbent head of the drafting room had drafting training in

Malawi. At this time one person from the drafting room is attending school in the U.S.A. The other establishment list person in the drafting room has received only on the job training, as have the daily paid workers. An attempt was made to set up a training plan for the employees in the drafting room but from lack of follow up this has been inactive, except that as new employees are hired they are given some basic training in lettering and other simple tasks.

2.1C VOLUNTEERS

Prior to hiring any volunteers in the Engineering Section an expatriate girl with college engineering training was hired. She had received her training at Silsoe College in England and needed very little training in Conservation Engineering. She was instrumental in designing a large number of waterways for the Kolonyama and Berea Majara Projects. Later in an effort to upgrade the engineering work in the MINRUDEV an IVS volunteer was brought in. She was not acceptable to MINRUDEV and was therefore posted to the Khomokhoana Project. She also had a diploma in agricultural engineering as well as a B.S. degree in another subject and very little training was required to get her ready to design the ordinary conservation structures. After a change of personnel on the Khomokhoana Project, she was transferred to Leribe to work on the Northern region conservation projects. Because of insufficient workload in the Northern districts she was later transferred to Maseru. She has been instrumental in training a diploma agricultural engineer and in setting up and implementing a training program in surveying and design for the conservation assistants in the field.

Another IVS volunteer was later secured for MINRUDEV. His time at MINRUDEV was not too productive since his job was changed from engineering to program formulation and MINRUDEV had no facilities for designing and supervising what work their Food Aid (conservation) workers were doing. He subsequently was seconded to the Conservation Division for extensive and intensive training in conservation engineering with the hope that when conditions improve in MINRUDEV he can go back and do the job of a Conservation Engineer for them.

2.1D CONSERVATION ASSISTANTS

Training of field personnel in surveying, design and construction inspection has been both in formal classroom work and on the job. For further details see Sections 2.9A, 2.9B and 2.3K.

2.1E B.S. RETURNEES

As part of the regular training and orientation procedure for B.S. personnel returning from the U.S.A., the Engineering Section conducts a week long orientation and training session. The training is coordinated with the ongoing work of the Engineering Section and the interests and needs of the returnee.

2.1F DIPLOMA ENGINEERS

Diploma engineers beginning work for the Engineering Section are given the regular orientation and then a special engineering training to acquaint them with the work of the section.

2.1G CCPP, TOU

The Engineering Section has been cooperating with CCPP in training them to do plane table surveying, reading and interpretation of aerial photos and measuring field areas.

2.2 INVESTIGATIONS, SURVEYS AND RESEARCH

2.2A WATERWAY OUTLETS

Since the incumbent arrived in Lesotho there have been problems with securing good outlets for grassed waterways. This is due mostly to the deep donqas and rivers into which many of the waterways must be outleted and inadequate design and construction procedures. The design and construction of rock structures for the types of sites must be very thorough and exacting, and we have not had the trained personnel nor time available to get any assurance that these type structures would have a suitably long life.

In order to alleviate some of these problems a number of steps have been taken, including the consideration of pipe outlets, chute spillways, reducing the need for and flow in the waterways and even eliminating waterways wherever feasible.

A pipe outlet has been installed in the Caledon River bank in the

Kolonyama Project because of the long drop to the river. Its operation will need to be monitored in the coming years to assess the feasibility of this type outlet under Lesotho conditions.

A small (75 ha) labour intensive project north of Leribe was designed to work without waterways. This was feasible since most of the land is in hydrologic soil Group A or B which has very little runoff under Lesotho rainfall and evaporation conditions. Level terraces are used which let any runoff infiltrate into the soil. This concept is also being tried in the Qalo Project where good outlet sites are rare. It will reduce the length of waterways needed in some instances and allow alternate outlet sites to be considered.

A chute spillway has been designed for Unit III of the Kolonyama Project where good outlet sites are also hard to find.

Reinforced concrete spillways were used in the Khomokhoana Project but the Engineering Section does not advocate their use because of the higher technical demands for construction and the danger of undermining and subsequent loss of the structure. Rock and/or gabion structures can be repaired/replaced much easier than concrete structures.

Inadequate construction supervision has been a problem with outlets installed in the past. This can best be remedied by training the conservation assistants and assistant conservation officers in proper construction supervision and putting engineering personnel in regional offices where they can more easily supervise construction.

Improper design has caused the failure of some outlet structures. Up until recently there were not enough engineering personnel to do all the work that needed to be done and the item that had lowest priority was the design of rock structures. With the engineering staff presently available this should cease to be a problem. (See also Section 2.3B 6).

2.2B ENGINEERING PLANNING

Engineering planning is mainly concerned with expanding or intensifying the conservation plans produced by the Planning Section but can also be concerned with planning special projects outside the conservation plans.

An example of intensifying the conservation plan would be the Qalo Project where the Engineering Section proposed modifications to the plan because of waterway outlet site problems.

Another example would be the proposal to rehabilitate the existing terrace/grass strip systems where feasible to reduce the cost of terracing, reduce field boundary disruptions and hence realignment problems and save the existing bench terraces that have become established over the years.

This concept is being tried on the 75 ha project north of Leribe. (See Section 2.3D 4)

2.2C TERRACE SPACING

The Thaba Bosiu Project engineer computed the terrace spacing using the formula vertical interval (V.I.) = 0.6 slope (S) + 1.5. This was later changed to VI = 0.6S + 2.5 when a revised edition of the USDA-SCS Engineering Handbook was received in Lesotho. In an attempt to arrive at a more rational method of terrace spacing the Universal Soil Loss Equation (USLE) was investigated by the incumbent during the first contract period. A publication on the USLE was printed in 1978 but the lack of rainfall data and research on USLE precluded the use of the USLE for terrace spacing computations. Work on updating and revising the USLE publication is ongoing but it can still only be used as a general guide to the relative erosion between different slopes, crops, soils, etc. It may be that additions or modifications to the spacing formula can be computed when the revised USLE publication is available.

In addition, work has been done on adopting the Soil Loss Estimator Model for Southern Africa (SLEMSA) to Lesotho conditions.

2.2D RAINFALL

Adequate rainfall data is essential for the proper design of any conservation measures. During the incumbent's first contract rainfall records were analyzed and depth-duration-frequency curves were procured. These were essential for the design of waterways and diversions. (See Item 2.3E for further details)

The annual yield of a catchment area is also needed when designing

storage reservoirs. Records of reservoir water level and rainfall were kept at upper Matsieng. The results of these records led to investigation into the antecedent moisture condition for design storms. This investigation is still proceding. (For more details see Section 2.3E or 2.3B 2)

The rainfall erosivity is also very important in erosion prediction equations such as the USLE and SLEMSA. (See Section 2.3A 3 and 2.3A 4 for further details)

We are utilizing microfilm records in the Meteorology Section, automatic rain gauge charts from meteorology, Khomokhoana and the Republic of South Africa and data from our own raingauges in the projects to increase the accuracy of our calculations of the above items. The Lesotho Agricultural Sector Analysis (LASA) group has also obtained some rainfall records for Lesotho from R.S.A. and placed them on discs for the Ministry of Finance computer.

2.2E SEDIMENT PRODUCTION FROM RANGELAND

When Booker International were formulating the conservation and livestock project for the Phuthiatsana Irrigation Project the Engineering and Range Sections attempted to assist them in predicting the erosion from Lesotho rangelands in various conditions, by the use of the USLE. It was felt that this effort was not very successful and continuing investigations are being made to find a better method of predicting sediment yield from rangelands. An article in "Soil Erosion: Prediction and Control", the proceedings of a National Conference on Soil Erosion, Purdue University, entitled "Use of the Universal Soil Loss Equation to Predict Erosion in West Africa", Table 6, Page 69, shows a C factor for grassland of 0.01 and overgrazed grassland with a C of 0.1. If this is true also in Lesotho it would essentially mean that we can reduce the erosion from grasslands by 90% by replacing the present overgrazing system with a good management system. Field research on this should be initiated as soon as possible.

2.2F LABOR INTENSIVE WORKS

During the first 2 year contract the incumbent operated 2 labor intensive construction schemes. One was a fishpond reservoir at upper Matsieng and the other a grassed waterway at Liphetu in the Thaba

Bosiu Project. Neither was very encouraging because of low rates of production.

Since then a labor construction unit has been set up by the Lesotho Government with a consulting firm managing it.

The labor construction unit has shown that labor construction is competitive with machinery construction on some projects such as terraces, waterways and diversions but not on dam wall construction.

The 75 ha project north of Leribe is to be done by labor and should give a good indication whether labor construction rehabilitation is less expensive than new construction. The use of labor intensive construction has been included in the new USAID Soil Conservation Project. (See Section 2.3D 5)

2.2G THABA PHATSO - SILT IN DAM

A survey was made of the depth at the Thaba-Phatsoa reservoir to determine if it had silted to any great extent. A quantitative estimate was not made since the original reservoir site survey was inadequate but visual comparison indicated that there was some silting in the upper reaches of the reservoir but probably very little in the main reservoir.

2.2H HA SEOLI FLOODING

Conservation was requested by the chief of this area which is below Lerato Mission between Maseru and Lithabaneng to help stop the flooding of houses and yards every time there is a heavy rainfall. An engineering survey was done of the area and an engineering plan drawn up. It was to be constructed by food aid laborers but they quit before even working one day, because they said the work was too hard. This area was proposed for the 1979 Independence Day Celebration and some of the work was started and is being continued by food aid labor. Conservation had originally built dams and diversions in this area before there were any houses there. It is surrounded with houses now and the dams only serve to spread water into the houses. The dams are being breached to allow the flood water to continue down the donga which is adequately covered with grass.

2.2I ROAD TO UPPER MATSIENG FISHPONDS

The existing road from Matsieng to the upper Matsieng fishponds is steep, winding, long, rough and hard to maintain. An alternate route going up the escarpment from Morija was suggested by the Conservation Assistant at Morija. A survey was made of this route and it was recommended to the Fisheries Section. They will probably have it built when money is available.

2.2J RESEARCH (See Section 2.10)

2.3 DESIGNS

2.3A PUBLICATIONS

1. Standards.
   Design standards were published during the incumbent's first contract and added to with standards for rock structures in 1979. All of the standards are now in the process of being revised by the local engineer.

2. A Small Waterway design publication including runoff calculations was put out during the first contract. This was later revised and included in Mike Nyquist's publications. (See 2.3A7)

3. A publication on the preliminary R factor for Lesotho was put out during the first contract then revised for inclusion in the USLE for Lesotho. (below)

4. The publication USLE for Lesotho was issued in 1978. It included tables adopted from a South Dakota publication using an R factor of 125. This has since proven to be too high and it is hoped that a revised USLE for Lesotho can be issued in 1980.

   This publication should prove helpful to Conservation Planners, and Crops Division personnel in assessing the erosion under different crops, soils, slopes, regions, etc.

5. Basic Engineering Surveying by Don Miller. Don Miller was brought to Lesotho from the USDA - SCS in Nebraska to train conservation assistants in the basic engineering surveying procedures used in conservation. He conducted 2 each 2 week-long courses which com-

bined the theory and practice and afterwards put together the Basic Surveying Handbook based on his teaching experience. It is a valuable aid to the Conservation Assistants.

6. Design Procedures by Mike Nyquist. Mike Nyquist had been a Peace Corps Volunteer with the Thaba Bosiu Project working under Conservation Engineer Glenn Ellithorpe. He also worked in the Conservation Division Engineering Section under a USAID contract as an Assistant Conservation Engineer. While in this position he put together the Design Procedures Manual to get the data and procedures needed for conservation design in one publication. The Engineering Section is now in the process of metricating and revising this publication to conform with updated material now available.

2.3B WATERWAYS

1. When Mr. Mochebelele returned to the Engineering Division after obtaining his Masters Degree, he suggested revising our waterway design procedure to add catchments sub-areas to obtain the design flow from rainfall instead of adding the design flow from each sub-area as we had previously done. This was a more correct procedure hydrologically and resulted in some reduction in the size of waterways.

2. AMC - Upper Matsieng. When the 2 fishpond reservoirs were completed at upper Matsieng, metric strips were attached to the intake towers and daily records were kept of the water level in the reservoirs. In addition a raingauge, anemometer and evaporation pan were installed near the reservoir. After two seasons of rainfall it was ascertained that the runoff into the reservoirs was not as much as has been predicted by the USDA - SCS runoff equation. In an effort to determine the reason for this the soils men were called in to recheck the soils. Some areas of the catchment were very shallow or rocky while others had a deeper sandy soil. This did not seem to adequately explain the lack of runoff.

   Another possibility was that the Antecedent Moisture Condition (AMC) at the time of the rainstorms was dry instead of average as had been assumed. A check of the available records indicated for

about 80% of the rainstorms of 50mm or more the AMC was I or the dry condition. This would explain the low catchment yield. Additional stations and more years of record are being checked to increase the relaibility of this assumption. If we can be reasonably certain that we have AMC I for the majority of major rainfall events it will also affect the size and number of waterways, the possibility of using level terraces and eliminating the need for waterways, and the reduction in size of other structural measures.

3. When we discovered the large number of rainfall events with AMC I Mr. Mochochoko the counterpart Conservation Engineer revised the rainfall runoff prediction procedure to take this into account. His interim procedure is to assume that we have a condition that is average between AMC I and AMC II. This reduces the sizes of structure somewhat but not as much as if we used AMC I as the criteria. If at a later date it is determined that AMC I is the predominant condition we could change to designs based on AMC I with the possibility in some cases of using AMC II to determine free board requirements.

4. Overgrazing. The existing condition of heavy overgrazing in Lesotho is a great hazard for conservation structures. As an example diversions must be made larger to accomodate the increased runoff that comes from overgrazed catchments. An an example of going from an overgrazed catchment to one with good range management a 200 ha. catchment would contribute a peak flow of about 300 cfs whenover grazed, versus about 130 cfs when under good management. Another way of assessing this would be to look at the amount of water that goes into the soil to help to produce more grass. With a 75mm rainfall on overgrazed catchment (C Hydrologic Group) about 35mm will soak into the ground and 40mm will runoff. On the other hand if the grassland is well managed and is in good hydrologic condition about 50mm will soak into the soil and only 25mm will runoff. Thus it can be seen that more water will be held in the soil to grow more grass.

   The overgrazing also contributes to the need for more maintenance of the conservation structures. For diversion which are generally built between the grassland and the cropland, on overgrazed grass-

land catchment will contribute much more silt to the diversion which will then have to be cleaned more often or the diversion will be subject to breakage and the creation of more dongas. On grassed waterways the silt from an overgrazed catchment will also tend to build the waterway level up above the surrounding land whereas the high flow of water associated with overgrazing will tend to make dongas in the waterway.

Rock structures are also endangered by the high flow associated with overgrazed catchments.

Overgrazing also makes it extremely hard to heal the existing dongas. We build rock silt traps in dongas but if grazing is not restricted in the donga and the donga catchment these structures may be short lived and/or ineffective. On the other hand there are a number of examples of dongas in Lesotho that have been healed simply by excluding grazing for 2 - 3 or more years.

Overgrazing also contributes to erosion in the cropland areas. One way is that the use of all the crop residues for fodder means that very little crop residue is returned to the soil. This loss of crop residue to the soil means that the soil is less fertile. infiltrates less water and is more easily eroded.

The overgrazing also means that the oxen are weak in the spring and it is very hard to get the farmland ploughed at the right time. This leads to lower production of crops which means greater soil loss through erosion.

It is a viscious cycle which is destroying Lesotho cropland and grassland and can only be broken by a nationwide system of good grazing management.

5. Grass for Waterways. When the incumbent arrived in Lesotho in 1975, the only grass used in waterways was Kikuyu. This proved to be unsatisfactory for many locations. If the soil is heavy clay or otherwise droughty the Kikuyu will die out. If the soil is good there is a tendency for the Kikuyu to spread into the surrounding fields where it is hard to control. A couple of mixtures of grasses were devised and seeded in the waterways with mixed results. One mixture had too much teff in it which prevented the

other grasses from developing properly. It was somewhat of a problem to get the mixtures seeded at a time that would get the grass growing as soon as possible after the waterway was completed to prevent erosion, because of germination problems at most times of the year.

Later Erogrostus Curvula was used and satisfactory stands were obtained but it is not a good waterway grass by itself since it is a bunch grass and not as tolerant of high velocities as the rhizomincus grasses. This means that the waterways would have to be wider to keep the velocity low thus taking up more farmland. We have seeded some waterways with a mixture of Erogrostus Curvula and Bermuda grass and this should be very satisfactory for preventing erosion in the waterway but we don't know if both grasses will stay in the stand over a period of years.

We have done some sodding with Erogrostus and Bermuda but the Bermuda is generally hard to find for sodding purposes.

Another problem with the grass waterways of course is that they are overgrazed if they are not fenced. Fencing is expensive and really not effective as they often cut the fences. We try to beacon the waterways and educate the people to realize the importance of not grazing them until the grass is well established, but they will still graze them at night.

This relates directly to the problem of overgrazing and I doubt if any waterway in Lesotho will be safe until the overgrazing problem is solved.

6. Outlets and Alternatives. (See Section 2.2A page 8 and 2.3D page 18.

2.3C DIVERSIONS

Diversions are similar to ridge and furrow terraces but larger. Generally their purpose in Lesotho is to intercept runoff from grassland or village areas and divert it to a safe outlet to reduce erosion on the cropland.

Often in the past we have tried to outlet the diversions into constructed grass waterways, instead of into dongas. The advantage of this that it greatly reduces the volume of flow in the donga thus

allowing it a chance to become grassed if overgrazing is concurrently stopped. The main disadvantage of using the waterways as diversion outlets is that we must make the waterways larger thus taking more of the farmland out of production. Occasionally the flow is so large that it cannot be accommodated in a waterway and then we must outlet in a donga.

When it is necessary to outlet in dongas we can reduce the erosion in the donga by building rock structure, for stream bank protection, and grade control. But as stated earlier the most effective method of preventing erosion in the dongas is to practice proper grazing management in the dongas and on the catchments that contribute runoff to them.

The design of diversions is based on the 10 year peak flow as are other conservation structures. As related in Section 2.3B 2, the AMC has a definite influence on the amount of runoff and this will affect the size of diversion hence its cost. We will continue to design diversions using the average of conditions AMC I and AMC II until enough data is analyzed to justify a change.

The peak flow is computed from the 10 year storm depth and these values are being revised by analyzing larger periods of rainfall records. When this analysis is completed a publication will be circulated to all relevant Divisions, Ministries and schools with the up-to-date depth-duration-frequency curves.

2.3D TERRACES

1. Size. According to the engineering design standards published in 1976 we design the terrace ridge and furrow to carry the runoff from a 10 year frequency storm with freeboard of 30 to 45cm depending on compaction. The depth of flow has been difficult to calculate in the past because of insufficient rainfall data being analyzed. This is being remedied and recommendations for depth of terrace will be published and distributed when computations are finalized.

2. Spacing. See Section 2.2C page 10.

3. Gradient. The engineering standards state that the grade shall be

that calculated to prevent sediment deposition and erosion. We are presently using 0.4% grade. For level terraces that are intended to receive the runoff from the cropland and let it infiltrate into the soil the gradient should be nil.

4. Rehabilitation. When the Thaba Bosiu Project first got under way the Thaba Bosiu Conservation Engineer looked at the existing terrace system in the project area and decided that the terrace gradients were so random that it was not feasible to rehabilitate them. We have continued with this policy of complete reconstruction in the Ministry, Conservation Division up until 1979. We are now taking a close look at any proposed terrace construction to determine if it is feasible to rehabilitate instead of reconstruct.

This change was brought about by a number of developments. One was the criticism we have received from a few sources that the construction of conservation structures was too high and that it could not be economically justified. Another was the very noticeable bench terracing that has taken place in many areas. Most of this bench terracing is due to throwing the plow slice down hill to the grass strip, bund or terrace ridge. The bench terracing helps control erosion and it is deplorable to destroy these benches if they can be used.

In an effort to determine if rehabilitation was feasible we picked out an area north of Leribe and conducted a topographic survey covering about 75 ha. When this survey was plotted it was determined that most of the terraces were near enough to being on the contour that they could be left in their present location.

We have since noticed some old contours on the Thaba Bosiu Project, where the labor construction unit was building terraces, that were on a very steep gradient. It is possible that the crews that laid out the terraces in the Thaba Bosiu Project 30 to 40 years ago did not do as good or as thorough a job as in other sections of the country.

Nevertheless we are now convinced that rehabilitation should be considered seriously in any area we start a terracing program.

Rehabilitation should reduce the cost of terracing which is the

single most expensive item in the conservation package. It should also greatly reduce the problem of land realignment.

Thaba Bosiu tried land realignment in two areas. In the first area (Ratau) it seemed to go fairly well, but in the next area it was a big problem. To properly do land realignment would take a great deal of time and effort with no guarantee that everybody would be happy. If we can eliminate the need for land realignment by rehabilitating existing terrace systems it will save us a lot of time and effort and the villagers a lot of grief.

Often the existing terraces that are benched especially if on Hydrologic Group A or B soils will require very little work. Often the bench has a reverse slope from the grass slope to the center of the terrace strip. Thus a terrace ridge does not have to be built except where there may be a low area that is letting water down to the next terrace.

5. Labour Intensive. (See Section 2.2F page) It has been brought out by Dr. Ron Wysktra in his publication, "The Use of Capital and Labour in Conservation Division Construction Work", that it is more beneficial to Lesotho to do conservation works by labour intensive methods even if it does cost more per unit. Since this publication came out the labour construction unit has shown that it can do terracing, waterways and diversions for less per unit than can be done by machinery under existing conditions in Lesotho.

   Labour intensive construction would be very beneficial in the rehabilitation of terraces discussed above since much of the work would be too small and scattered for efficient operation of machinery. It would also reduce the efficiency of the labour crews but probably not as much as the machinery - also if the rehabilitation work were too small to be attractive to the labour construction unit it could be done easily by Food Aid workers.

   The question of where the responsibility for labour construction work will be placed has apparently not been answered. The labour construction unit now housed at the Ministry of Works claim to be the implementing agency government wide for labour intensive construction. If this is in fact, or becomes, government policy we will certainly abide by it but we would feel that the respons-

ibility should be in the Ministry and Division that is doing the work especially if it will be a large program such as we foresee for the Conservation Division.

One reason to place the responsibility within the implementing Ministry and Division is the many implications that labour intensive works will have on our agricultural production.

Firstly, the labour construction work should be used as a tool to aid the agricultural production and not work as a deterent.

It could act as a deterent if the crews worked all year around and did not have time for ploughing, cultivating, or harvesting their crops, or if the wages paid were actually a disincentive to farming as mine labour and Food Aid labour so often appear to be.

The labour construction program could be used as an incentive if properly handled. Some of the ideas we have discussed to make it an incentive are as follows:

a) We could write a contract with each labourer much as they now do with the mines in which among other things we could agree with them that we would furnish them inputs such as cash, credit, fertilizer, seed, machinery, etc., if it were not readily available through the normal channels, they would agree to do a good job of farming and spend as much time on their farms as was necessary to do this. If they did not have land or leased it this would be considered. They would cooperate with government programs designed to increase crop and animal production, improve the health and welfare of the village people.

b) We would conduct information and education work with the men to increase their knowledge of proper farming and grazing methods.

6. Machinery. We have been using two motor graders furnished by the Canadian government to do terraces. This number is totally inadequate, since they can really work most advantageously on terraces during the winter months when crops have been harvested. Also they seem to be broken down a large amount of the time and

it takes a long time to get them repaired.

In an attempt to alleviate this we are using disc plows which make terrace ridges rapidly. The problem with the disc plow is that they do not make good enough furrows for water conveyence or storage. To overcome this we have tried using tandem scoops but they are relatively inefficient for this type of work. We have also tried a pull grader but the big problem is getting some one trained to operate it properly.

Another alternative is to use labour to excavate the furrow. If we could use labour and disc plows together it would make a much better job since the tractor compacts the ridge very well, which labour does not do and the labourers can excavate the channel which the disc plow cannot do. The problems with this approach is the money to pay the labourers. Our existing funding does not provide for labour of this type and magnitude.

Another piece of machinery that would be very useful in terrace rehabilitation would be a "Bob Cat" which is a small 4 wheel drive tractor with a small front end loader.

7. Standards and Specifications. The existing standards and specifications cover graded terraces only. These should be revised and additional standards written for level terraces with the additional provision in each that the spacing formula can be modified by results from the Universal Soil Loss Equation.

8. Alternatives. (See Section 2.3B 6 page 17)

A practice that would be very beneficial in getting rainfall into the soil and preventing erosion would be furrowing of maize. The predominant practice of ploughing and planting in the ploughed ground is very beneficial as far as erosion is concerned, but a great deal of additional benefit could be obtained if a large shovel were used on the rear of the maize cultivator to create a furrow. This would store much of the rainfall until it could be infiltrated into the soil. There would be no runoff from most rainfalls, hence no erosion plus more water would be stored in the soil for plant growth. One requirement of this practice is that the farming must be on the contour or the furrows will cause

more erosion instead of less.

Another alternative of using grass strips or contour strip cropping has been suggested. Grass strips 2-3 meters wide will do very little if any good to prevent erosion except that they do catch some silt as the runoff goes through them. They do not reduce the length of slope as terraces do hence the water going down the slope increases in quantity and velocity and therefore has more erosive power. The one large benefit of grass strips is to keep the people farming on the contour, and this practice does reduce erosion considerably.

Contour strip cropping where the grass strips are equal in width to the cropland strips is much more beneficial than narrow grass strips but it does not eliminate the need for terracing on many slopes and soils.

2.3E RAINFALL - RUNOFF RELATIONS

To be able to properly design any conservation structures we must have some estimate of the amount of water they will be required to carry. With catchments of 10 square kilometers or more this information can be obtained from the Hydrology Section of the Ministry of Water, Energy and Mining. The catchments that we deal with are always much smaller than this therefore we must rely on a prediction equation.

1. Formulae. When this writer arrived in Lesotho the Thaba Bosiu Project Conservation Division personnel were using a modified USDA formula suggested by Norman Hudson. It did not seem appropriate for Lesotho since its rainfall factor were so general as to try and cover all of Southern Africa. Therefore we adopted the USDA - SCS method contained in SCS-TP-149. Doubt was cast on this formula by Professor Schmidt of the University in Pietermaritzburg but no better alternative has been suggested. He was particularly concerned about the Antecedent Moisture Condition (AMC) and the changes in cover conditions with time. Our own findings on this are outlined in Section 2.3B 2. In 1979, Mr. Mochochoko made an evaluation of the various methods available for calculating runoff from rainfall and concluded that the

USDA-SCS method was still the best one available for Lesotho.

LASA is working on a computer program for predicting soil moisture that has a runoff component. When this program is operational we should evaluate its possibilities as a runoff prediction method.

2. Antecedent Moisture Condition (AMC). See Section 2.3B 2 page 14.

3. Depth-Duration-Frequency Curves. The normal method of determining runoff from rainfall for conservation structure design is to find the depth of rainfall that will probably occur once in ten years, and use this amount in a suitable rainfall-runoff equation as discussed above. During this writer's first tour of duty in Lesotho, Depth-Duration-Frequency Curves were computed and drawn, using rainfall data that was available in Lesotho. This was only that data from Independence in 1966 to 1976, the time when the calculation were made. This is too short a period of record for accurate curves but it was a good first estimate. Since then Mr. Mochochoko analyzed some longer record for his comparison of different runoff prediction equations.

   Also during the writers first tour, the rainfall records from the years previous to 1966 were secured from Pretoria and also a micro film reader printer was secured with USAID funds to process the records. We are now in the process of using these much longer records to recalculate the Depth-Duration-Frequency Curves. Many of the records date back to the 1920's thus we should have very reliable estimates of the storms depths when these calculations are complete.

4. Catchment Yield. The amount of runoff to be expected from a catchment will vary with the size of catchment, the rainfall pattern, the soils and the cropping pattern. On large catchment (10 km² and above) the yield has been estimated by Mr. H.L. deBaulny in a publication issued by the Hydrologic Branch, the Ministry of Water, Energy and Mining. On the larger catchments the size catchment and the amount of annual rainfall are the most important factors determining the amount of yield. On smaller catchments the soils and cropping pattern and rainfall pattern enter

in as very important factors.

One of the rainfall pattern factors is the amount of rainfall that comes in the days immediately preceding a major rainfall. This was discussed in section 2.3B 2. The cropping and grazing practices also have an effect on the smaller catchments with which we are concerned.

Practices that are considered bad for crops and grassland will generally mean a higher yield whereas good conservation cropping and grazing management practices will lead to a reduction in yield.

Artificial catchments are a possibility for water supplies for livestock and villages. These catchments can be constructed from galvanized steel, plastic, tar, clay, termite mounds or other water shedding materials. Bare rock areas can be utilized to fill reservoirs since they will yield the maximum possible amount of runoff.

The runoff from catchments whether natural or artificial is useful for many purposes including fishponds, irrigation, and domestic water. An estimate of the amount of runoff to be expected during average and dry years is necessary to be able to predict the size of storage reservoir necessary to fill the expected need. From the factors previously discussed such as the Antecedent Moisture Condition, the cropland and range condition are being evaluated to increase the reliability of our predictions for the catchments. Further work needs to be done and more catchments should be instrumented like our Upper Matsieng fishponds to increase the accuracy of our predictions.

5. Moisture Conservation. The new USAID Land and Water Program which is to begin in 1980 points up the need for emphasizing moisture conservation. This means retaining the rainfall on the land which will generally increase crop and grass production and decrease erosion. As is pointed out on page 195 of the "Conservation Ideal", as much as 50% of the rainfall received on the land can be evaporated from the bare soil between plants. It was found that a mulching practice would conserve approximately 152mm of the moisture that would otherwise be lost to evaporation and

this would greatly increase crop yields.

The primary objective of the Ministry is to increase production and one of the least expensive methods we have for doing this is moisture conservation. We should be emphasizing this in our conservation plans, and the methods that can be used to increase moisture conservation, the main one being the retention of crop residue on or near the soil surface.

2.3F IRRIGATION SYSTEMS (See Section 2.7)

2.3G DAMS

In the years immediately prior to the initiation of the USAID Land and Water Resource Development Project in 1979, the Conservation Division had been building many small dams and a few large ones. Some of the larger ones were Thaba Phatsoa, Sebaboleng, and Leloaleng. With the advent of the USAID project, priority was directed to building waterways, terraces and diversions. Since 1974 some dams have been designed but very few were built.

1. Cana High School. A dam was designed for the Cana High School by Mike Nyquist. It was to serve as a storage and diversion dam for a small area that the high school would like to irrigate. It has not been built because they have not been able to secure the necessary funds.

2. Thaba Bosiu. A dam had been planned for the Ratau area of the Thaba Bosiu Project to serve as a recreation area and to store water for some fishponds. The site was investigated by the Thaba Bosiu Conservation Section and later by the Soils and Engineering Sections of the MOA Conservation Division. A design was prepared by Mike Nyquist and construction was initiated under his direction. In the attempt to excavate for the cutoff trench, it was found that there were numerous springs in the foundation area and the construction was cancelled.

3. Upper Matsieng. In 1976, we were requested by Alistair Tedder, then head of the Fisheries Section, Livestock Division, MOA, to look at the feasibility of building walls around 2 pans on the plateau above Matsieng-Morija. Piet Bonnema and I looked at the

site with Mr. Tedder and agreed that it looked feasible and that we would investigate the site. John Lepele checked the soils at the wall locations and we decided that a core would need to be placed on the bedrock since the soils were very sandy. An estimate of the runoff from the catchments indicated that there would be sufficient runoff to fill the reservoirs once they were built.

USAID had provided funds to hire labour for conservation work therefore we decided to build one of the dam walls with a labour gang and the other with machinery. The core material for both walls was excavated from the bottom of the lower pan.

The labour construction of the lower pan took about one year to complete and proved to be very expensive. The one advantage of the labour construction over the machinery was that the labour method took about 1/3 or less core material since the core trench was only about 1 meter wide. The core trench for the machinery on the other hand was about 3 meters wide.

We were somewhat concerned about leakage from the reservoirs therefore we installed depth measurement markers on the side of the monk towers. Also we installed a weather station with rain gauge, evaporation pan and anemometer. From these measurements we were able to determine that all of the loss from the reservoir was by evaporation and there was no leakage.

The years of 1976 and 1977 were above average in rainfall but 1978 was not and it became apparent in 1978 that we were not getting the runoff that we had predicted. This led to the investigation into AMC as already mentioned in Sections 2.2D, 2.3B 2 and 2.3E 2.

2.3H HOUSING

1. The conservation housing at Lithabaneng was originally planned with the idea that the effluent from the houses would be collected in a concrete tank, then pumped out every week or two. There turned out to be more effluent than was estimated and the collect[illegible] by the trucks was unreliable, therefore engineering was asked [illegible] system t[illegible] would take the wash water in a sep[illegible]em to be disposed of elsewhere. This was done but it [illegible] lengthy, expensive project.

2. Houses built by the Conservation could be easily improved to be more comfortable and useful with a little planning and engineering. The Operations Section does not have the personnel to do this but the expertise is available in the Planning, Soils and Engineering Sections.

3. The proposed Conservation Office for Leribe has been surveyed by Engineering and we are working with the Operations Section to design a suitable building.

4. The above examples point out the need for closer consultation and cooperation by the Operations Section with the other Sections in the planning and design of buildings.

2.31 STRUCTURES

Most of the structures installed in the past few years have not been designed by the Engineering Section. This has partly been due to a shortage of personnel and the fact that rock structures had a lower priority than other items such as waterways and diversions. Many of the structures were silt traps installed by Food Aid workers and sometimes with inadequate supervision by the project personnel or the project personnel did not have adequate training in the construction of rock structures.

1. Gabions. A large number of gabion structures have been built by the Conservation Division in Lesotho. The advantages of gabion structures are that they can be filled with small rocks that would not be suitable for loose rock structures, and the gabion structure will generally be safer than a loose rock structure or concrete structure since it is flexible and will settle without loosing its effectiveness. The disadvantages to gabions are that they are expensive, subject to vandalism and corrosion and do not give the people a structure that can be built with local materials only.

2. Loose Rock. Loose rock structures are common in Lesotho and are reliable when properly designed and built. There have been numerous failures of loose rock structures in the past, but it was generally due to poor or no design and to building them in dongas that had too high a flood flow or making the structures too high. Loose rock structures are ideally suited to Lesotho since rock is

almost everywhere available. Sometimes rock of a large enough size are not readily available but gabions can be considered in this instance. Standards for loose rock structures were recently completed.

3. Concrete. Concrete structures have been used mainly by the Khomokhoana Project Conservation Section. The Engineering Section feels that concrete should not be used except in unusual situations since it involves importing cement and the local sand is of poor quality for concrete.

4. Outlets. Outlet structures for grassed waterways are necessary in most of the projects in Lesotho. They are a continual problem because the vertical distance from the end of the waterway to the waterway to the bottom of the donga or river is often large and also the soils in many locations are poor for rock structures.

   A. Thaba Bosiu. The Thaba Bosiu Conservation Division built a number of rock outlet structures in the first few years of their project. Some of these were of the hewn block type, but these are time consuming to build.

   B. Gabions. A number of large gabion outlet structures have been built in Lesotho. Some have had to be rebuilt once or twice because of inadequate design or improper construction. The useful life is questionable under Lesotho soil conditions. They are also expensive thus increasing the need to consider alternative ways of disposing of excess runoff.

   C. Drop Structures. Most of the outlets built in the past have been drop structures whether they were of loose rock, hewn rock or gabion construction with the exception of one concrete structure on the Khomokhoana Project which was of a chute spillway type with a cantilever outlet.

   D. Chutes. An an alternative to the drop spillways with their inherent problems of stability, and construction we are exploring the use of chute spillways constructed of loose rock. There should be less risk of failure with the chute spillways since the floor of the spillway is on a flatter slope than the angle of repose of the rock therefore any settling of the rock should

not immediately endanger the structure. The first chute spillway of loose rock will be built in the third unit of the Kolonyama Project in early 1980. It will be followed by one or two more in the same area using the experience of building the first one to make any design changes.

E. Cantilever Pipe. We have installed a cantilever pipe outlet for three waterways in the second unit of the Kolonyama Project where there is a long drop to the Caledon River. We have considered using cantilever pipe outlets for individual terraces into dongas but none have been installed yet. One problem we are concerned with for the small pipe outlets is the possibility (probability) of their being plugged by rocks. (herdboys, etc.) Maintenance would be much more critical than with open rock structures.

5. Policy. To alleviate some of the problems we have had in the past with lack of proper design, improper construction etc., a policy memorandum has been issued relative to engineering design. Engineering Memorandum No. 3, Engineering Designs, sets out who will be responsible for different sizes and types of structures as far as design is concerned. This policy designates the Engineering staff as the ones responsible for designing or approving designs for gabion structures and other complex designs. Thus no more gabion structures should be built unless the design has first been approved by the Conservation Engineer or his designee. The above memorandum was signed by the CCO, September 17, 1979.

.3J FISH PONDS

The Conservation Division has assisted the Fisheries Section of the Livestock Division in planning and designing fish pond projects.

1. Upper Matsieng. As mentioned earlier under Section 2.3G 3, we were involved with the Upper Matsieng fish scheme since its inception. We are still assisting the Fisheries in trying to get the scheme operational. They were concerned a few weeks ago that the ponds were leaking excessively and we drilled a few holes to try and find if there was any excess leakage. We could not find any leakage and the filling continued. They still seem to lose

water but we have not been able to ascertain where it is going. The road to the fish pond scheme is long and hard to maintain. An alternative has been suggested.

2. Ts'akholo. We have assisted the Fisheries a great deal in investigating, surveying and designing for the proposed 40 Ha scheme. Economics has reduced the scheme to 10 Ha which still is not assured of funding. It seems that large fish schemes are uneconomical in Lesotho under present cost and price conditions.

3. Other. We occasionally have requests from people in our projects for a small fish pond scheme. When this happens we work with the Fisheries personnel to determine if it is a feasible venture and if so the best way to proceed.

2.3K TRAINING

We have been training field personnel in design procedure since 1976. This training has accelerated with the transferring of Jean Fowler to Maseru, since one of her priority jobs is the training of field personnel in engineering skills. This training should continue since the field personnel will do a better all around job the more they understand of each phase of their work.

2.4 CONSTRUCTION INSPECTION AND APPROVAL

2.4 A. POLICIES AND PROCEDURES

Engineering Memorandum No. 4, Construction Approval covers the policy of the Conservation Division relative to the inspection and approval of conservation measure construction. The bulk of the inspection work will need to be done by field personnel as part of their routine supervision of construction.

B. TRAINING

This will entail proper and adequate training of all field personnel to insure that they are able to do the job. The memorandum also calls for certification of the field personnel once they are adequately trained. This will require a systematic

evaluation of all field personnel by the Engineering staff and others.

2.5 COOPERATION WITH THE CONSERVATION OPERATIONS OFFICER

The work of the Engineering Section and the Operations Section are so inter-related that close cooperation between these Sections is necessary to obtain optimum results. The heads of these Sections, as is true of the other Sections, should be willing to work for what is best for the Division as a whole and not for their own Section or personal interests.

2.6 STANDARDS AND SPECIFICATIONS

Engineering standards and specifications for most of the common conservation practices were published in 1976. One additional pratice (Rock Structures) was added in 1979. These standards and specifications need to be revised and updated to include the experience gained over the last three years.

In addition there needs to be a concerted effort on the part of the Engineering Section to see that all field personnel are aware of these standards and specifications and use them for design and construction.

Engineering Memorandums No. 3 and 4 require the use of these standards and specifications in all Engineering design and construction done in the Conservation Division.

2.7 ENGINEERING CONSULTANT

2.7A PHUTHIATSANA PROJECT

This writer has served as an advisor to the Phuthiatsana Irrigation Project since 1976. This included being a member of the committee that evaluated the consultants that tendered for the Irrigation Project and the Levestock and Conservation Project.

We then worked with the consultants Montreal Engineering and Booker International as they carried out their investigations. When the Ministry decided to rewrite the Project in 1979 the Engineering Section assisted in the sections on irrigation and conservation. As

part of this assistance we have done engineering surveys and preliminary dam site investigations, as well as other site investigations in relation to the irrigation aspect. We are in the process of trying an experimental infiltration gallery to facilitate irrigation from the river during low flows. We have also looked at the feasibility of using run-of-the-river flows for irrigation.

2.7B MINISTRY OF RURAL DEVELOPMENT

Assistance has been given to MINRUDEV in the form of advice on job descriptions for a Volunteer Conservation Engineer for their Conservation Section, copies of pertinent design publications, advice and training as requested.

2.7C CANA HIGH SCHOOL

After receiving a request from the High School for advice on erosion control, drainage and irrigation, we made a detailed topographic map of the school site and made numerous trips to give them advice on various aspects. A dam was also designed, see Section 2.3G 1. We are currently advising them on the installation of a pump and motor for their water system.

2.7D HOLOLO PROJECT

We have worked with the Irish on this Project since its inception furnishing maps, drawing room services, project visits, surveys and advice on erosion control.

2.7E KHOMOKHOANA PROJECT

Prior to the departure of the FAO Engineer little help was requested from this Project. Since then we have furnished an engineer (see Section 2.1C), surveying and design help and visited the Project as requested. The future of this Projects' activities is now being discussed in the Ministry since it has ceased to operate as a funded Project.

2.7F BASIC AGRICULTURAL SERVICES PROGRAM

We have worked with the BASP since it's inception mostly on the road construction planning until their roads engineer comes to post. We have since worked with the BASP roads engineer furnishing him with

survey help as requested. We also attended a number of BASP advisoring group meetings.

2.7G LIVESTOCK DIVISION

The work of the Conservation Division and the Livestock Division is necessarily concerned with some of the same objectives since high animal production, and animal health are dependent upon a high production from the grassland and a high producing grassland has a low erosion potential.

1. Quthing Sheep Stud. We have made numerous trips to the sheep stud in an attempt to get the pump operating, which is used to pump water from a stream to a tank on the plateau. The problem has been isolated and now awaits repair by a qualified mechanic.

2. Fisheries. As already mentioned above under Section 2.3G and 2.3J we have had a long and detailed involvement with the fishery schemes at Upper Matsieng and Ts'akholo and other small schemes.

2.7H ABATTOIR

We have worked with the Livestock Procurement Officer of the abattoir scheme in designing an irrigation system to dispose of effluent from the plant. This assistance is continuing.

2.7I TEYATEYANENG RESIDENTIAL FLOOD PREVENTION

At the request from a group of people in TY we designed a surface drainage system to safely dispose of storm runoff. Lack of funding has delayed construction.

2.8 WORK WITH CONSERVATION PLANNERS

The work of the Conservation Planners necessarily precedes that of the Engineers. We have cooperated with the Planners to assure more effective conservation on the ground.

2.8A OUTLETS

As mentioned under Section 2.3I waterway outlets have been one of our most vexing problems. We have reviewed plans with the Planning Section to arrive at the best solution under different conditions. Sometimes it must be solved by picking the best alternative structure

for an outlet. At other times alternate outlet sites can be located or the use of waterways may be eliminated entirely.

2.8B UNIVERSAL SOIL LOSS EQUATION

If we could rely on the factors in the USLE to closely estimate soil erosion in Lesotho it would be a valuable tool for the Planning Section, and could probably replace the Land Capability Unit classification for most Conservation Planning. The Engineering Section has been working on the USLE factors for almost four years and we feel that they are probably about as accurate as we can get without a few years of research data. The National University of Lesotho is setting up some research plots at the Lesotho Agricultural College but data from these will not be available for a number of years especially if they rely only on natural rainfall.

1. Alternatives to Terraces. The possibility of doing without terraces or replacing them with grass strips or contour strip cropping is often brought up. The USLE will generally show that there is no satisfactory alternative to terracing on most soils and slopes found in Lesotho. It will show which soils and slopes can be treated by alternative methods and what cropping practices we should be using to reduce erosion to the minimum.

   There is a question of the effect of slope length and steepness on erosion under African conditions, but without field research we cannot assess these factors.

2. Crop Rotations. Growing one type of crop on a field year after year is conducive to excess erosion whereas a rotation that includes fodder, legumes and/or grasses will keep erosion to a minimum. The use of the USLE will point out quantitatively the difference in soil lost from fields where different rotation systems are used. The use of rotations suited to different soils and slopes should be encouraged by the Planners. The question of soil moisture conservation should also be addressed. (See Section 2.3 E5).

3. Steep Slopes. There are many farmers in Lesotho that are farming slopes that are too steep according to our Land Capability Unit Classification. It will be extremely hard to stop these people

from farming these steep slopes and I would suggest as an alternative that we can point out alternative practices that will greatly reduce the soil loss on these steep slopes. We may not be able to reduce the losses to what we would consider acceptable levels, but we could certainly reduce them a great deal from their present levels.

As an example with terraces and contour strip cropping with 1/2 the land in grass strips the erosion would be minimized and very little soil would actually leave the field. The USLE is an indispensible tool in any of the above mentioned alternative suggestions, although as mentioned above, we need research data to refine the factors in the USLE.

2.8C SOIL LOSS ESTIMATOR FOR SOUTHERN AFRICA (SLEMSA)

The Rhodesians tried for a number of years to adopt the USLE to Rhodesian conditions. They claimed that it was not suitable for their conditions and devised a system of their own called SLEMSA. The Southern African Regional Commission for the Conservation and Utilization of the Soil has decided to use SLEMSA for this region instead of USLE, therefore it would be to our advantage if we were prepared to use this system also since a great deal of information relative to its use will be available from neighbouring countries. The Engineering Section has been calculating the rainfall factor for use in this equation and the Planning Section could avail themselves of this formula for planning uses also.

2.8D IRRIGATION

The Conservation Division is certainly interested in the welfare of the village people and in our planning and engineering work for conservation, I think we should be on the lookout for suitable dam sites near villages. Many villages are located such that the women must carry water for domestic uses from a great distance. This generally does not leave them with time or energy to carry water to their vegetable gardens. If nearby water were available for vegetable gardens they would have more incentive to raise and care for these gardens and thus supplement their food supply which for many families is at its lowest in the spring and summer months. The village water

supply section of the Ministry of Co-operatives and Rural Development are doing some small irrigation schemes in connection with their domestic water supply schemes and we should work closely with them.

We should also be careful in our planning not to design diversions unless necessary because it may be on some soils that the runoff from the grassland and escarpments would be more beneficial as supplemental irrigation water than it would be detrimental as far as erosion is concerned. This should also be considered in the design of terraces, such as using flat channel terraces where possible to keep the rainfall on the land.

2.9 SURVEY, DRAFTING, DESIGN AND CARTOGRAPHY

2.9A SURVEY

Engineering surveys are generally concerned with design surveys for dams, terraces, diversions or waterways and occasionally with property surveys. It is important that the personnel doing the surveying are properly trained, otherwise a lot of survey, design and possibly even construction time may be wasted, because of improper information going into the design. (See Recommendations No. 4, Section 2.3A 5, and 2.1C).

The surveying equipment needs to be handled carefully. The levels, transits and theodolites are expensive and easily damaged by careless handling or by attempted repairs by unqualified people. We should possibly consider a short training seession for the Conservation Engineer (local) on the maintenance and repair of our instruments. Perhaps this could be done by one of the repair firms in Johannesburg.

2.9B DRAFTING

The drafting room personnel are mainly concerned with tracing maps, lettering booklet covers and other items and reproducing maps and letter size documents by Xerox or blueprint machine. In addition designs are drafted from the engineer's sketches of structures, etc. and some planimetering of areas is also done.

The bulk of the work is not of a highly technical nature and does not require a great deal of training. Most of the personnel are

daily paid and are given on the job training to enable them to do the basic jobs.

The incumbent head draftsman has received formal training in drafting (communications) in Malawi, and is able to do conservation engineering drafting with some help from the engineers. Another draftsman is now enrolled in a drafting course in the USA and will return in 1981.

The newly formed Range Division is apparently setting up a drafting and mapping section. Whether they will have enough work to justify a full section remains to be seen. I would think that one drafting section would be enough for the Ministry of Agriculture, but perhaps this can be looked at more closely in a few years when the Range Division is settled down into a routine.

Equipment in the drafting room is a constant problem. It is being lost or misued and is expensive to replace. Perhaps we need to consider a storeroom where equipment is signed out to a person and they must pay for it if it is damaged or lost.

2.9C MAPPING

The Drafting Section also takes care of the storage and indexing of the contact prints from the various flights, i.e. 1962, 1975-76, and 1979-80. It is sometimes called a cartographic section, but this is a misnomer because the sophisticated equipment and facilities used by a cartographic section are neither available nor necessary. Reproduction of aerial photos is by a firm in Johannesburg and some facilities are available at the Lands and Surveys Section of the Ministry of Interior.

The Planning Section stores the photo enlargements for the various projects except for the soils photos which are stored in the Soils Section.

Various national, district and project maps are also filed in the drafting room. Ortho photos (aerial photos with elevation contours) will be made for the lowland-foothill area. The photography for this was initiated in 1979 and should be completed by 1980. The 1:5000 enlargements should begin arriving in 1981 and be completed by 1982. These photos will greatly improve our ability to

plan and design works in the lowland-foothill area. The best available maps now are 1:50,000 scale with 50 meter contours. The 1:20,000 maps with 30 meter contours are being prepared and should be available next year. The 1:20,000 were requested under the BASP program for planning purposes.

The Lands and Surveys Section does have 1:5000 and/or 1:2500 maps of the main villages and their immediate areas that are useful when we are working in those areas.

In cooperation with the CCPP we tried to measure fields using the 1976 photo enlargements. We discovered that the scale of these photos varied from 1:9000 to 1:11,000 or more between photos and also within individual photos. It was finally decided that we would have to use planetable surveying to obtain sufficient accuracy. When the 1:5000 orthophotos are available they will be much more accurate and can reliably be used to measure areas of fields. This will require well trained and conscientious planimeter operators but it is a much faster and less expensive procedure than plane tabling.

2.10 RESEARCH

The Conservation Division is an implementation oriented arm of the Ministry of Agriculture but through lack of research data and personnel we have been forced to do some research oriented activities.

On page 77 of the LASA Research Report No. 3, is a quote from a paper by Qalabane K. Chakela which says in part, "another striking feature of these schemes (area based agricultural projects) is the lack of hydrological data and analysis. The only thing of main concern seems to be soil, soil and nothing but soil (of studies on Khomokhoana). How the erosional processes can be dealt with without hydrological data is a puzzle, as water is the main driving force in this process".

From the same publication (LASA Research No. 3) on page 149 (last paragraph) it states "another project objective not provided in the PROP (for the Land and Water Conservation Project) was a research component. While both the training aspects and

the various action programs did envision some data gathering activities. The distinction between that function and research per se was apparently not clearly recognized. Further there was an apparent faith that the research and technology developed elsewhere could be imported and easily adopted for use in Lesotho. In this regard the PROP states: 'The Basic Information relative to the relationships between climate rainfall, soil types, slope of land and erodibility is in general well known. Worldwide studies are available for use by the land use planning staff and the Conservation Engineer as they adopt this technology to the conditions of specific water sheds under analysis'. Personnel well versed in research methodology will recognize the weakness in these assumptions".

One of the LASA recommendations in Research Report No. 3 was (Page 157 (2)) "Develop a continuing soil and water research and basic data collection network within the MOA".

Again on Page 173 they have, "Reduced Sedimentation. A research program should be established now to investigate major erosion and sediment source areas, delivery processes and possible control practices in channel and near channel areas".

I would heartily endorse the above observations and recommendations. In the absence of a research program we have done the following to enable us to do better designing, consider alternatives and make recommendations that will increase crop and grass production.

2.10A DEPTH-DURATION-FREQUENCY CURVES

(See 2.3E3, page .) Additional rainfall records are now being analyzed to draw more accurate D-D-F curves. These should be available for publication in early 1980. These curves should should also be of use to design personnel in the Ministries of Works, Co-operatives and Rural Development and Water, Energy and Mining.

2.10B R FACTOR FOR LESOTHO

In order to arrive at the optimum method of reducing erosion on cropland an empirical formula called the Universal Soil Loss

Equation (USLE) has been derived in the U.S.A. At the urging of Mr. Robert Flannery, Conservation Lecturer at the Lesotho Agricultural College, the Engineering Section began analyzing rainfall data in 1976 to compute the rainfall (R) factor for use in the USLE in Lesotho. This has been a slow tedious process because years of data need to be transfered from the charts of automatic rainfall recorders then calculated. We began with the records from Maseru, then Oxbow and Lets'eng-la-Draai.

The mountain stations showed a much lower rainfall erosivity even though the rainfall was as high or higher than the lowlands therefore we only had one station in the lowlands with records of sufficient length to be of any value. To partially overcome this limitation we have obtained records from Wepener, Bethlehem and Ficksburg.

Analysis of these records indicate that the R factor calculated for Maseru is too high. This could be true because of the three years of exceedingly high rainfall in the Maseru records and the length of record not being long enough to even out these high years. Preliminary projections indicate that the computed R for Maseru would be lowered by 20%± if we had at least 20 years of record.

We feel that the R factors now calculated are sufficiently near the average to enable us to use the USLE in Lesotho.

There are a number of additional recording raingauges in Lesotho but it will be a few years before enough data is available from them to be more confident in the value of the R factor. The recording raingauges are located at Mafeteng, Mohale's Hoek, Ha Seeiso (Mafeteng District), Maputsoe, Corn Exchange (Leribe District), upper Phuthiatsana catchment (3 each) and Roma.

It may take 10 to 15 years before these stations can contribute any meaningful data to refine the R factor.

One item of concern about the R factor is the influence of the Antecedent Moisture Condition (AMC). Mr. Wischmeier has stated that the AMC is taken into account in the USLE, but this may be true for the USA and possible not for Lesotho since we have shown the AMC here is dry compared to the USA.

Hopefully the research plots being set up by Mr. Seithleko at LAC will be able to help us evaluate this factor.

2.10C C FACTOR FOR LESOTHO

To use the USLE for Lesotho we adapted the cropping management (C) factor to fit Lesotho conditions of rainfall and crop management. Whether this paper adaptation is correct is open to question but the only way to determine the "C" factor with any certainty is with experimental plots. Threee plots were initially set up at LAC by Mr. Flannery but the installations were not complete so no data was forthcoming. Mr. Seithleko is using these plots plus others to begin his erosion experiments. Hopefully in a few short years we will have some meaningful data from these plots for re-evaluating the C factor.

Meanwhile the new USDA Booklet on the USLE, Agriculture Handbook No. 537 contains an improved method of calculating the C factor. We will use this to improve the C factors as originally calculated.

2.10D CATCHMENT YIELD

(See 2.3B 2 and 2.3E 4).

Further catchments on different soils and in different areas than Matsieng-Morija should be instrumented to increase our knowledge of catchment yield for small agricultural catchments.

2.10E ANTECEDENT MOISTURE CONDITION (AMC)

(See 2.3B 2, and 2.3B 3).

The effect of AMC on peak runoff, catchment yield and the probable effect on erosion is discussed elsewhere. Field research should be conducted in Lesotho to more accurately determine the relationship between AMC and these rainfall effects as it bears on almost every facet of soil and water conservation.

2.10F LEVEL TERRACES

We are now using level terraces on Hydrologic Soil Groups (HSG) A and B to conserve moisture and reduce the need for waterways

and outlets. The possibility of using level terraces on HSGs C should be investigated and tried as it would possibly reduce even further the need for waterways and outlets. The two problems would be waterlogging during wet periods and the possibility of over topping.