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AN EVALUATION OF THE WINTER SNOWPACK AUGMENTATION PROJECT IN MOROCCO

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CONTENTS

		Page
I.	Executive Summary	1
II.	Introduction	4
III.	How the Assessment was Conducted	5
IV.	Project Background and General Status	6
	Objectives	7
V.	Scientific Design and Evaluation	8
	Introduction	8
	Scientific Problem	10
	Instrumentation and Development of Scientific Capability and Research Efforts	11
VI.	Implementation	17
	Introduction	17
	Project Sites	17
	Summary	22
VII.	Field Operations	23
VIII.	Institutional Arrangements and Management	24
	Introduction	24
	Institutional Arrangements, Development and Support	25
	Project Management	28
IX.	Technology Transfer and Training	29
X.	Water Resources Planning and Management	33
	Introduction	33
	Impact-Related Studies	34
XI.	Key Issues and Recommendations	36
XII.	Appendix	41
	a. Agenda for Review	41
	b. Figures	44

-1

AN EVALUATION OF THE WINTER SNOWPACK AUGMENTATION PROJECT

I. EXECUTIVE SUMMARY

A 2-week project assessment by a 3-person external review team was conducted in April 1985, the end of the first year of the Winter Snowpack Augmentation Project in Morocco. The evaluation assessed the progress and problems, and developed recommendations needed to improve the scientific, technical, and institutional aspects of this $12 million, 5-year demonstration Project funded by USAID and Morocco.

The project's goal is to develop and use a scientifically-based weather modification project to improve Moroccan water supplies. The purpose is to develop capabilities to design and execute a scientifically-based weather modification program in Morocco.

The project is ending its implementation phase, revealing excellent progress. The U.S. equipment installations, staffing, and training are on schedule, and Moroccan commitments of facilities, equipment and staffing have largely been fulfilled. Field operations including cloud seeding missions on 16 days were accomplished in the winter-spring seasons of 1984-85. These operations have served as an excellent shakedown and training period, and have yielded badly needed weather data sets (radar, satellite, and aircraft) for planning future operations and the scientific research which is just beginning in the U.S. and Morocco. Progress in training and technology transfer is on-schedule with rapid learning by well-trained and highly motivated Moroccan meteorologists and technicians. In addition to its excellent progress, the supporting agencies are still committed to the project, and the project management bodies and individuals are reasonably well organized.

This project is well known to atmospheric scientists in the U.S., as well as to the international weather modification community. It is recognized by these groups that a successful weather modification project anywhere must be based upon sound scientific principles. It is therefore essential that this project embrace essential, high quality scientific research. In our review, we focused on the present scientific and related technical planning, and on needs to address the key scientific issues.

The project will have a greater liklihood of achieving its stated scientific goal if the recommended additional scientific measurements and studies are made (Chapter V). The progress in training indicates a high liklihood of attaining the stated project purpose.

The major problems encountered in the formative year were (a) difficulties in coordinating field operations, and (b) inadequacies of the cloud seeding system. The major field activities were located and operated at four widely scattered sites. Poor communications between sites led to inferior operations during many precipitation periods, and kept project personnel from all important interactions needed for learning and planning. The cloud seeding was accomplished by Moroccan Air Force aircraft that for various technical reasons were limited for desired long-period and night operations.

Recommendations:

1. Consolidate operations by locating project aircraft at Casablanca, and by performing numerous other site actions to improve communications, training, maintenance, and general coordination. This is an effort seen primarily as the responsibility of GOM.

2. Do airborne seeding with aircraft capable of all weather flight conditions (GOM); provide for installation of special meteorological systems on 2 aircraft (U.S.); train at least 2 pilots in cloud seeding techniques (U.S.); and inititate data collection and studies by U.S. scientists to develop, install, and test a ground-based cloud seeding system in the mountains to supplement the aircraft seeding.

The shift to more complex future operational efforts and the initiation of several research studies raises five issues that need to be addressed. These issues and their related recommendations follow:

A. Clarification and prioritization of the project objectives is needed to define future project directions, to help set funding priorities, to improve agency interactions, and to guide future operational choices. There are at least nine objectives of varying nature, some non-complementary and non prioritized, that cause undue confusion at all levels of the project.

   Recommendation: The Program Steering Committee should develop a list of project objectives that all parties can agree to, and rank their importance.

B. Several future scientific research needs must be addressed. There are a series of issues concerning atmospheric measurements and research, analysis facilities, scientific staffing, designs of studies of weather change impacts, and research funding that are critical to a successful scientifically-based project.

   Recommendation: Measurements and modeling studies in the mountainous area of the target are needed to determine airflow characteristics and continuous water vapor and ice contents in clouds; thus, instruments such as a radiometer and Ka-Band radar

should be brought for two winter seasons (1986-87 and 1987-88); and field airflow measurements using chemical tracers, tetroons, and aircraft should be obtained. These efforts should be supported by the U.S. with GOM scientists participating in the field measurements.

C. The rain modification phase of the project now needs to be clarified and planned in detail. The opportunities to attempt modification of rain bands in the plains look promising, but research planning for this needs to be developed.

Recommendation: Scientists familiar with the Israeli and Santa Barbara projects should analyze the 1984-85 radar, satellite, and meteorological data to develop a comprehensive, scientifically-based modification plan including a scientific hypothesis, modification approach, and physical evaluation by late 1986. Synoptic climatological studies of the rain band data should be pursued immediately by U.S. and GOM scientists as input to the design plan.

D. The project is in rapid change but is at a point where it needs a definitive assessment of its goals, activities, and achievements. Key information is scattered among past documents, and plans for future activities need definition and specification to better delineate future directions and integration of research studies.

Recommendation: A concise report describing the project and its achievements should be prepared by June 1985. The Project Director and Resident Scientific Advisor should author this for issuance by the Project Steering Committee.

Recommendation: A definitive plan of future research efforts should be prepared to show how the studies will be performed, scheduled, and integrated to yield answers to critical questions so as to satisfy the project goal, purpose, and objectives. This should be drafted immediately by the BuRec, and then reviewed by AID and GOM, and completed by June 1985 so as to not delay issuance of pending contracts.

E. A major objective of the project is to train and educate Moroccans about how to design, operate, and evaluate scientifically-based weather modification projects. Concerns over the technology transfer in the first year and for future years have been expressed. Institutional development of the Meteo, a prime objective, is proceeding. In general, we find the training efforts and learning rate of year one to have been of good quality, but we are concerned about certain aspects of future efforts.

Recommendation: The recent training plan of the BuRec is endorsed with emphasis on continuing instrument and technique training as problems arise, as refresher courses, and as new facilities are brought to the project; these should be provided by the U.S.

Recommendation: The project needs a fulltime director, provided by GOM, to provide the oversight for all facets of the project and to interact with the RSA and AID.

Recommendation: There will need to be simulated operations and training in the United States for project operational leaders and pilots to properly address the complexities of future, more intricate cloud seeding operations in and around clouds. The U.S. should support this.

Recommendation: Technology transfer and project operations will be facilitated by continuation of English lessons for all project scientists with GOM committing its project staff to this program.

Recommendation: U.S. contractors who have projects involving (1) implementation of techniques or equipment in Morocco, or (2) joint U.S. - Moroccan research studies should visit Morocco at the initiation of their efforts. This familiarity with conditions and staffing will help project design and ultimate utility of products and facilities in Morocco. Ability of some staff to speak French is advisable.

Recommendation: Education of Moroccan scientists in atmospheric sciences at the M.S. and higher levels should occur in the U.S. At least 5 research scientists with advanced education will be needed by 1988 for GOM to have a viable scientific research effort in weather modification.

Recommendation: BuRec and AID should ask NSF to encourage atmospheric research in Morocco to increase knowledge about atmospheric processes.

II. INTRODUCTION

The goal of this assessment was to perform a thorough evaluation of the scientific and technical aspects of the Moroccan Winter Snowpack Augmentation Project. We reviewed and critiqued the design; the implementation and management of the project; its scientific quality; the effectiveness of the institutional development; the transfer of technology and training, and the water resources planning efforts.

The assessment was accomplished during a 4-week period and by conducting extensive discussions with interested parties in the United States and Morocco; by study of project documents, and by visiting project facilities and staffs in Morocco during 19 April - 4 May, 1985. Discussions were held with AID (Agency for International Development) and BuRec (Bureau of Reclamation) staffs in the United States and Morocco. Discussions during the 14-day assessment in Morocco included meetings with staffs of the Moroccan Air Force and Meteo, as well as with other government officials.

The assessment effort was a result of a contract developed in response to an RFP issued in March 1985 by the Bureau of Reclamation. It called for a 3-person team of assessors (a team captain with water resources expertise, an atmospheric scientist, and an operational management expert in weather modification). The team was asked to perform three assessments (in April 1985, September 1986, and September 1988). The team assembled included Stanley A. Changnon, Jr., as team captain and water resources expert; R. Lynn Rose; operational expert; and Joseph A. Warburton, atmospheric sciences expert. This report was completed shortly after field assessments in Morocco and after verbal presentations of findings with Moroccan officials, USAID officials in Morocco, and BuRec officials in Denver.

This report first presents short texts describing the assessment, and the project background and its status after one year and how this relates to the development of other major field efforts in weather modification. To adequately assess any multi-year project is also to understand clearly what phase it is in such as design, implementation, operation, or evaluation phase.

This status chapter is followed by six chapters each addressing major program areas including scientific design and evaluation, implementation, operations, institutional arrangements and management, technology transfer and training, and water resources planning and management. Major issues are identified in each section along with recommended actions. In the final summary section, we identify the key issues and recommendations to help continue and improve the conduct of this program.

III. HOW THE ASSESSMENT WAS CONDUCTED

The first phase of the assessment involved the study of project documents and discussions in the U.S. with AID and BuRec officials from Washington, D.C., and Denver, respectively. Much of the first week in Morocco was devoted (1) to discussions with project staff and government officials, and (2) to site visits to field facilities. The third phase was a team assessment phase followed by further local project discussions to clarify issues unresolved in the initial discussions. The next phase consisted of writing the first draft of the report. The final phase involved debriefings and discussions of findings with U.S. and Moroccan officials i Morocco and in the United States. Following these discussions, the assessment report was completed. The assessment plan used closely followed that presented in Project Paper. The assessment agenda is in the Appendix.

The philosophy of the assessment was to reach everyone involved, and to have open and thorough discussions on all issues, large or small. We attempted to group several of the smaller problems into major key issues

that cross cut several facets of the program. The assessment also attempted to be in the context of the real world with problems and our recommendations developed against what could be achieved; not just what was scientifically or technically ideal but impractical from institutional or financial constraints.

IV. PROJECT BACKGROUND AND GENERAL STATUS

This is a joint project between the United States and Morocco with the goal to develop and use a scientifically-based weather modification project to improve Moroccan water supplies. The purpose is to develop capabilities to design and execute a scientifically-based weather modification program in Morocco (Program Paper, 1984).

The project began in April 1984. The first year has been devoted to extensive equipment installations by U.S. contractors with support and training of Moroccans to operate equipment; the development of facilities for staff; the assignment of staff and training; and a winter and spring season of shakedown operations. The project is meeting the schedule set in 1984.

This joint program is a first for USAID concerning weather modification. It is an effort, over a 5-year demonstration period, to provide scientific and technical assistance in the field and classroom, plus major facilities. The Division of Atmospheric Resources of the Bureau of Reclamation has the expertise in weather modification to serve as the action arm for AID, through a PASA, to provide staff and facilities largely through contracts to non BR entities. The Moroccan effort is to provide personnel to operate the project; major facilities; and to help train staff in operations and analyses.

The resulting complexities of a multi-national project involving sophisticated scientific research and very complex field operations have been excessive. In the first year of the program, a comprehensive plan has been completed; many interactions between government agencies performed; most equipment and facilities procured and installed; staffing largely obtained; and seeding and field data collection operations conducted during portions of the winter-spring seasons of 1984-85. In general, the progress and attainments are outstanding when considered against the degrees of difficulties inherent in the project and comparable projects in the U.S.

A key to the current status, and the timeliness of this assessment, is what the participants have learned. Training and learning have moved forward rapidly. The project is moving rapidly from implementation to full field operations, and the next year effort should reflect a better operation than in 1984-85. The project is also beginning to move into its initial scientific and economic evaluation phase. It is a critical time of change in the project, and this situation greatly affected the difficulty of our assessment, both in assessing the change and in recommending various future courses of action.

OBJECTIVES

A program involving two nations and several federal agencies can be expected to have several objectives, some written and some only stated. Since our assessment had to deal with progress towards attainment of the goal and the objectives, we made an effort to delineate these objectives. It is of further importance because of the rolling or constantly evolving design and operation of the project.

Important to our assessment is a clear understanding that this is a scientifically-based (emphasis added) demonstration program of winter precipitation augmentation in the High Atlas (Assessment Team, 1983). This philosophy is found as a mix of an operational (non randomized) type project overlain with science, as presented in the Project Paper (February 1984) which states "the evaluation will focus on the verification of changes in the water resources base...an element of the evaluation will be an examination of the clouds and precipitation to improve the scientific basis of the program."

The Operations Plan for 11/1/84-4/30/85 states the following objectives:

1. to conduct a scientifically-based demonstration program of winter snowpack augmentation over a critical basin...

2. to assess...the amount of added water produced...

3. to develop the physical and economic information required for establishing the feasibility of the demonstration program and a systematic...long-term program of precipitation management...

4. to develop...the ability of Moroccan scientists to design (and execute) weather modification programs.

The Project Grant Agreement states there are two objectives for Phase 1, defined as years 1-3 of the Project. These are:

1. Enhancing the existing weather modification operations to help alleviate...drought, and

2. Establishing the organizational structure, equipment, design, operational procedures, training and experiences, and a firmer scientific foundation for a long-term weather modification program to contribute to the water resources of Morocco.

Assessment of the project reveals at least three other major objectives exist. These are:

1. to make precipitation at any time by any reasonable technique to help alleviate Morocco's drought.

2. To train staff and better equip the meteorologic service (Meteo) so as to better pursue their normal duties.

3. To focus attention on the broader issue of water resource management, preceived by several as a major problem for Morocco.

These multifaceted objectives are not all complementary and indeed cause confusion, leading to diversification of effort, and cause controversy between institutions and staff.

The project needs, through its objectives, clarification on several questions we perceive to be unanswered. For example:

Will the project develop a viable summer-oriented component?

Is the major project emphasis on getting more water on the ground in 5 years, or is it on having enough scientific measurements and research to develop, over a longer period, greater understanding and the capability to predictably and more reliably modify the precipitation?

Is the project to be restricted to the target area, or should it also make critical atmospheric measurements throughout Morocco to allow a cost effective and scientific extension of modification activities elsewhere after 1988?

Recommendation: The objectives need to be clarified and prioritized by the supporting and participating agencies so that the project can move forward more definitively.

The labeling of the project as the "Winter Snowpack Augmentation Project" is misleadng. The project focus (according to the Project Grant Agreement between the U.S. and GOM) is "on precipitation enhancement for reservoir storage (in target basin) with emphasis in Winter Snowpack Augmentation. Since the target has several reservoirs in the flatlands as well as in mountainous areas of the basin, this means that rain-producing situations in the target during winter or other seasons (fall and spring) could be considered for modification, as well as the snow-bearing systems over the mountains.

A clarification of the definition of the scientific bases for the project should be made so that assessment of their implementation can be conducted.

V. SCIENTIFIC DESIGN AND EVALUATION

INTRODUCTION

A general description of atmospheric complexities is given for the purpose of illustrating the absolute necessity for research investigations of the cloud systems and the forcing functions which are in effect in Morocco, and which determine, on the mesoscale and microscale, the amounts

and types of precipitation which fall in the watersheds. It is essential to have this knowledge so that the project can attempt to take advantage of a variety of meteorological situations for optimal modification purposes.

The lower atmosphere is the medium by which water substance is tranferred from the ocean to the land. The complexity of the lower atmosphere is evidenced by the high natural variability of its several important characteristics, in particular those relating to potential modification for man's benefit. The rapid changes in space and time of degrees of turbulence, updraft and downdraft regions, liquid water content, ice particle concentrations and nuclei numbers and types can all influence the precipitation growth processes with which weather modification must be concerned.

As well as these examples of the microphysical properties of clouds, there are also those properties commonly grouped under the term 'mesoscale features'. These features, too, can be highly variable but on the scale of kilometers rather than the scale of micrometers or millimeters. Inversions of temperature at cloud top, or isothermal layers within cloud system can play dominant roles in cloud growth or in preventing the transfer of vertical momentum (either upward or downward), thereby affecting the diffusion and dispersion of seeding chemical aerosols within the cloud systems.

Also, on the mesoscale, the role of orography is important and this will certainly be true in the region of the Atlas Mountains, the Rif Mountains, and even over smaller ranges of hills in the Morocco Watersheds. These orographic effects can, in general, be very beneficial to the conduct of a seeding program because they can provide one of the driving forces for vertical motions and subsequent mixing in the boundary layer, a necessity for transporting cloud seeding aerosols to colder layers within the clouds where they can be more efficiently used for initiation of precipitation growth.

Another important mesoscale feature worthy of discussion is that of entrainment. Although this does occur over a broad scale of dimensions, it is readily observable at cloud top on scales of tens of meters to a kilometer or so. it is the process of mixing of dry air from above cloud top into the more moist cloud layers below. This process is important because it plays an important role in the development of cloud drop sizes and thereby the subsequent development of ice particle sizes and numbers as well as of precipitation sized particles.

All of these and several other features of clouds (temperatures, vertical wind speeds, etc.) play important roles in precipitation formation and, if we are to assess our ability to modify these same clouds, it is essential that we know as much as possible about these features prior to and during such modification attempts.

The present lack of knowledge of this kind does not prevent the operational aspects of the program from moving ahead. Rather, the designed operations provide the framework within which the scientific

assessment of seedability and the evaluation of seeding effects can be conducted.

If this program is to be successful in the long term as a means for providing additional water to the region, and in order to incorporate this technology into the overall water management program of Morocco, it is essential, from the very beginning, that a strong scientific capability be developed for the project. The question is, how much capability is needed? The scientific assessment and evaluation aspects of this project are essential to its success.

THE SCIENTIFIC PROBLEM

For cold cloud seeding to be effective, it is essential to disperse ice nucleating materials (normally aerosols) into regions of supercooled clouds containing liquid water drops. The differences in saturation vapor pressure over water and ice at temperatures below freezing, leads to preferential growth of ice, and at rates considerably higher than those for water droplet growth.

Hence, in a pragmatic sense, a successful seeding program requires that the ice-nucleating aerosol particles be brought into the same cloud volumes where the liquid water exists. In addition, these same cloud regions should contain a sparsity of natural ice particles.

Here, then are several of the scientific issues from the cloud physics viewpoint:

a) Which cloud systems in Morocco contain substantial supercooled liquid water?

b) Where is this liquid water being generated and how does it vary spatially and temporally?

c) What at the degrees of supercooling of this water, since this affects the differential vapor pressures important for precipitation growth?

d) What are the ranges of cloud temperatures occurring during the operations period for the Project, because the ice nucleating effectiveness of the seeding agent (silver iodide) increases with decrease in temperature below -5°C, maximizing asymptotically at -20°C.

Similarly from the mesoscale viewpoint:

a) What are the effects of orography on vertical cloud growth?

b) What changes are produced in air mass motion by mountain barriers?

c) If aerosols for seeding are released from the ground, what is their dispersion and transport over the mountainous terrain?

d) Do stability layers which usually form over the ocean, persist into the project areas and do they influence how the clouds can be adequately seeded?

Finally, how can we assess (a) cloud seedability, (b) frequency of seeding opportunity, (c) water augmentation potential, (d) the most efficient and cost effective seeding methods and most importantly, (e) the success achieved?

The first phases of the scientific effort have been evaluated and are described in the next Section.

INSTRUMENTATION AND DEVELOPMENT OF SCIENTIFIC CAPABILITY AND RESEARCH EFFORTS

A. Cloud Physics Aspects

Physical data on cloud characteristics are being acquired for four separate sections of the project: rawinsondes, radar, meteorological satellite photos, and cloud physics aircraft.

1. Rawinsondes:

One complete RD-65 and one partial unit (on loan) are in the project. The data system and the unit itself are functioning well. The Moroccan Operators are able to make the balloon-releases, acquire the data, plot the data and present it for use in the project. The operators appear to be well trained and are functioning normally.

Recommendations: (a) The second rawinsonde unit should be upgraded for use at sites other than Beni Mellal. This would enable studies to be made of changes in atmospheric moisture, temperature and winds, in other critical areas.

(b) Some equipment upgrade is needed for this second RD-65 equipment but the costs would not be high (< $50K) and the data obtained would be very useful in evaluation and decision making. The system could be installed in the radar trailer if the radar were removed, as proposed in Chapter VI.

2. Radar

The radar system is installed and is substantially in good working condition. There are some concerns about the IFF adjustments and sensitivities for aircraft tracking, and this should be resolved before the next winter field season.

The radar system is being used both for aircraft control and for atmospheric physics data acquisition. This leads to conflicts of priority in operations. The time of greater need for scientific data

from the radar is during the aircraft operations. This is because the Citation and in 1985-86, the King Air seeding aircraft will be acquiring in-cloud measurements of water, ice, air motions, temperature, etc. in the same clouds under observation by the radar. These two concurrent sets of measurements are complementary and essential to the scientific evaluation.

Recommendations: (a) In the absence of a second radar, it is essential that the Scientific Advisor and the Operations directors develop a procedure for ensuring regular PPI and RHI data acquisition to be carried out during such periods of conflict.

(b) The Operations Directors should review the radar data on the day immediately following an operation. They should produce plastic overlays of significant portions of the data stored on disk. To replay the disk data, the micro-processor unit presently located at Beni Mellal for rawinsonde analysis, should be moved to the building in Khouribga. The micro-processor at Beni Mellal should be replaced by a less expensive personal computer capable of processing the rawinsonde data twice per day.

(c) The one-dimensional upper-air model presently in the computer at Beni Mellal, should be put into use, at least for training purposes. Software is already available.

(d) Extreme care should be exercised in erasing data already acquired on disk. Problems of this type can be avoided if Operators review the radar data on the day following the operations and annotate those disks which have valuable data on them. This will also assist people involved in future analyses of the data.

(e) To reduce the conflict between the seeding operators and ATC operations, it is recommended that aircraft recognition and meteorological radars be separated. Separation will provide safe aircraft observation and control with meteorological data collection without competing for time on the existing system.

3. Meteorological Satellite Photographs

The black and white photographs and the color enhanced display of satellite cloud coverage over the target and control areas, are yielding some useful information. However, much more valuable information would be attainable with some improvements and additions to this equipment housed in the APT room. The Moroccan personnel operating this equipment and recording cloud data are trained well beyond this equipment's capabilities.

Recommendations: (a) The Operations Sections for this Satellite receiving equipment should be copied from the Manuals presently held in the Engineering Section. Fine scale color adjustments must be made by the operators during periods of data acquisition. This is normal procedure and this Operation Manual information should be supplied immediately.

(b) Higher resolution block coverage of the target and control areas are available with the same receiver system. An equipment unit capable of doing this should be installed to replace the video camera and oscilloscope "blow-up" display presently being used.

(c) Cloud top temperature estimates with present equipment are coarse (plus/minus 5°C). METEO should look at the options for obtaining more accurate cloud temperature measurements (plus/minus 0.5 to plus/minus 1°C).

(d) The observers should begin to develop a cloud climatology for the target and control areas, including best methods for displaying the information for operational and research use. The Resident Scientific Advisor can give guidance on this work.

4. Cloud Physics Aircraft Program

Although the operations plan lacks a conceptual model, the flight plans for studying cloud seedability over the target, central and other areas, have been well designed. The choice of the -4°C level for observing threshold levels of water and ice is a good one since it provides the opportunity of determining the presence or otherwise of secondary ice. It also yields an estimate of supercooled liquid water at a temperature just warmer than the threshold nucleation temperature of the silver iodide aerosol being used for seeding.

The choice of the -12°C level for study is a reasonable one, but is in the regime where ice crystal growth rates are relatively slow and where aggregational growth of ice particles is also somewhat minimal. Consideration should be given to shifting those in-cloud penetrations to a slightly higher elevation (temperatures around -15°C).

The flight pattern given in Figure 6.5 of the Operations Plan should, with some slight modification, also be used for seedability studies. It is important to make observations of the water and ice along a steadily rising track orthogonal to the mountain range. This could be done by dropping in elevation from 16000 ft, 200 Km from the radar, to 4000 ft., 40 Km from the radar, followed by a sounding back to 16000 ft 20 Km south east of Khouribga as shown in Figure 6.5.

The flight patterns designed for the airflow studies seem reasonable, but this section of the plan is also lacking a conceptual model. There is no statement of why the particular flight patterns were chosen.

Similarly, in the evaluation studies, the goals of the program and the flight patterns planned have been well designed with the possible exception that flight elevations should extend to the -15°C level for the same reasons stated earlier.

The quantity of scientific data acquired in the first season is unfortunately small. Prior to April 20 only 15 hours of flight data had been collected but several flights in the last 10 days of April may have improved this greatly. There were difficulties in air traffic control coordination and Citation flight plan needs. There is no problem with controllers when they are on duty and when the Citation is flying. The cost of this effort rated against the low yield of data, for whatever reasons, is a serious problem.

The Citation scientists did not present a clear picture of the quality of data so far collected nor of the specific details of cloud microstructure for the flights already made prior to April 26. Apparently the intended post-flight analyses of the collected data have not occurred or are difficult to work with. The launching of the Citation at least two hours before seeding commences has not occurred consistently as planned. This is an operations problem addressed elsewhere in this report, but it would appear that decisions to fly the Citation are not well coordinated with the meteorological forecasting of cloud systems in the project area. This is in part due to communications problems between Casablanca and Marrakech. In the event a more sophisticated METEOSAT receiver is installed at Casablanca, the present satellite system might be relocated at Marrakech for use in flight decisions for the Citation 11 studies.

Recommendations: (a) Much more attention be paid to post-flight analyses and some modest operational data analysis be carried out at Marrakech or where ever the Citation is based.

(b) Installation of METEOSAT apparatus (similar to Casablanca) at Marrakech for use by Citation scientists and others if the aircraft is not moved to Casablanca, as recommended elsewhere (Chapter VII).

(c) Develop sound physically-based conceptual models for each section of the work and adjust flight plans accordingly. Get the scientists who will analyze these data involved in this process.

B. Climatological (Statistical) Evaluation

Assessment of proposed climatological-oriented statistically based evaluation studies was limited to review of ongoing operations, data collection and quality, and future plans for as yet unlaunched climatological evaluation studies. These studies, as identified in a BuRec document of April 1985, include (1) a precipitation and streamflow evaluation, design and implementation study, (2) a Landsat snowcover - runoff study, and (3) a river basin modeling study for the target area.

Recommendation: The Landsat study appears, after preliminary testing on Moroccan data, to hold the potential for providing needed estimates of snowcover useful in comparing year-to-year snow differences in the target and control. It should be pursued using BuRec staffing to complete the study.

Recommendation: The precipitation-streamflow evaluation design study appears to be very critical and essential to the ultimate determination of a target-induced difference in precipitation, largely using streamgage data.

Examination of field sites and of data suggest high quality streamflow data exist, although continuing non-uniform land use changes may confound a historical regression approach. The mountain precipitation data appear of unlikely quality and density so as to limit their use in a potential study.

The future studies of radar data for evaluation purposes will not be very successful if the radar operations in seeded periods are heavily devoted to aircraft tracking and occasional RHI scans. Future radar operations will have to be altered to allow for an adequate statistically-based assessment of echoes.

Recommendation: The river modeling studied will be important to this effort and should be pursued. The results will help explain the distribution of added water and the results of the target and control regression studies. Data needed for this exist. The BuRec staff and modeling expertise should perform this study.

C. Upgrading Scientific Aspects of Project

In the Middle and High Atlas mountains, the precipitation comes from moist air masses moving into Morocco from the Southwest, northwest and northeast. Most of the enhancement opportunities occur with the passage of low pressure troughs. Because the cloudiness persists for relatively long periods (more than 24 hours), it is desirable to make measurements of some of the key cloud parameters for extended periods of time.

It is possible to use newly developed remote sensing equipment for making observations of liquid water, water vapor and spatial and temporal distributions of 100 micrometer to millimeter sized cloud particulates. This type of data, when combined with concurrent aircraft acquired cloud physics data, would provide a much more powerful combination of relevant information for this project. Such a major scientific upgrade will necessitate acquisition of a scanning dual wavelength microwave radiometer and a short wavelength (Ka Band) radar system for two seasons of the project. This equipment and their data would be under the control of the U.S. scientists who would instruct and train Moroccan scientists in their use. The equipment would not remain in Morocco but, as with the Citation aircraft program, would be returned to the U.S. at the end of the observational period.

Recommendations: (a) Develop plans and funding arrangements for installation and operation of a dual wavelength scanning microwave radiometer and a Ka Band radar in the project for two successive seasons beginning in the fall of 1986.

(b) One additional year of data analysis and scientific interpretation must be supported beyond the end of the second field season of observations with this equipment.

D. Design and Analysis of Ground-based Seeding Activities

It has been estimated that 65% of the seeding opportunities in the first year occurred in the night-time hours. This, together with the normal delays which occur with aircraft seeding (ferry time, refuelling, etc), reduces the available seeding opportunities to 20% or less of those possible.

Although little is known at this time about air mass trajectories at low levels over the mountainous terrain in the target area, some effort is definitely warranted at this time to determine the feasibility of installing and operating a ground-based aerosol generator net work for complementing the aircraft seeding activities. The aircraft seeding should not be abandoned in favor of a ground system - the two should complement one another.

The low level air mass flow over the mountainous terrain should be studied using tracer technology, constant level ballons and modeling techniques. Moroccan personnel would be instructed and trained in these technologies during these studies. The end product of such studies is to locate in the best sites a number of seeding aerosol generators which would provide night-time seeding and supplement day-time seeding of the aircraft.

Recommendation: Begin, as soon as possible, a feasibility study for ground-based aerosol generator use in the target area.

E. Computer Facilities

The minicomputer which METEO was planning to acquire has not yet been delivered. There appears to be some doubt about its future status. The acquisition of a minicomputer by this project was never included in the original plan because it was to be provied by GOM.

Many, if not all of the analyses for precipitation data, steamflow comparisons, rawinsonde processing, satellite cloud photographs, etc. can be carried out on microprocessors. The aircraft data analyses, radar data analyses, modeling of airmass flow and hydrologic modeling should be carried out by U.S. scientists in the U.S. with Moroccan trainee involvement. The purchase of a minicomputer with funds from this project apparently can only be done by curtailing and/or delaying the scientific and economic evaluation work already planned.

Recommendations: (a) The minicomputer should not be purchased with funds from this project unless additional new funding can be made available.

(b) The first few members of the Moroccan Scientific analysis team should be identified and assembled as soon as possible. This is to allow their involvement in the forthcoming data analysis work planned for subcontracts during 1985 and 1986 in the U.S.

(c) As subcontractors are selected for scientific analyses, appropriate Moroccan scientists should be assigned for training and involvement in this work.

F. Suspension Criteria

It is well recognized that this project needs a well planned set of suspension criteria. The avoidance of flooding, damaging rains at harvest time, etc., demand such a set of criteria. Criteria now exist but need refinement to Moroccan conditions. A study of the several aspects of this issue, which are well outlined in a series of project documents, should begin as soon as possible. This will involve interaction with senior Moroccan personnel from several agencies and departments, AID staff and Bureau of Reclamation.

Recommendation: Implement as soon as possible the suspension criteria study in order to place such criteria in effect at the beginning of the 1985-86 seeding season.

VI. IMPLEMENTATION

INTRODUCTION

The proper implementation of equipment, personnel, training, and facilities for the scientific studies and seeding operations is a key to the success of this project. Effective implementation of these various components has been the main objective of the 1984-85 season, and in general, the implementation has been notable. However, improvements are needed and time is adequate to address most areas of concern before the 1985-86 operational season.

The operational centers of Casablanca, Khouribga, Beni Mellal, and Marrakech where project staff exist werre reviewed. Each center has specific attributes and problems.

PROJECT SITES

Casablanca. The forecasting, scientific, and equipment maintenance headquarters of the project were established at Anfa Airport in the Meteo offices. The GOM project director has his offices at this location along with many other key project personnel, including the operations coordinators.

Offices in the heart of meteorological activities of GOM are valuable. Major institutional improvements of the Moroccan weather services have been made by the project's installation, or upgrading, of

the following equipment: satellite ground station with laserfax, weather graphic recorder, remote radar monitor, Alden color graphics processing system, satellite loop playback unit and recording system, and data modem.

The office space provided by GOM offers suitable accommodations for the RSA and his necessary support staff, a secretary and one aide. Concern has been expressed by GOM that this staff is too large, but considering the project work load requirement of the RSA, the staffing is not excessive.

Training of program personnel was pursued in seeding operations, ATC coordination, radar and satellite interpretation, and equipment maintenance. Resistance or concern of interrupting project operations has made non-project personnel at Meteo reluctant to fully use the radar and satellite information. Such usage could aid the daily briefings and improve the overall objectives of Meteo. The RSA has planned to offer training in the use of the equipment outputs being provided, but time has not permitted this yet. It is urged that such arrangements occur.

Equipment personnel seem well trained in maintenance and operation. Most of the maintenance books provided however, have been removed from the systems for central storage. Reasons for removal are to centralize maintenance, but technical staff are being limited without easy reference to materials when problems occur, particularly the operational sections of the manuals. These sections, or copies thereof, should be at instruments.

Communications between Casablanca and the other sites are mostly conducted by telephone, and this is often limited by faulty service. The RSA telephone often has not worked effectively, so the use of telephones in other offices has been common. For quick transmission of written documentation, the telefax machines, which are located at the major sites, have been employed. Some resistance by Moroccans in use of the telefax has been noticed. This may stem from uncertainties over what types of information are important enough for this type of transmission. Whatever the reason, more reliance in this system usage should be developed by GOM. Radio communications between Casablanca and Khouribga were established to aid the overall project and to by pass the telephone problems. The antenna installation at Casablancva was placed next to the satellite receiver. Subsequently when transmissions over the radio occurred at the time of satellite transmission, the strong RF of the communication signal would leak over to the satellite antenna and disrupt the satellite signal. This problem was not corrected during the project season and radio communications were lost between Casablanca and Khouribga.

Recommendation: Action is needed to correct this problem, and to greatly improve the between site communications.

Khouribga. Equipment installations and operations at Khouribga are split between a newly remodeled 3-story building (with an enclosed aviation tower) and the radar trailer. The oddity of this arrangement is

that there is too little space available in the radar trailer during operations, while the building goes largely unused. We recommend that the radar be installed in the building. The RSA was correct in waiting to determine if Khouribga was a proper location for the radar ionstallation. However, the radar is being blocked to the North by the building at elevations angles of 0° to 5°. This does not hamper the snowpack portion of the operations, but affects measurement of rain and monitoring of such operations. The in-building location would better protect the radar components from blowing dust and other elements. Ground clutter will increase, but the advantages of the re-location outweigh the disadvantages. The radar is well equipped with spares and test equipment.

Training of operators and technicians was well performed by CIC. The contractors were convinced the technicians were knowledgeable in their duties and abilities to maintain the radar. Of all the site locations, Khouribga is the most difficult to find personnel willing to relocate to. Local housing is minimal and standards low when compared to other sites. The radar site is located on an abandoned Air Force base, is several minutes driving from the center of town, and transportation can be a problem for staff. The GOM has provided an automobile to exchange crews. This decision has helped the morale of the crews, but the long term outlook is one of major turnovers in personnel. Much of the success of Khouribga has been due to Mr. Majdoub's personal efforts and leadership ability. He has accomplished much in a difficult situation. We recommend no further enlargement of staff or field operations at this site.

Training at Khouribga of the operations coordinators was also conducted by Mr. Brown. He considered them to be "skilled meteorologists". Mr. Brown's training also included monitoring of ATC operations.

The staff are somewhat confused by data collection. They do not sufficiently understand the need for data for future studies or the importance of the frequency of measurements. The radar data collection is repeatedly hampered by the air traffic control work due to the continually debated aircraft interrogation troubles. The collection of data is being made on floppy disks from the zilog-80 microcomputer. The disks are filed in a box and as of this time, are stored in Khouribga. When no diskettes are available, paper copies of the disks are made before reformattting and the reuse of the oldest existing file. Obviously this is not a prudent approach to data collection for scientific investigations. A method of placing the stored information on 9-track tape is required.

We recommend that the zilog-80 computer (in Beni Mellal) be transferred to Khouribga, and equipped with a 9-track tape unit and software for extracting the radar data from the diskettes to tape. The tapes can then be transferred to Casablanca for storage and disposition. The need and use of a microcomputer at Beni Mellal is discussed later.

The aircraft interrogation is central to many of the operational complaints of GOM. The areas of contention are strength of aircraft signals, computer processing of the data, and flight elevation as displayed by the radar. Each of these items should be reviewed with action taken by the U.S. and GOM to correct the problems before September 1985.

Beni Mellal. The project radiosonde station is located at Beni Mellal. Ballon releases are made at 00 and 12 GMT. The contact points are then entered into the zilog-80 computer which was originally designed to operate at Khouribga. The computer has a 1-D time dependent cloud model which runs in about one-half real time. The model should be used by project meteorologists at Khouribga as a learning tool. We recommend a less expensive micro-computer be installed at Beni Mellal to facilitate the radiosonde observations and data reduction.

A near complete spare radiosonde is at Beni Mellal. It is recommended that this unit be installed in the current radar trailer (after radar removal) for use at various locations as research needs dictate. One option is to place it for one season at Ouaouizarth to monitor the valley flow and a second is to sample other areas of the frontal mountain area to the northeast.

Radiosonde operators at Beni Mellal were well trained by NAWC. The installation and calibration of equipment were also provided under this contract. The radiosonde operators spoke very highly of the contractors performance and are looking forward for their return in October 1985 and continued training. Mr. Ouassou, the Beni Mellal station manager, is very competent. Two more radiosonde trainees are needed if the back up unit were used for research data collection.

An automated weather station (AWS) was also to be installed at the local Meteo station to be tested against the observations made from local instruments. This did not function during the 1984-85 season. This system was provided by BuRec and installed by CIC, but is being returned to the manufacturer for warranty work. It is hoped that this will become a weather station for making desired observations in the remote areas of the Atlas Mountains in 1985 and beyond.

Another system that had been planned but not established for the 1984-85 season was a mountain snowcourse. If the snowcourses are to be established for the 1985-86 season, ample time should be made for the selection. A special vehicle will more than likely be required with extensive time for site selection. We question the need for snowcourses if the budget is limited.

Marrakech. The operation and research aircraft are located at the Air Force base at Marrakech. The operational seeding aircraft are three OV-10 Broncos. Cloud physics measurements are made by the University of North Dakota Citation. These systems and their operations are major and costly contributions by both governments. Thus, how the aircraft are used is important to the overall seeding success and the critical measurements of cloud effects and airflow over the mountains.

The OV-10 is an aircraft which was not intended for IFR flight. It carries no de-icing equipment. It is an excellent airplane for cloud base seeding, but it is very limited for icing conditions due to its large leading surface area. The PT-6 engines could ingest ice from the air intakes. Given these considerations, the OV-10 is not a good selection for cloud penetration and delivery of seeding agents in winter conditions.

The OV-10's each have two Loshe wing tip generators installed on fuselage hard points. The mounting limits the amount of solution from the regular 34 liter volume to 27.5 liters, 90% of which is usable for seeding. This restricts seeding time. Flow restrictors are normally used in the flow lines. Restrictors are currently not being used but will soon be installed.

The aircraft were in good visual order. One problem noted was a missing wind shield of a thermometer and another thermometer was touching the wind shield. We suggested these problems be corrected, and a calibration test be conducted on the thermometer for the accuracy of 0°C.

We strongly recommend, because of the serious limitations of the OV-10, that other aircraft capable of safe in-cloud operations be provided for the 1985-86 season.

Their utility for collecting useful atmospheric data and for discerning correct seeding locales will be facilitated by an on-board meteorological sensing and recording system to measure vertical notion, temperature, dew point, ice crystals, etc. We further recommend acquisition of such systems for future seeding aircraft.

The mixing of the seeding solution follows the well developed procedures of Colorado State University. The mixture is one of the most efficient in producing nuclei that has been developed. The mixing of the chemicals and storage uses safe procedures. Access to chemistry expertise may be needed.

The pilots' experience is more than adedquate for the safe operation of aircraft types considered for seeding and the 1984-85 type of flight operations. Morale seems high among the pilots and their willingness to do the best job possible was evident in their briefing. The pilots need training in actual in-cloud seeding operations, opportunity recognition, and for learning types of visual observations that are helpful to the project meteorologist in directing operations.

We strongly recommend future cloud seeding training of 2 or more seeding pilots in the U.S. The complexities of future operations, to be successful, will require knowledge that can only be acquired in this manner.

The operational plans for the UND Citation aircraft were to collect 40 hours of flight data to compare seedability and airflow in control and target areas (32 hrs.) and a limited number of hours (8 hrs.) evaluating seeding signals per month. This was the first major attempt to collect cloud physics data in Morocco with a sophisticated instrumented

aircraft. Specific flight patterns were designed to fly over the Atlas Mountains. Only two such profiles were attempted. One a practice mission and one an in-cloud attempt. The in-cloud mission showed that the aircraft could not fly safely at the altitudes where the supercooled liquid water was, and could not make the desired wind measurements.

The Citation was originally planned to be based at Casablanca, but due to a lack of proper hanger space, the aircraft was moved to Marrakech. Arrival at Marrakech was on January 23rd, with support equipment and aircraft ready by February 1. The first meeting between the air traffic controllers (ATC) and the Citation flight crew for allocation of block airspace was February 5. After several meetings with various officials of the GOM, final approval from the GOM ATC was granted on March 29. Due to the ATC limited operations, poor weather opportunities in February and March, and problems of the inertial navigation system (INS) in March, only 6 missions were conducted in the first 60 days. The INS malfunction required the aircraft to be absent 12 days for repairs.

The secondary flight plan called for profiling the convective bands. Such flights were hampered by ATC restrictions and were unable to be accomplished.

Recommendations: For next seasons flight operations, a more opportunistic mission plan is needed to collect more cloud physics data in and out of the target. Second, much greater coorindation with seeding aircraft operations is needed by GOM and the Citation crew to ensure collection of cloud physics in seeded clouds.

SUMMARY

Implementation of the project has been largely successful to date. Equipment, crews, training, and data collection have been implemented on schedule. Preliminary plans for the 1985-86 operatins should be finalized soon to give all parties time for review and comment. Contractors performance was good. In most instances, they started from an obscure point and delivered on their objectives.

Meteo is congratulated for supplying bright and willing individuals for all positions we assessed. This has made the technology transfer of high quality. This commitment by Meteo shows their interest in the project's overall success. Likewise, the RMAF has provided very capable pilots and ground support crews. It is urged that minimum of 2 pilots be given advance seeding training.

Local facilities are generally excellent. Remodeling has taken place where needed, another favorable sign of the commitment of GOM. The involvement in Morocco by the U.S. is centered on the leadershiup of Dr. Matthews. He is looked upon by the GOM as the scientific leader of the project. He tries to advise a ship but has no hands on the rudder. The project needs a fulltime director. As expertise grows within the GOM, the position of advisor should become more tenable. It is obvious that Dr. Matthews has grown with the position and in his management role. He

will continue to need support from the various parties in Denver BuRec and USAID. His duties are so extensive that we recommend added professional help during the operational periods.

VII. FIELD OPERATIONS

The prior chapter on Implementation addressed several aspects of the operations. This chapter focuses on how the 1984-85 operations were organized and conducted.

Basically, the operational decisions followed the sequence shown on Figure 2 (Appendix). Mr. Brown (NAWC) made important contributions in training as to the concepts of organizing the daily decision processes and operations, which to be effective must simulate a military type operation. Everyone must understand his duty and directives as to action, and action must flow in a timely manner. Inspection of activities during our visit, including those on two operational days, was convincing that the rudiments of operational procedures are now understood and generally followed.

Forecasting for operations was done as Casablanca. Relatively long (about 24 hr.) lead times were required because of widely distributed personnel; the need for key persons to move from one place to another for operations; and to hedge against the poor communication system.

Figure 2 shows the Daily Operational Decision Procedures and Record form used as a checklist by the operations directors. It was used each day, and their check lists provided a good record of forecasts and operations, or stand downs.

A key feature of the daily check list is the consideration of suspension criteria. Figure 3 shows the daily review guidelines the operations director considered for suspending operations. Since 1 November 1984, the suspension criteria placed operations in the stand down category five times. It is of meteorological interest that only one criteria accounted for all these suspension, the forecast of high winds. Suspension criteria should be reviewed and modified before the next operational season. Other problem areas may need to be considered, while predictors of severe weather hazardous more suitable than those developed for the central U.S., should be developed.

A major concern is the geographic scatter between project personnel and project assignments. Travel time and lost operational opportunities add to the overall project costs. To reduce some of the distance and travel problems, it is recommended that the operations of the aircraft be moved to Casablanca from Marrakech. A vehicle should be provided by GOM for moving ATC and operations staff to Khouribga. These efforts will aid in reducing the 1984-85 logistics problems and yield more timely operations.

Communications difficultues hindered the overall strategy of the program. Moving the flight operations to Casablanca would greatly relieve the communications gap between the pilots and meteorological staff. Debriefings, which are now held somewhat sopradically (weekly) could be held routinely after each operational day. This would add to the overall success of the operations. Telephone communications are unreliable with the exception of Casablanca to Khouribga. However, the telex system has been reliable and is used for transmission of weather data from the various sites. Again, by reducing the number of operations points and by consolidating the aircraft operations to the Anfa Airport at Casablance, the communications problems would be greatly reduced. FM radio communication beteeen Casablanca and Khouribga, as discussed in the previous chapter, will also aid in passing information between sites.

The lack of staff understanding of continuous operations and data collection has caused losses in seeding opportunities. Operations were limited to daylight because of aircraft restrictions. Aircraft crews, meteorologists, and radar operators need to develop a system of covering for one another during these times. A work shift plan is needed to take advantage of all seeding situations.

Recommendations: a. Research to develop more meaningful suspension criteria is needed.

b. Continued training in operational procedures by RSA and contractors, particularly since the future operations and cloud seeding techniques will be more complex than 1984-85, is needed.

c. Operations must be consolidated to save time and resources; to gain operational opportunities, and to improve training the complexities of the project.

VIII. INSTITUTIONAL ARRANGEMENTS AND MANAGEMENT

INTRODUCTION

A developing large-scale weather modification program, such as that being conducted in Morocco, is a complex mixture of design, operations, and research, all with an evolving nature. Hence, it is commonly troublesome and the only certain thing is change. The mixture of Moroccan and U.S. agencies further complicates the situation. Hence the institutional arrangements and ensuring management lines can be difficult, yet must be clearly stated and well understood by participants for the project to succeed. Assessment, over a 2-week period, of the institutional arrangements and management is difficult because it is hard to accurately discern the complex aspects and interactions.

INSTITUTIONAL ARRANGEMENTS, DEVELOPMENT, AND SUPPORT

The U.S. effort involving AID and BuRec is defined in the PASA. This agreement adequately describes the project and the interactions, although the project represents a very different kind of AID project with the BuRec the action arm and the expertise in this effort when normally an AID project is based on its own staff. This means the AID and its Moroccan Mission (OTP) are highly dependent on the BuRec for proper program planning and management, for expenditure of funds, and for scientific and technical advice. Placement of the project in the Office of Technical Programs appears to be the most logical entity in AID to manage the project.

We are concerned about the inconsistent and conflicting project views obtained from the AID Mission. We read in project documents and from discussions with S. Lintner that a project plan of objectives and supporting studies have been agreed upon by AID and BuRec. However, at the AID Mission, we received a variety of views, some which agreed with the 5-year planned studies, and others expressing disagreement and uncertainties over project goal, objectives, and the launching of several studies. The net effect of this situation appears to be continuing internal confusion as to AID's objectives and it is damaging to the credibility of the project.

Thus, interactions between the BuRec and AID Mission are less than perfect. BuRec is geared to a systematic project development and an implementation effort that requires longterm detailed planning and thus sufficient lead times to deal effectively with many contractors and to get all desired results in a timely manner for an integrated project. This effort is based largely on the PASA and the plan it contains. The BuRec, as the project's action arm and expertise (both scientific and technical), provides a major service. As such it must provide the information to AID that supports its needs to oversee the project for the U.S. At the highest levels, this function is adequately provided by B. Silverman to AID Washington (S. Lintner) and to the AID Mission in Morocco. In Morocco, this project information is also to be provided by the RSA. This interaction is less than desirable. The monthly project reports by the RSA to AID have been delayed. There should be a more effective programmatic interface provided by the RSA to AID (and to GOM Rabat).

Conversely, the AID Mission provides BuRec with varying attitudes about project objectives, management informational needs, and project support. The Mission's views on such issues do not always support the Washington AID views nor those in the PASA. Collectively, this situation is confusing to the BuRec and makes systematic implementation of equipment acquisition and research studies difficult. Given the agency roles, we urge the AID Mission to involve the RSA in its internal project meetings and all top-level meetings with GOM on the project.

We further urge, as noted in Chapter IV, clarification by AID of their project objectives. AID should provide more effective responses to BuRec's requests for information on studies questioned by AID. The BuRec should provide more frequent and better reporting on project planning,

execution, and achievements. The project would be more meaningful, for both institutional development and for BuRec-AID interactions, if AID had a specific mission of "improving water resources planning and management in Morocco."

There is also concern at BuRec over the AID provision of funds sufficiently early in FY-86 to address a possible funding gap. AID officials assured the team this potential problem would be resolved by timely transfer of funds so that contractors to the project would not be temporarily unfunded and key efforts stopped or delayed. This would be a very serious problem and affect the project's progress detrimentally.

The U.S.-Moroccan interaction is defined in the Project Grant Agreement which briefly but succiently defines the relationship and roles of U.S. agencies and the Moroccan agencies involved in the project. This appears adequate and the relationship is generally effective. Concerns were expressed by all major participating agencies over the conduct of the evolving project. These largely related to questions of commitment and the fulfillment of staffing and training obligations. These problems are described in Chapters V, VI and VII. GOM expressed desire to review all further U.S. contracts before they were issued. We understand copies have been supplied in the past without commentary from GOM. Such actions only serve to delay implementation.

An apparent underlying problem relates to the sources and distribution of funds. The USAID support goes totally to the NMO for facilities and personnel training, whereas the majority ($4.0 million of the $6.4 million total) of the Moroccan support comes from the Air Force which receives no U.S. AID. Furthermore, there are more project needs relating to RMAF aircraft meteorological equipment, and especially for pilot training in weather modification. These are defined more fully in Chapters V and IX. Hopefully more U.S. support can be found by some means. The U.S. agencies are providing the staffs and facilities promised in the agreement.

More U.S. support than currently available will be needed to meet the added atmospheric data collection and research (Chapter V) we have recommended to improve the scientific level of the project. We recommend consideration of added funding to support additional scientific research.

Important to this project is institutional development in Morocco. Depending on this project's success in changing the weather and in gaining related understanding of this technology, this project will provide either a fully defined functioning technology to GOM, or a partially defined technology by 1989. The project has already provided several weather equipment facilities that have upgraded Meteo immensely. We believe that by the project's termination, the technology, at whatever level of definition, should be directed and managed by Meteo with operational (when to use it) input from effected agencies (hydrology, power generation, and agriculture). This input should come through the National Steering Committee. The weather modification project is essentially a meteorological effort and will lead to major development in staffing skills and equipment of Meteo.

Recommendation: Develop and manage this project, and the ensuing GOM weather modification programs within Meteo. The long-term concept to be sought for Morocco is awareness that the atmosphere is a resource, as is land and water.

The institutional relationships between Moroccan agencies could not be assessed very directly in our visit. We got impressions that aircraft issues were unduly dominating certain project decisions. During potential seeding conditions, aircraft operations decreased at noon periods and on weekends presumably to address eating of lunch and weekend leaves. There are too few seeding opportunities in Morocco to allow such activities to hinder operations. Operatins would not be halted for such needs if more adequate aircraft exist, as indicated for the future.

Other agencies have participated by providing funds, equipment, and/or personnel. This includes NOAA which provided and installed needed weather equipment, and the Peace Corps which has provided two persons to teach English. However, this Peace Corps program should not be continued. The NMO needs to provide time for project personnel to be properly instructed in English at Casablanca. Those from other project sites should be provided with lessons in English. Scientists in the U.S. should be encouraged to pursue allied scientific research in Morocco through NSF support.

Other Moroccan agencies, such as the Hydraulique, O.N.E., and Agricultural Departments, are expected to participate in the impact (economic) studies and evaluations, yet to occur. This involvement is highly desirable and needs to be urged and monitored by the National Steering Committee, and specific planning for this is needed in future studies.

Summary. The existing institutional documents appear adequate to define roles and responsibilities, but concerns (real and perceived) exist over fulfillment of certain provisions. There are developing needs for new (or redirected) funding and/or assistance as new project issues arise; needs for AID to present a more unified position to BuRec on project objectives and studies; and needs for BuRec to more effectively advise AID Morocco. All agencies appear to have supplied most of the funding, staffing and facilities for project equipment expected in the first year. The project should be developed in Meteo as it will help the institutiional development of Meteo. Involvement of Hydraulique will be needed in the future. Added support will be needed for recommended equipment, data collection, and research

Recommendation: There needs to be clarification of the AID-BuRec relations on project objectives, (see Chapter IV) and certain studies. Better 2-way communication is needed, and AID needs to adopt a more stable and internally consistent view of the project objectives.

PROJECT MANAGEMENT

The flow diagram (see Figure 1, Appendix) and the management design and agency roles (see the USAID-Moroccan Grant Agreement) spell out the complex hierarchy of project management. NMO (Meteo) is the primary Moroccan agency in the project and BuRec is primary for the U.S. General Kabbaj provides general direction of the entire program

A National Steering Committee composed of all effected Moroccan agencies coordinates the overall effort. It has met once and there is no evidence of any impacts from its activities. The future actions of this group are as yet unclear. Hopefully, it will be able to translate te project's goals and concerns for water management to the highest levels of GOM.

The Project Steering Committee membership is adequate and the committee is now functioning. The concepts of teamwork and commonality of problem solving seem to be evolving. We urge the prompt preparation of a special report by the Resident Scientific Advisor (RSA) and the Project Director for this committee to issue as a committee report to the National Steering Committee, describing the project, highlighting the 1984-85 operations, and indicating the water resource situation in the target and control areas. The Committee with its exofficio members also needs to address the confounding issues of project objectives and their priorities, and to identify and try to resolve those project problems.

The documents state that the GOM is to provide staffing to manage the project beginning with Project Director (Benarafa). Mr. Benarafa also directs a sizable meteorological staff of Meteo and has too many duties to provide adequate time for directing, supervising, and monitoring a large scale (>100 staff) complex weather modification project.

Recommendation: a fulltime Project Director be appointed as soon as possible. Possible candidates include Lt. Hamri or M. Maidane

The GOM also provides at the next level, the director of seeding aircraft operations (Hamri), the director of operations (Le Goff and Maidane), and the manager of the maintenance (Louaked). GOM has not yet provided the Director of Scientific Research, supposedly to be Dr. Amrani. These existing managers appear dedicated, skilled, and learning their taks quite well. Majdoub, head of the Khouribga base, and Ouassou, head of the radiosonde base at Beni Mellal are both quite competent. Identification of Moroccan staff in the un-named positions on the organization chart (appendix) is needed to ensure their presence and future training.

Recommendation: The GOM should provide a research director soon.

There are two principal management contributions of the U.S. One is the Mission Project Officer of AID, Mr. Giusti, who provides the project monitoring and interface with BuRec. Although not an atmospheric scientist, we were impressed with his concern for the project and its success.

The other person is the Research Scientific Advisor (RSA) of the BuRec. This person has sizable and diverse duties and many staff interactions (see flow chart), including provisiion of scientific management, field supervision of contractors and of project coordination, provision and monitoring of advice and training for the Moroccans, project monitoring and report preparation, and project information to the AID Mission. We envision that this person, or others, needs to provide during the formative project years, moderately strong scientific and technical guidance and training for the Moroccan staff, as they learn the extremely complicated aspects of weather modification operations and research. We are impressed with Dr. Matthew's scientific skills and breath of knowledge about the project. It appears that the RSA may have too many duties, particularly during the operational seeding season. The RSA effort is further hampered by the lack of a GOM scientist leader for interaction.

Recommendation: The RSA needs to spend more time involved in programmatic interactions with AID and GOM leaders.

Recommendation: The U.S. effort would be enhanced by an additional professional staff member, experienced in field operations, for the future operational seasons.

All U.S. contractors have provided some management functions, primarily through their training roles. These specific activities were often frustrated by (1) language barriers further discussed in the Training Chapter IX, and by (2) differences in the U.S. approach and Moroccan expectations for training.

The final aspect of project management is project evaluation. The approach involving annual monitoring by leaders of AID and BuRec, plus external evaluations in 1985, 1986 and 1988 appears adequate. However, these activities would be aided by annual reports summarizing the project and its accomplishments.

Summary. The existing management structure for the project is necessarily complex but generally adequate. The management entities and staff are developing much as planned 12 months ago. However, GOM must provide a fulltime project director and the scientific research leader. The RSA needs to become more involved in programmatic issues and may have too many duties. The GOM leaders in key project positions are working hard, learning rapidly and show great promise. They will need further training and guidance as the project opeations become more complex. Project leaders and participating agencies would benefit from more concise project information and routine reporting procedures.

IX. TECHNOLOGY TRANSFER AND TRAINING

The review of the technology transfer and training efforts is divided into three components: the Technical Level, the Operationns Level, and the Scientific Level. It should be noted that differences in U.S. and

Moroccan teaching approaches have led to different expectations for training and certification. This problem is somewhat compounded by language differences; hence training in English is highly desired for all project staff.

At the technical level the transfer and training have been very effective to date. Hands-on training and experience have been gained for the following efforts.

1. Rawinsonde operators have been well trained in all aspects of this work - balloon inflation, releases, tracking, equipment operation, data acquisition, data management and data transmission. Good record keeping habits have been developed and a better understanding of the behavior of the lower atmosphere in various meteorological situations is being acquired.

2. METEOSAT receiving equipment in all its aspects is well understood by the operational staff at Casablanca. In fact, these personnel are trained well beyond the capabilities of this particular equipment and could handle more advanced systems were they available. These personnel handle the equipment, operate it routinely, record specific data from it, and are ready to begin initial analyses relating to Target/Control comparisons.

3. Radar technicians are well trained and capable of maintaining the system in good operating condition. There are some frustrations in not having sufficient copies of technical manuals and this should be resolved quickly. The technology transfer has been rapid, positive and confidently executed. It includes not only the microwave aspects but the IFF and diesel generator systems as well as the on-line microprocessors for data acquisition and display. The choice of personnel by METEO for this work has been excellent and all seem to be enthusiastic about their responsibilities. There are some computer software problems which must still be resolved by U.S. personnel. Review of training in the fall would be important.

4. Weather facsimile equipment installed by NOAA for the project has been assimilated well by the Moroccan personnel. Operation and interpretation of data from this apparatus are handled confidently on a daily basis - the technology transfer has been very effective, as has the training. The maintenance of this equipment appears to be well in hand by the Moroccan engineering staff.

5. Seeding technology is well understood by Moroccan personnel at Marrakech. They are able to service all seeding equipment on the aircraft and keep it operational. They have learned the chemical mixing processes for the seeding material and do this work completely without external supervision. It is not known whether they have the capability of dealing with, for example, unexpected quantities of water entering the seeding solution tanks and reservoirs.

6. General equipment maintenance appears to be led by a competent and highly motivated person (Louaked). The tendency to centralize this effort is understandable. The developing competence in repair and maintenance suggests more extensive equipment and repair manuals could now be provided. More extensive training (basic principles to applications) is desired for the future, but may be time consuming and not cost effective, at least for certain aspects of electronics.

At the Operational Level, the training shifts from purely technical to the professional and intuitive aspects. In these areas, progress has been slower but this is normal.

1. Seeding aircraft pilots are beginning to learn about the behavior of the lower atmosphere and clouds in particular. The pilots will be faced with decisioin-making on a variety of complex weather issues. Typical questions are: how long is a cloud an identifiable entity? Where are the principal updraft regions into which the seeding aerosol should be released? Based upon the available meteorological data, what will the ATC operator require my aircraft to do?

   At this time the pilots are performing their seeding duties in an admirable fashion. Simple flight tracks have been designed and used for the seeding activities. This aspect of the operations is functioning well.

   The advent of future in-cloud seeding and seeding of convective storms in updrafts both below and in-cloud, will make future seeding operations much more complex. Opportunity recognition needs operational experience. Because the pilots may also have other duties aloft, this sometimes results in quick shifts of priorities.

   Recommendation: Specialized pilot training and experience in the U.S. on seeding opportunity recognition is highly desirable.

2. Air Traffic Control

   There has been significant training of the ATC operators for their activities in this project. This training was completed in November 1984 and the ATC personnel are now functioning very well in the project. However, the seeding operations at present are restricted to a small number of prearranged flight tracks. As the project seeding approach becomes more complex in 1985-86, it will be necessary to use a greater variety of flight operations and real-time alternatives. This will necessitate further training and discussions with the ATC personnel. We recommend that a skilled operator from the U.S. be provided to work closely with them during portions of the 1985-86 seasons.

3. Operations Directors

In this area, the training of personnel is progressing well. Maidane and Le Goff are very capable and are directing operations in a satisfactory manner. This is the portion of the program that requires meteorological intuition. This will come with time and experience. The Operations Directors must learn to visualize the region of the atmosphere within which the operations are occurring. The combination of the visual radar data, the seeder aircraft locations and capabilities, and the cloud physics aircraft's scientific goals and flight plans must be brought together to produce a successful seeding and research operation. The Operations Directors are strongly encouraged to make themselves familiar with all of these facets of the problem prior to the 1985-86 season. The control of this more sophisticated operational direction of complex situations would be enhanced if the two directors were involved in further training in the U.S., and in simulated cases.

We recommend that the operational directors be sent to work with one or two projects in the U.S. for 1 to 2 months, to gain experience in complex cloud seeding operations under difficult and different weather conditions.

The Scientific Level is the area in which there has been only a modest transfer of knowledge and understanding. Several lectures and seminars have been given describing the basic principles of weather modification in cold clouds. Such courses were included in the ATC and pilot training. Operations Directors have visited the U.S. as has the station manager at Khouribga. METEOSAT staff have received training on specific aspects of their work relative to weather modificatioin.

Because the scientific research aspects of the project are beginning to be addressed, it is essential that the Scientific Analysis team be identified amongst the Moroccan personnel. They should be assigned, if possible, to U.S. institutions who are conducting the initial scientific evaluation studies. Dr. Amrani appears to have the educational background and leadership qualities to head this effort. However, to be most effective, he needs one or two semesters of research and study of weather modification at U.S. institutions.

The two advanced degree students chosen in February 1985 for training in the U.S. should be brought to the project for thorough briefings before their departure from Morocco. They should spend time while in the U.S. visiting those institutions doing scientific studies for this project.

The desired transfer of scientific knowledge at the level required will take place during the remaining years of the field project and probably several years beyond that time. We envision a need for a director broadly trained, a cloud physicist, a cloud dynamicist, a climatologist, and a hydrometeorologist to form a desirable research group.

Some of the less sophisticated analyses should be conducted in the short term in Morocco for the project. These studies include comparisons of cloud frequency, cloud types, cloud top temperatures, radar echo climatologies, cloud lifetimes and cloud trajectories in the target and control areas. They could also include comparisons of air mass characteristics at Casablanca, Agadir and Beni Mellal using radiosonde data and also additional studies of streamflow and precipitation data from existing historical METEO records.

Advice on these types of studies should be provided by the Resident Scientific Advisor. A plan, or outline, of study should be jointly developed. Meteo must provide the time for qualified people, such as Maidane and Le Goff, to be involved in directing and conducting these research studies. Hopefully, Amrani can be assigned to the project immediately so that the joint research and interaction with the Resident Scientific Advisor can begin.

Summary. Future training plans of the BuRec, as described in a April 1985 document, appear well conceived, based on our review. We recommend their pursuance. Much has been accomplished and expectations for further training and education are high. Institutional development is clearly evident. This assessment and awareness of future more complex scientific investigations and field operations has led to the several specific recommendations noted herein.

X. WATER RESOURCES PLANNING AND MANAGEMENT

INTRODUCTION

The driving force behind the Moroccan precipitation enhancement project is the current drought and a desire to help relieve that drought. An equally important reason is to develop the technology in a manner useful to a long term program to enhance the water supplies of Morocco. In that sense, the program correctly recognizes the tie between the use of weather modification and the wise management of the nation's water resources. Since the comprehensive evaluation of water resource changes due to modification has not begun, the research on hydrologic impacts has not been initiated. The water resources planning and management efforts for this project represent studies and training efforts planned to begin soon. Their assessment was based on review of limited statements in the 1984 Project Paper; on a document prepared by D. Matthews on 16 April 1985; on two letters from B. Silverman to J. Giusti in 1985; and on other recent BuRec documents.

The basic interest in water resources planning is to fulfill one of the project's objectives, "to develop the physical and economic information required for establishing the feasibility of the demonstration program and a systematic long term program of precipitation management." (Operations Plan, 1985). That is to say, increased precipitation should be accounted for in the hydrologic cycle; ie., is there more water, how

much, and where? Ansers to these questions mean that the added water, in time and space, can be accounted for and its use wisely planned as part of the management of the water resources of Morocco.

To this end, the plans call for three studies under the misleading label of "economic studies". One is a river basin simulation modeling effort designed to do water budgeting in the target basin, and to discern the impacts of added water due to more precipitation. A second study is of agricultural impacts involving use of crop yield models to ascertain yield changes due to more rain (rain-fed areas) or more water for irrigation. A third involves a water resources survey of Morocco.

The general thrusts of these studies are quite important since GOM and U.S. decision makers on this project will want to know what the value of the altered precipitation has been to Morocco. The river basin modeling and agricultural impacts studies can be improved by slightly different approaches.

> Recommendation: The two recent BuRec planning documents need to be consolidated into a single research planning document. This should be based on the realization that with existing funding two objectives can be satisfied: 1) institutional development of weather modification capabilities in the Meteo, and 2) development of local awareness of the need for better water resource management in Morocco.

The river simulation and agricultural impact studies could have two phases. They should begin with a probing assessment involving review of past studies, available data, and available scientific skills and staff interests in Morocco. Since our recommended approach is basically a 2-step process beginning with a probing, Morocco-based assessment involving Moroccan scientists and engineers and AID staff, it may take longer than the currently envisioned studies. We recommend pursuance of the probing studies soon so as to define the necessity and scope of the follow-on impact studies.

IMPACT-RELATED STUDIES

River Simulation Modeling. This study will be very useful in assessing the effect of precipitation changes on the water resources of the target basin (Chapter V). It will also be useful in gaining an understanding of the water distribution potential and possible uses of added water. This should help GOM assess the value of the added water, and lead to better management of the river and its reservoirs under different conditions. The project needs to involve GOM hydrologists but how this will occur is largely unplanned. The computer of the Hydraulique Department could be used in this modeling. How this involvement could occur should be defined in the plans for this study.

> Recommendation: The river modeling study is important to two major objectives (evaluation and building awareness) and should be pursued.

Agricultural Impact Studies. The development and use of crop-weather models to simulate the effects of addes water on crop production are important. Do the data and information exist to perform these studies? How and when will AID and GOM scientists be involved? The analysis of how the economic impacts, presumably flowing from these yield changes, will be calculated is not yet defined suffiently.

> Recommendation: This study should begin with a probing, scoping study and attempt to specific crop yield changes resulting from altered weather.

Water Resource Assessment. A third part of this phase of the project is a survey analysis of the water resources of GOM to consolidate and interpret information as to water resources availability and usage, GOM management practices, and on water needs. It will directly serve two major project objectives: (1) to evaluate the role of a weather modifiction program within the total context of Morocco's water needs; and (2) to presumably increase local awareness of the need for better water resource management in Morocco.

The performance of this study is partially based on a perceived AID goal (letter of 22 February) of "AID's policy-related efforts to promote an effective water resources management system in Morocco". This goal, and the general assessment of increased water from weather modification as part of the national whole, are well served by this proposed field assessment involving GOM and US scientists working in concert.

> Recommendations: This expert-oriented analysis is highly desirable and should do a great deal to build new interest in Moroccan water management, and show Meteo and the National Committee how weather modification fits in a water resources context. The timing of this study in relation to the river simulation modeling and agricultural modeling studies needs to be considered. We would recommend launching this assessment before the proposed drought and water conference in 1985, so as to involve the scientists and engineers of this study in the conference.

Integration of Results. An on-going scientific integration of the results of the impact and physical-climatological studies is essential. We support this as a function of the BuRec with consultants adding specific skills when are needed. A major concern is whether the technology transfer of Morocco (proposed as seminars and discussions) during and after the integration process is adequate to fulfill the project purpose. Can more planned integration occur? Will an integrative team be found? We recommend a more definitive plan be developed for integration of results.

XI. KEY ISSUES AND RECOMMENDATIONS

SUMMARY

Like many external reviewers asked to intensively assess a large and complex program, we believe we might have designed part of the effort in a different way. However, we recognize that hindsight is infinitely better than foresight, and that the program designers possessed much more information relating to their design decisions than we can possibly acquire. Thus, what we offer are comments and recommendations rooted in acceptance of several of the original design decisions. Hopefully, our assessment will be useful in emphasizing further development of those aspects of the program we believe are going in the right direction to fulfill the project objectives, and helpful in altering other aspects that we believe need redirection if the program is to progress in a most economically and technically effective manner.

The most outstanding aspect of this weather modification project is its overall progress and success to date. In one year, a very complex scientific and technical project involvig two nations and more than 100 staff has been not only established, but has been operating and collecting data for several months. This is a major accomplishment involving great dedication by leaders in both nations, diverse expertise, sizable funding, rapid learning and abaove all, good understanding of the needs of all. The project is on a good foundation ready to move forward.

There are seven key issues with recommendations for action. These are presented in order of priority.

A. Field Operational Problems. Important project functions are scattered among four sites (Casablanca, Khouribga, Beni Mellal, and Marrakech). This is too much distribution and the sites are too widely separated. This leads to inadequate communications before and during actual operations, leading to difficult coordination of critical field measurements. It also hampers desired interactions of the operational team in de-briefings after each mission, and in general, slows technology transfer and training.

We recommend consolidating the field operations as much as possible. First, the field operations should be directed from Khouribga. We think this has been done to its reasonable limit. Second, the seeding and cloud physics aircraft should be located at Casablanca as the operations center. Several other remedial actions suggested below and in Chapters V, VI, and VII will greatly improve the future field operations. GOM needs to provide a fulltime Project Director.

Among the other actions recommended are: the relocation of the radar in Khouribga (GOM-U.S.); relocation of the microcomputer at Beni Mellal to Khouribga and get another microcomputer for Beni Mellal (U.S.); enhance the spare radiosonde at Beni Mellal and use it in various locales to obtain research data (U.S.); install and operate

the planned mountain weather station (U.S.); develop a more effective operational plan for the cloud physics aircraft (U.S.); refresher training for operations of existing equipment (U.S.); and development of a procedure for radar operations to ensure systematic data collection during aircraft operations (GOM and U.S.).

B. Inadequate Seeding System. For a variety of reasons related to equipment and operational limitations, the curent seeding system using OV-10 aircraft is inadequate to deliver the quantities of seeding material in those cloud areas needed to affect the often long-lasting precipitation conditions, and particularlyin the mountainous area of the target.

We recommend several changes and major actions. First, the RMAF should replace by 1985-86 season the OV-10 aircraft with aircraft capable of in-cloud flying, delivery of various seeding materials, and fitted with meteorological sensors and recorders. The two King Air aircraft proposed by GOM appear to be a satisfactory solution.

Second, since the seeding of the future will be more complex both in mountain areas and convective clouds, the pilots and operational directors should have special training in the U.S.; and each aircraft should have a set of meteorological sensors and recording equipment to aid in the seeding decisions and to collect valuable atmospheric data. The training and aircraft meteorological instruments should be provided by the U.S.

Third, the data from 1984-85 (radar, satellite, and aircraft) should be analyzed as rapidly as possible by U.S. and GOM scientists (1) to develop by the fall of 1985 a more definitive approach for the modification of rain and convective bands/cells in the target, and (2) to develop a definitive plan for the aircraft seeding approaches (using King Airs) to be used on the mountain-type storms, and on the convective systems of the flatlands. These plans should be quite detailed, and incorporate the aircraft systems available, skill levels of staffing, and ground support systems.

Fourth, even with superior aircraft, the optimum seeding of the persistent precipitation systems in the mountains can not be adequately achieved with aircraft. We recommend the immediate launching of studies of the 1984-85 data, albeit limited, to design the measurements program needed in 1985-86 to develop a ground-based seeding system by 1986-87. This may include installations of some generators in 1985-86, to be provided by the U.S. and GOM.

C. Clarification and Prioritization of Program Objectives. The assessment of this project's status (Chapter IV) revealed that there were at least nine objectives, some non-complementary, with a lack of agreement by the participating institutions as to their priorities. Assessment of the institutional arrangements and project management (Chapter VIII) revealed further problems related to the project planning, implementation, and operations. This situation provides confusion in the project planning and management, in the implementation of

the project, field operations, in the acquisition and use of equipment and facilities, and in the research studies selected. Institutional development is focused on Meteo, the logical entity to manage and serve the project objectives.

There are major agencies involved in the program and each has one or more objectives that it perceives as the key ones. The top prioirities of different institutions involved in the project do not agree, and this makes designing, conducting, and evaluating the project confusing. This leads to uncertainties and occasional controversies between staff and between participating agencies.

Our recommendation is to develop a more clearly focused set of prioritized objectives which all agencies can agree upon and which can be clearly translated into operational and research guidelines and actions. This should be done by the project Steerig Committee including its ex officio members, by August 1985. The BuRec and the AID Mission need to clarify different views of the project goal, purpose, and objectives through better communication.

D. Future Scientific Research Needs. Assessment of existing plans for future research, both atmospheric and that addressing water and agricultural effects, reveals needs for critical measurements, analytical facilities, staffing, better designs for certain research studies, and funding.

First, critical field measurements of airflow and cloud moisture and ice contents are needed in the mountainous areas of the target to better define the seeding potential and approaches. Thus, airflow-measurements (aircraft, tetroons, tracers, etc) and related modeling are needed in the 1985-86 season. Similarly, water vapor and ice particle values determined from a scanning radiometer and a Ka-band radar are needed. presumably operations could be conducted in 1986-87 and in 1987-88. These will be expensive and should be provided by the U.S. Other related recommendations are found in Chapter V.

Second, analytical facilities for research are needed in Morocco for data entry, quality control, data base management and applied research studies. We recommend a phased approach involving first, immediate U.S. provision of 3 microcomputers at Casablanca and related training by U.S. scientist. Since a minicomputer is not needed now but may be needed in Morocco to support its research role in the project by 1987 or 1988, we recommend that project requirements for larger computer capacity until that time be fulfilled by use of computers of the U.S. research contractors and BuRec. Moroccan programmers and research scientists should be identified and assigned to appropriate studies and trained in computer usage in the U.S. They will then be ready to effectively use a larger system in Morocco.

Third, are the staffing needs for project direction and research. The Moroccan recommendations are identified under Key Issue G. U.S. needs will be met by the contractors, by BuRec staff including the RSA.

Fourth, the studies of effects, or impacts of weather modification need to be designed with an initial assessment phase in Morocco to identify the scientists, the available information and models, and existing data bases. These efforts should lead to the designs of the second in-depth research phases. The effects studies and water resources survey are very important to assessing the value of weather changes and should be pursued by BuRec staff working with GOM counterparts.

Fifth, we urge various funding considerations. If one followed the above recommendations, there will need to be funding reallocations between existing planned efforts, but we suspect that even then there may not be sufficient funds to pursue all the research and data collection efforts needed. Recommended assessment and planning (see Issue F below) will delineate funding needs. Weather research and field data collection are expensive and often require stability and long-term (multi-year) commitments to attract top scientists and to achieve an optimal, cost-effective project. Delays in funding, either between AID and BuRec, or between BuRec and contractors, will (1) seriously damage the scientific credibility of the Moroccan project, and (2) effectively turn a 5-year funded project into only 3 or 4 years of effective data collection and research. Delays in funding would seriously damage the scientific quality of the project.

E. Planning for Rain Modification. The overall plan for the modification of convective cells and systems to enhance rain over the non-mountainous target areas needs clarification and amplification. This includes the modification hyotheses, operational plan, and the physical-statistical design and evaluation.

In the Project Paper we found insufficient explanation of these issues with only brief mention of possible evaluations such as study of randomly chosen pairs of echoes. The scientific basis for modifying the rain in the plains of the target appears less certain. It is certainly less well defined than that for adding snow in the mountains. The convective rain bands observed by radar in 1984-85 season in Morocco suggest the possibility of using the Santa Barbara Project and/or Israeli Program findings as a scientific basis for addressing the questions of the modification of convective bands over Morocco.

We recommend that the available 1984-85 satellite, radar, and synoptic weather data be carefully studied by those familiar with the Santa Barbara and Israeli projects. This study could provide results allowing for a definitive plan by the summer of 1986 for this type of modification program in 1986-87 including a scientific hypotheses, a design of a modification approach, and a plan of evaluation.

We also recommend studies of the rainfall yield from the convective bands. These will help determine their climatological, water resources, and agricultural importance. this study should include a synoptic climatological assessment which would begin to categorize the

various precipitation-producing systems of Morocco and their modification potential. This study should be a joint effort of U.S. and Moroccan scientists with analysis of 1984-85 done by early 1986.

F. Current Assessment and Future Planning. The project is in a period of rapid change, new staff experiences, and a shifting direction from implementation to an operational effort of great complexity with parallel scientific evaluation and economic impact research efforts. Our assessment has been difficult because of these shifts and because project information on current status and future planning are not easily accessed. This situation also leads to uncertainty by the participants and the agencies.

We recommend two actions. First, a concise report describing the overall project and its accomplishments to date needs to be prepared by the Project Director and the RSA, and issued by the Project Steering Committee.

Second, two planning documents are needed; one being the seeding plan for 1985-86 described in the prior section. The other is a research plan more definitive than currently available. it should show how (and why) the various future research studies (cloud physics, climatological and hydrologic evaluations, water resource and agricultural impacts, etc.) will be performed, scheduled, and products integrated so that their results will yield the answers needed to satisfy the project goal, purpose, and objectives, focusing on the institutional development of capabilities within the Meteo, and development of local awareness of how the weather modification fits within the management of the nations water resources. This document should be drafted immediately by the BuRec, and then reviewed by AID and GOM, yielding a project research planning report by June 1985. This timetable should not delay issuance of pending contracts.

G. Technology Transfer and Training Uncertainties. All agencies and many project staff are concerned over the adequacy of activities under this broad issue. Part of this concern relates to different perceptions and varying expectations for training and education. We find (1) the 1984-85 information transfer on how to operate a field project, and (2) the hurried and informal training on special equipment (operations and maintenance of radar seeding systems, radiosonde, satellite, and other equipment) by U.S. contractors to be well done and on schedule, with the Moroccans generally eager and well informed. Our concerns are for the future efforts.

We recommend following the BuRec 3-phase approach and plans as stated in their document of 15 April 1985, with certain additions and caucions. Training by U.S. contractors on equipment must continue, both to learn as problems arise and to address handling of new equipment.

Second, as new and more complicated seeding operations are used, operational staff, both field directors and equipment operators, will need to be further trained. Addition of a person experienced in

field operations from the U.S. during 1985-86 operations is recommended allowing the Resident Scientific Advisor more time for scientific assessment and planning. Simulation will be an important approach to use. Training of cloud seeding pilots and operational directors in U.S. cloud seeding programs for multi-month periods is needed.

Third, the project lacks a fulltime director. The current director has too many other duties in Meteo to provide adequate guidance and supervision for a project involving more than 100 staff and a 5-year budget of $12 million. The GOM should provide soon a person to serve as the fulltime director.

Fourth, the language problem must be better resolved which will aid greatly in training and education, and in better field operations. The English teaching program of the Peace Corps should be ended, and all project staff scheduled by GOM for training.

Fifth, U.S. contractors who have projects involving implementation of techniques or equipment in Morocco, and those with joint research studies, should visit Morocco at the beginning of their efforts to se the project and to meet Moroccan counterparts. In situations where a U.S. contractor will be involved in training of Moroccans over extended periods, knowledge of the French language is of critical importance. Where possible, the Phase 2 training should involve a classroom type approach.

Sixth, the education of Moroccan scientists at the MS and higher levels in the U.S. is needed if Morocco is to develop its atmospheric research capabilities to address adequately weather modification research complexities. At least 5 research scientists with MS or PhD level training will be needed by 1988 for GOM to have a viable research effort. The Moroccans need to identify now a head of this effort and to get the research team identified.

Seventh, the BuRec and AID should ask the National Science Foundation to encourage atmospheric scientists in the U.S. to pursue research relevant to the Moroccan project. This will further expand the scientific research efforts of the project and help in the education of Moroccan scientists.

XII. APPENDIX

AGENDA

April 11 - Team met with P. Hurley to be briefed and provided with project documents.

April 15 - Changnon met with S. Lintner for briefing.

April 19 - Changnon met Bureau of Reclamation (BuRec) messenger in Chicago and got documents for Morocco. Team flies to Morocco.

April 20 - Team arrives Casablanca, and held discussions with D. Matthews.

April 21 - Team met for briefing; then met with Matthews for project discussions and final schedule planning.

April 22 - Team went to Rabat accompanied by Dr. Matthews. AID meeting with Robert Chase, Harry Petrequin, Ken Scherper, Robert Kahn, and John Giusti to discuss plans. Then team met for issues discussion with Petrequin and Giusti. Team, Matthews, Petrequin, and Giusti met with Col. Bamaarouf to discuss our assessment (1430-1600), and then with General Kabbaz. Team met with Messrs. Bensari, Maidane, Le Goff, Amrani, and Benarafa of the Meteo from 1630-1830 to discuss the review and key issues. Met with John Giusti from 1845-2000, and returned to Casablanca.

April 23 - Team spent day at Meteo in Casablanca in a series of individual discussions of each team member with Matthews, K. Brown, S. Benarafa, M. Maidane, and Y. Le Goff. Changnon also met with J. Hajjar of the Peace Corps (1645-1800).

April 24 - Team attended project weather briefing at Casablanca (0830-0930). Conditions indicated an operational seeding day. Groups left for Khouribga (radar site) for site visit. Discussions with L. Davis and J. Welker of CIC, M. Majdoub (site director), and other members of Meteo including Amrani, Benarafa, Maidane (who was directing the operations and under much pressure), Lt. Hamri of RAF, ATC personnel, and 3 radar technicians. The Citation aircraft flew two missions, and a decision to launch OV-10 and Alpha Jet seeding aircraft for seeding was made at 1600. We visited the refurbished airport building at the airport in Khouribga. Departed at 1800 for Beni Mellal, and stopped to see streamgage site on L'Oued Oum er Rbia.

April 25 - Team in Beni Mellal with Benarafa, Louaked, Matthews, Amrani, and Vince Biolley (translator). Visited radiosonde site and met staff; went to Regional Hydrologic Office in Beni Mellal for visit and discussions. Meet Mr. Fougerolles (dam engineer), head of Hydrologic Office and 5 staff members. Discussed streamgages and data, and went to Bin El Ouidane, and Ait Ouamed sites to inspect two streamgages and three raingage sites. Left Beni Mellal at 1700 and drove to Marrakech. Team discussed project there with Benarafa and Louaked.

April 26 - Team in Marrakech to inspect seeding aircraft and Citation aircraft and to discuss operations with 6 Air Force pilots, aircraft maintenance crews, and Citation crew. Met Air Base commander and head of weather station at Marrakech, plus Meteo crew. Attended weekly project debriefing. Returned to Casablanca at night.

April 27 - Team rested and conducted review discussions.

April 28 - Team began writing draft report and assessed further information needs. Discussions with Dr. Davis of CIC.

April 29 - Team wrote, met with more project staff at Casablanca, and went to Rabat with Matthews. There, team met with Col. Ross Gubser (USAF), with J. Giusti on AID issues, and at 1430 with Col. Bamaarouf, Mr. Bensari, Petrequin, Giusti, and 6 other GOM project leaders to discuss our initial findings and project issues. At 1700, we met at AID with Malcolm Purvis, Giusti (and joined later by Petrequin), and Matthews to discuss proposed studies and AID views.

April 30 - Writing on draft report. Discussions at Casablanca with Matthews, Maidane, and Le Goff.

May 1 - Writing of draft report.

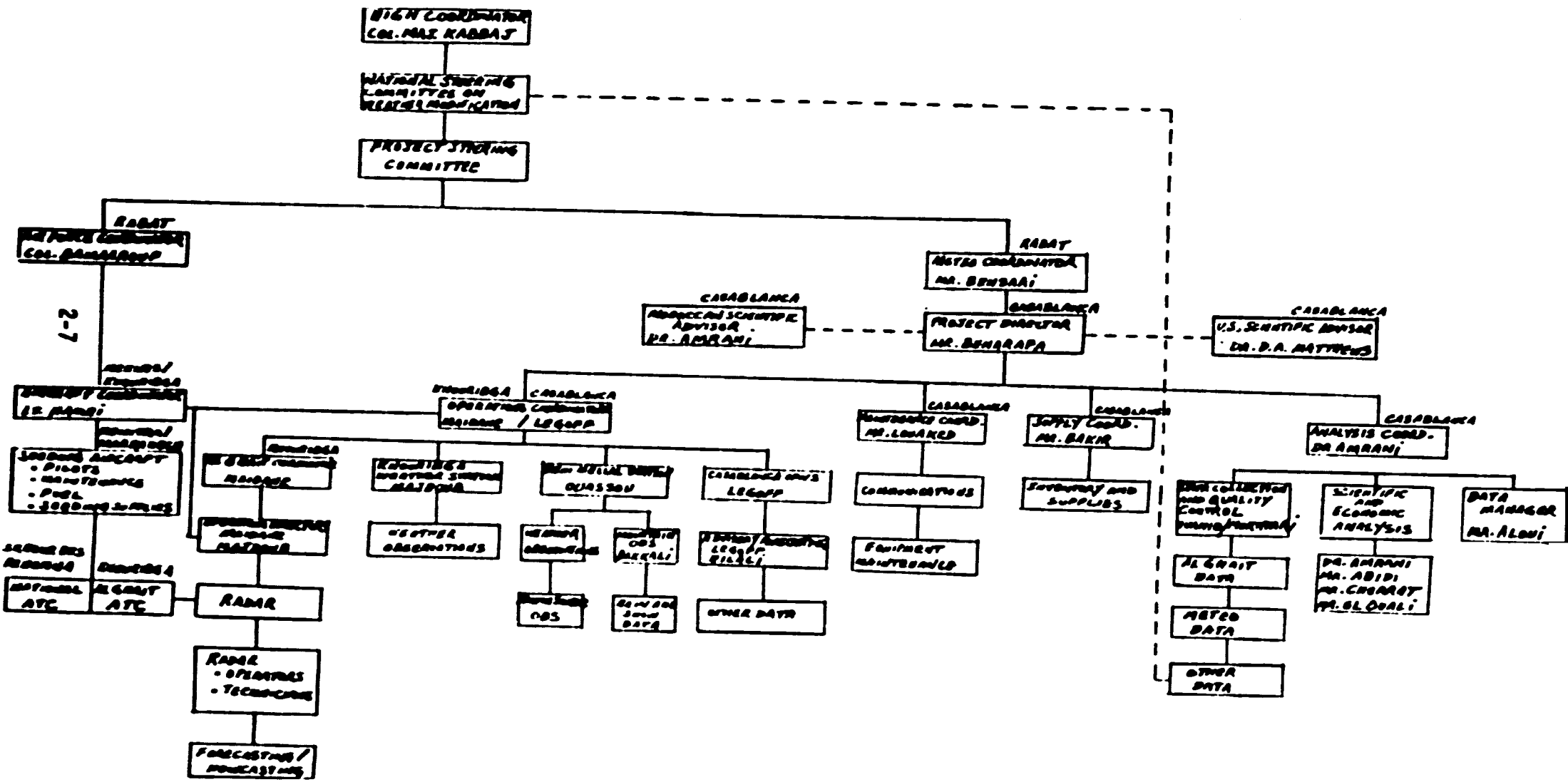
May 2 - Overflight of the target and control areas. Completion of draft report.

May 3 - Debriefings in Rabat of AID staff (H. Kirby, R. Chase, H. Petrequin, J. Giusti, M. Purvis, R. Kahn, S. Rhodes, and comptroller), and of Moroccan project participants (Bamaarouf, Bensari, Banaraba, Midane, Amrani, Le Goff, and Louaked) and Petrequin.

May 4/5 - Departure and travel to Denver.

May 6 - Debriefing of BuRec staff (Silverman, Hurley and Hartsell) in Denver.

Figure 1. Organizational Structure
1984-1985



MORNING: _____ AFTERNOON _____

DAILY OPERATIONAL DECISIO[illegible]
PROCEDURE & RECORD

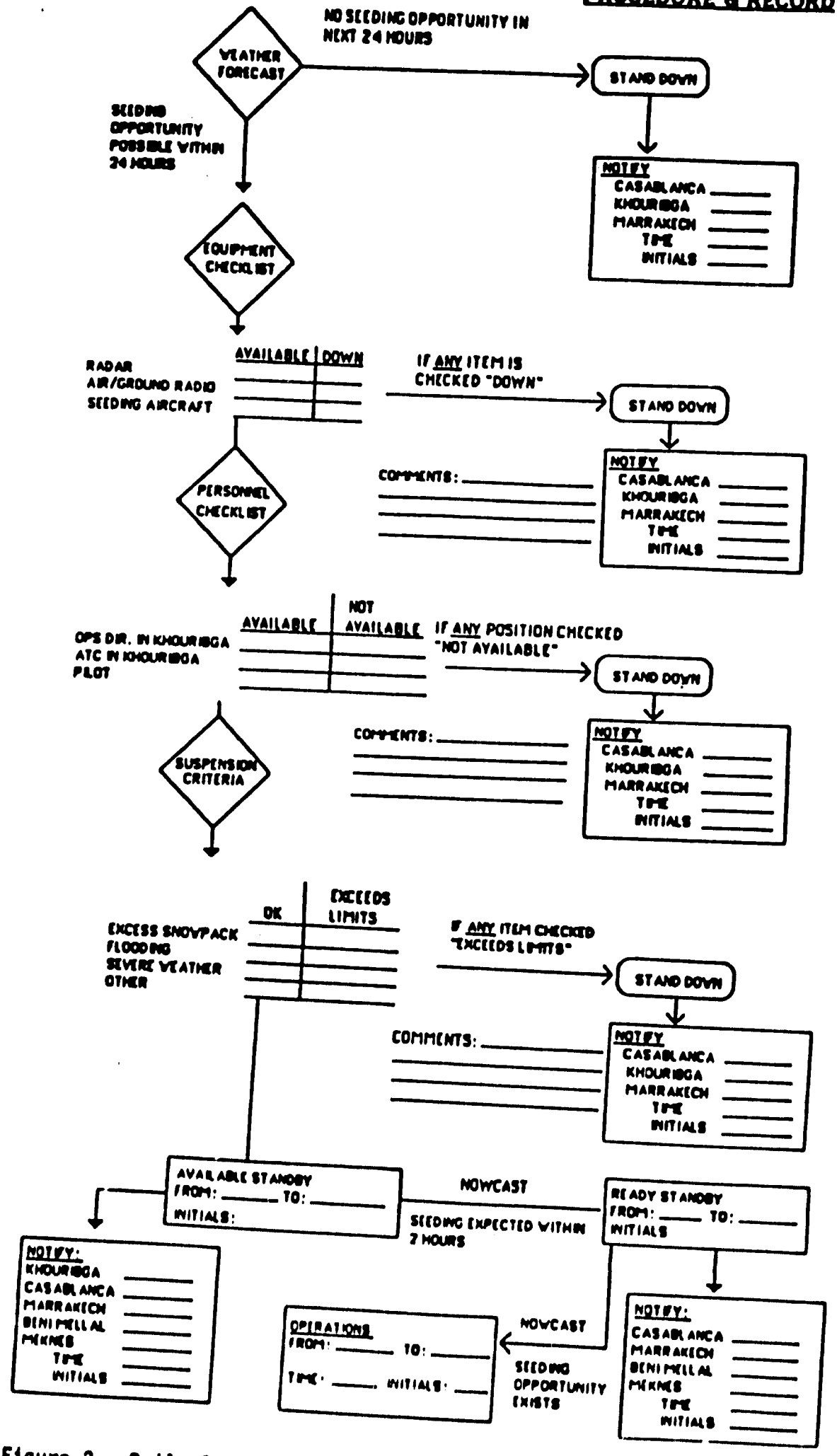


Figure 2. Daily Operational Flow Chart for Decisions and Actions in Use in April 1986

Figure 3. Suspension Criteria Form in Use in 1985.

AL GHAIT

Date_____ Project Forecaster_____
Time_____ Operations Director_____
Suspend? No____ Yes____

Excess Snowpack
Cumulative Precipitation for Beni Mellal since Nov. 1 _____
x 1.75
Critical value is_____ mm

Enter critical value in graph for determining suspension.
If point falls above line suspend operations.

Flooding
Annual Average Peak inflow into Bin El Ouidane Reservoir:_____
x 5
Critical value is _____

Measured inflow into reservoir _____
Suspend if the currently measured inflow exceeds the critical value.

Severe Weather
Suspend if the Sweat (Severe Weather Threat) index calculated on the latest rawinsonde data from Beni Mellal exceeds a value of 400.
Time of rawinsonde:_____Sweat Index _____

Suspend if the Hail Forecast Model run on the latest rawinsonde data from Beni Mellal predicts a hail size greater than 2.5 cm in diameter and/or a maximum convective wind gust greater than 25 mps.
Predicted Hail Size: _____Predicted Wind Gusts _____

Suspend if the Al Ghait project radar indicates convective development within the project area exceeding 12.5 km in height or 50 dBz radar reflectivity at elevations above the melting layer.
Time: _____GMT Location:_____km _____degs.
Echo height: _____km Reflectivity: _____dBz

Special Circumstances

Unsafe Aircraft Seeding Conditions? No Yes
Holiday? No Yes List: _____
Other? No Yes List: _____