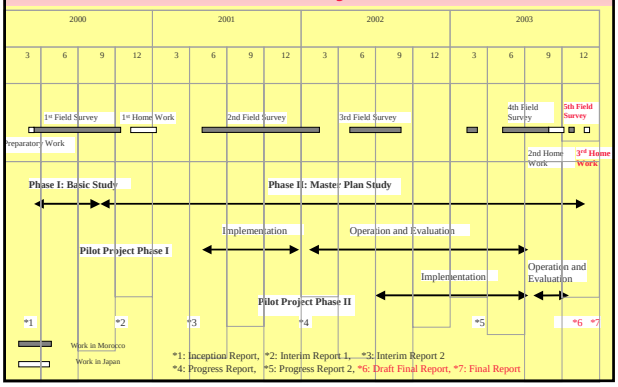
# The Master Plan Study on Flood Forecasting and Warning System For Atlas Region in the Kingdom of Morocco

(Formulation of Master Plan)

November 2003


## Tentative Study Schedule





## Problems of Existing FFWS

| Subsystem | | Problems |
|---|---|---|
| Hydrological Observation and Information Collection | Observation | Network is poor in quality and quantity |
| | Data Transmission | Manual and voice communication, etc. |
| | Collection | Accuracy is poor |
| Data Analysis, Forecasting, Distribution of Flood Information | Data Analysis | Insufficient data analysis, etc. |
| | Forecasting | No forecasting (no simulation model), etc. |
| | Announcement | No criteria for announcement, etc. |
| | Distribution | Inevitable verbal communication errors, etc. |
| Issuance of Warning | | No criteria for issuance of warning, etc. |
| Dissemination of Warning | | Inevitable verbal communication errors, no alarm equipment, etc. |
| Issuance of Warning | | No criteria for issuance of warning, etc. |
| Evacuation | Facilities | Insufficient evacuation and parking spaces, etc. |
| | Operation | No evacuation system, etc. |

## Basic Strategy for the Formulation of Master Plan

- Identification of the necessity and role of the FFWS to cope with the inherent flood problems of each basin.
- Assurance of the reliability of the system to take a proper action.
- Consideration of sustainability of the system.
- Full Utilization of results of pilot project.

## 5.1.1 Basic Conditions for the Formulation of the Draft Master Plan

- As the target completion year, it is assumed that the Master Plan will be completed at 2007.
- As the target flood, the flood condition in 1995 is applied.
- Future basin condition is assumed to develop in accordance with GDP in the region.

## 5.1.2 Selection of Target Areas for FFWS

- High risk areas are selected as the target areas.
- Classification of high risk areas is based on dead casualties in the past disasters.

## 5.2 Improvement of the System in the Master Plan

- Installation of New Hydrologiacl Observation Stations （12 Rainfall and 5 Water Level Station, in total 20 Rainfall and 12 Water Level Station）
- Establishment of Communication Network for Data Collection（Through Alternatives）
- Data Processing and Preparation and Dissemination of Flood Information
- Preparation of Gudiline for Issuance of Flood Warning
- Issuance of Flood Warning through 17 Warning Post
- Preparation of Guidline for Evacuation

## 5.3 Setting up Alternatives

- Alternative-A: combination of option-A based on manual system.
- Alternative-B: combination of option-B based on semi-automatic system.
- Alternative-C: combination of option-C based on automatic system

## Comparison of Alternatives

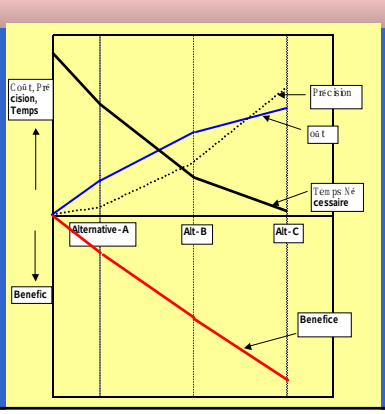
**Table 4-1 Comparision Table of the System**

| System | | | Option A | Option B | Option C |
|---|---|---|---|---|---|
| Sub-system | Component | Item | | | |
| Meteo-hydrological Observation and Data Collection | Meteo-hydrological Observation | Observation Equipment | Manual Observation | Automatic Observation | Automatic Observation |
| | Data Collection | Data Transmission Equipment | Radio Communication by voice | Radio Communication by voice | Radio Telemetry System |
| Data Analysis and Forecasting of Flood and Debris Flow | Data Processing | Data Management Equipment | Manual data processing | Computer Data Processing | Computer Data Procesing and Home Page service |
| | Data Distribution | Data Monitoring Equipement | Data distribution by telephone and Facsimile | Equipt with PC for data monitoring at agencies concerned | Equipt with PC for data monitoring at agencies concerned with Internet Service |
| | Data Transmission | Transmission Method | Telephone Line | Telephone Line | Own Radio network and Telephone Line as Back-up |
| Dissemination of Warning | Warning Command | Warning Control Equipment | Warning Control Equipment is not installed at Caidat. | Simple Warning Control Equipment is installed at each Caidat | Issuance Warning message at Provincial Office directory through Warning Control Equipment |
| | Warning Dissemination | Warning Post | Off-line Voice amplifier at each Warning Post | Off-line Voice amplifier at each Warning Post | On-line Voice amplifier at each Warning Post |
| | Message Transmission | VHF Radiotelephone or Telephone Line | No transmission line is provided. Caidat goes to the Warning Post and broadcasts warning message | Between Caidat and Warning Post connects by Public Subscriber Telephone and VHF radiotelephone | Own VHF Radio Network |

## Compasiron of Alternatives

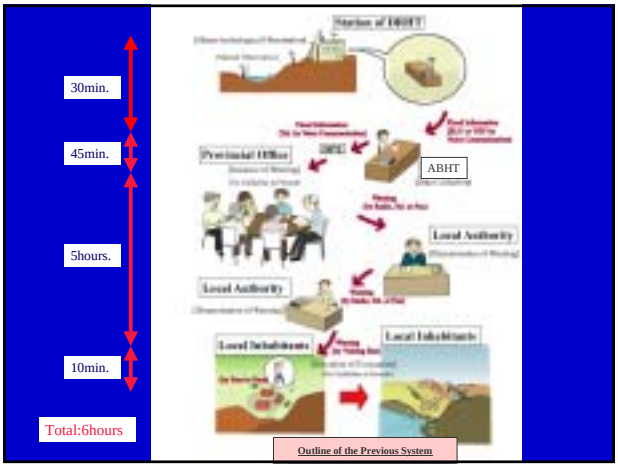
| Alterna-tive | Cost (Mil. DH) | Accuracy | Necessary Time for Total Operation* | Sustainability | |
|---|---|---|---|---|---|
| **Alt-A** | 5.7 | Low | **1.5 to 6 hours** | Good | |
| **Alt-B** | 34.3 | **Medium** | **50 min.** | Fair | |
| **Alt-C** | 47.7 | **High** | **30 min.** | Need Effort | |

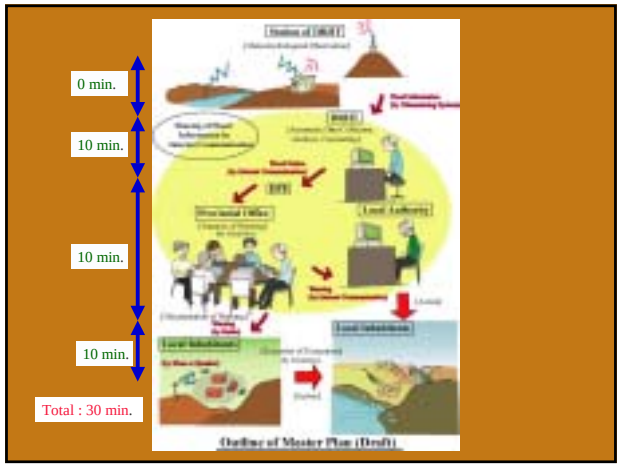
## Relataion among alternatives in Cost, Benefit

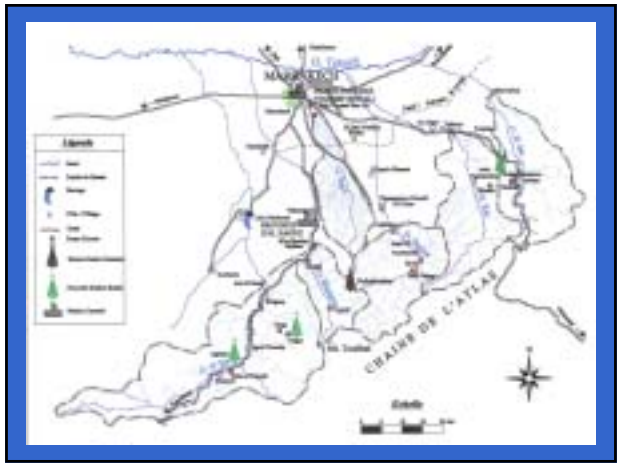



## 4.6 Selection of Optimum Plan

- Introduction of automatic system is strategy of the DGH.
- Alternative-A (manual system) is inferior to B and C in time and accuracy for system operation.
- There is not a big gap in the cost between Alternative-B (semi-automatic) and C (automatic), while a big gap in time and accuracy.
- Alternative-C was selected as the optimum plan.



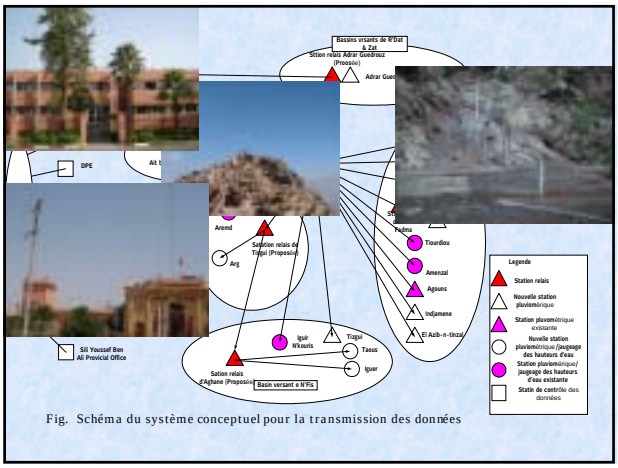



Fig. Schéma du système conceptuel pour la transmission des données

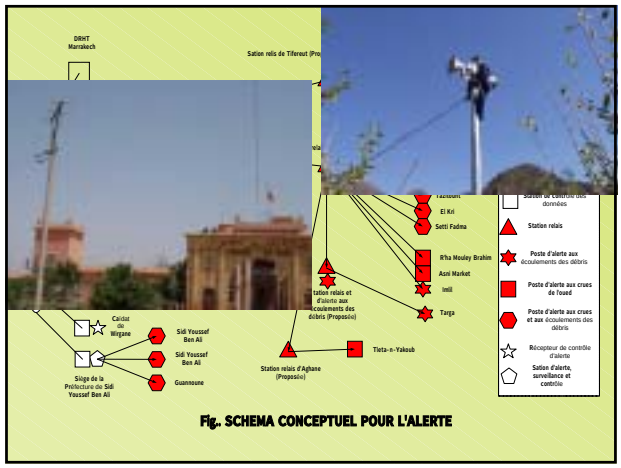
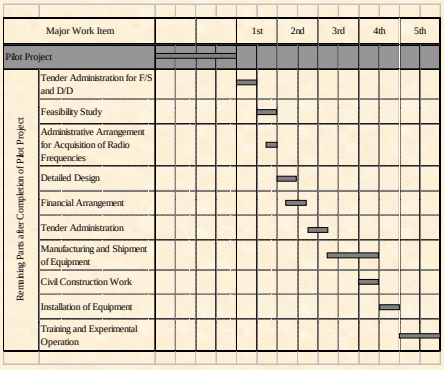



Fig.. SCHEMA CONCEPTUEL POUR L'ALERTE

## Implementation Schedule




## Evaluation économique

| | Movable assets only | Human life included |
|---|---|---|
| EIRR | Negative* | 14.2% |
| B/C | 0.07 | 1. 4 |
| NPV | -Dh 60 million | Dh 25 million |

## Pilot Project

## Summary of Evaluation

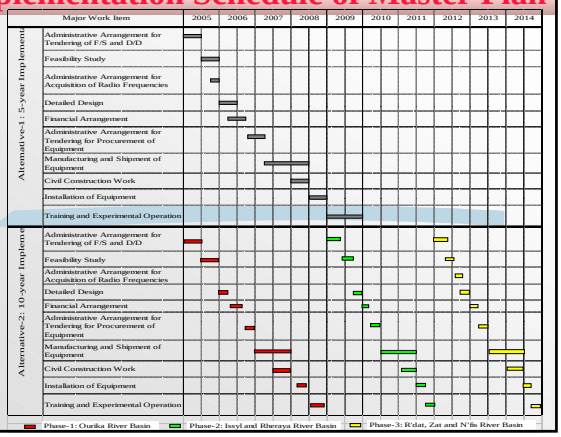
| Criteria | Consideration | Evaluation | Issues |
|---|---|---|---|
| Adequacy of Equipment | Effectiveness | B | Measures against lightning should be considered |
| | Sustainability | B | Maintenance works should be assured |
| Adequacy of Guidelines | Effectiveness | B in simulation drills | The guidelines of which effectiveness was confirmed tentatively in the simulation drills should be examined in actual floods. |
| | Sustainability | C | Strengthening of permanence system and provision of necessary equipment is indispensable.<br>Training programs and simulation drills should be executed regularly |
| Adequacy of Total System | Effectiveness | B | ·Effectiveness against flash flood debris flows of tributaries is insufficient<br>There are still many problems that cannot be solved by FFWS alone.. |
| | Sustainability | B | Machinery to support the pilot FFWS is indispensable. |

A: excellent, B:good, C:fair, D:poor

## Modification of Draft Master Plan

| Item | | Modification |
|---|---|---|
| Basic Condition of M/P | Target Completion Year | Long term implementation is considered as an alternative (5-years and 10-years) |
| Modification of Sub-system | Hydrological Observation and Data Collection | Redesigning of radio network for telemetry system is made. |
| | Diffusion of Flood Warning. | Semi-automatic system is introduced. |
| Modification of O/M plan | | **Creation of a coordination committee** |
| | | **Strengthening of Permanence duty** |
| | | Necessity of explanation and training |
| | | Necessity of interactive analysis with DMN is emphasized. |
| | | Importance of information from local authorities |
| | | Importance of evaluation and grade-up |
| | | Importance of participation of inhabitants and tourism |
| Necessity of comprehensive approach for disaster prevention | | Comprehensive approach including a variety of structural and nonstructural measures |

## Implementation Schedule of Master Plan




## Cost Estimate

| | Cost Item | Amount (1,000 Dh) | |
|---|---|---|---|
| A. | Construction Cost | **60,516** | **(16,612)** |
| | (1)Equipment Cost | 47,749 | (12,826) |
| | (2)Installation and Commissioning Cost | 6,384 | (2,072) |
| | (3)Civil Construction Work Cost | 4,386 | (1,178) |
| | (4)Software Development Cost | 1,000 | (269) |
| | (5)Technical Training Cost | 1,000 | (269) |
| B. | Engineering Services Cost | **15,000** | **(4,029)** |
| C. | Physical Contingency (10% of (A+B)) | **7,552** | **(2,064)** |
| D. | Project Cost (A+B+C) | **83,068** | **(22,706)** |
| E. | Annual Maintenance Cost | **2,387** | **(641)** |

( ) : Cost for Pilot Project

## Project Evaluation (Economic Evaluation)

| Item | Alternative-1 (5-year Implementation) | | Alternative-2 (10-year Implementation) | |
|---|---|---|---|---|
| | Movable Asset Only | Human Life included | Movable Asset Only | Human Life included |
| EIRR | Negative* | 16.7% | Negative* | 19.7% |
| B/C | 0.08 | 1.6 | 0.08 | 1.7 |
| NPV | -Dh 50 million | Dh 31 million | -Dh 45 million | Dh 31 million |

* EIRR can not be calculated due to small benefit

## Project Evaluation

### Financial Consideration

- Annual additional burdens for the O&M are not small.
- Involvement and assistance of regional and even national levels is a must. The proposed coordination committee is expected to become a propeller for promoting the Master Plan.
- DGH provides budget for the correction maintenance.

### Consideration of Social Aspect

- For inhabitants, their strong concern was proved in the pilot project with the voluntarily participation of 30% of inhabitants.

### Initial Environmental Evaluation

- No serious impacts was predicted.

### Technical Acceptability

- ABHT technicians became capable of the operation of the system and it can be said that ABHT is almost ready to accept the Master Plan.

## Comprehensive Approach to Disasters

### Limitation of FFWS

- The FFWS is originally not a measure to eliminate all the damage completely but only a supporting measure to alleviate the disaster risks.
- The safety of the people could not be assured unless they themselves take appropriate actions.
- The system is composed of so-called man-machine system.
- Depending on the magnitude and characteristics of the disaster, they may fail even if they do their best.
- Damage to immovable assets such as infrastructures, buildings and agricultural products is unavoidable with the FFWS alone.

## Comprehensive Approach to Disasters

- **Introduction of Structural Measures**
  - Debris Flow Control: Check dam, Channel work, Sand pocket works
  - Erosion Control : Hillside works, Reforestation works, others
  - Flood control: River channel improvement, Dam and Reservoir
- **Non-structural Measures**
  - Publication of Flood Risk Maps
  - Monitoring of Debris Flow Potential Streams
  - Introduction of Traffic Control
  - Introduction of Land Use Control and Guidance
  - Provision of Facilities for Tourists

## Conclusion and Recommendation

- **Conclusion**
  - In conclusion, the Master Plan is generally viable in terms of economical effectiveness, financial affordability, social and technical acceptability, and environmental impacts.
- **Recommendation**
  - Establishment of Coordination Committee
  - Sustainable Operation of Pilot Project System
  - Comprehensive Approach to Disasters in Atlas Region

# Comprehensive Approach

## UN POINT FAIBLE DU BASSIN VERSANT DE L'OURIKA

- Le bassin versant de l'Ourika est l'un des plus célèbres sites touristiques du Maroc.
- Beaucoup de touristes s'y rendent à bord de leurs voitures.
- En haute saison touristique, un grand nombre de voitures est stationné au long e l'oued.
- De ce fait, en cas d'alerte soudaine, les touristes risquent de s'affoler et de se diriger vers leurs voitures, mais ils se trouveraient dans l'impossibilité d'évacuer.
- Ainsi, on pourrait assister à de nouveaux désastres semblables à celui de 1995, même après l'établissement du SPAC.

## LE CONTROLE DE LA CIRCULATION EST NECESSAIRE

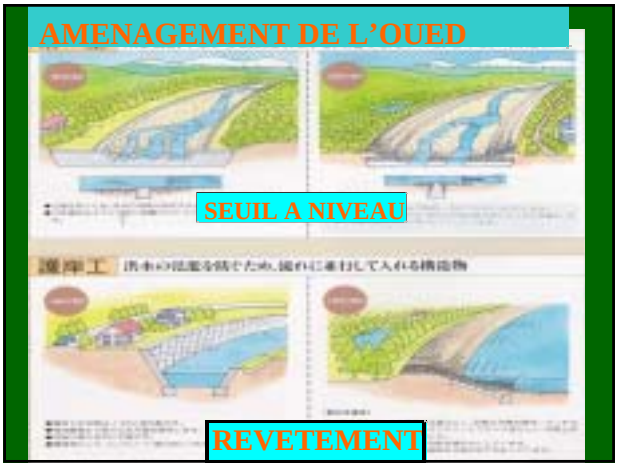
**En référence à cette mesure, on peut citer l'exemple du Japon,la Suisse et l'Autriche**

## L'EXEMPLE DE KAMIKOCHI

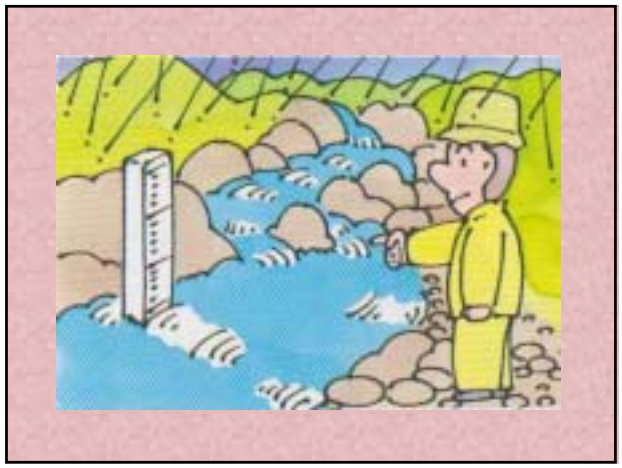

Kamikochi
Ourika River Basin

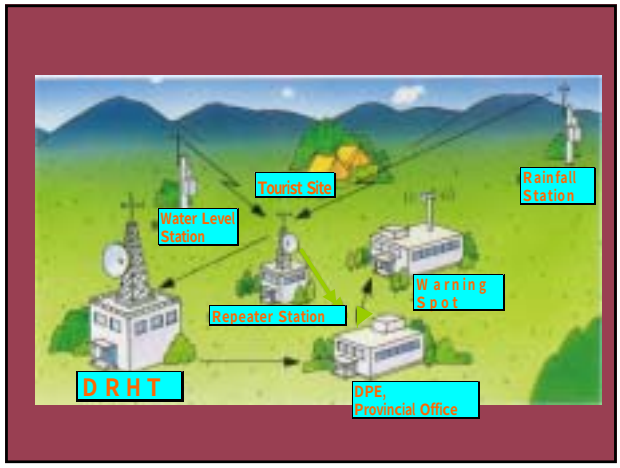

KAMIKOCHI DISASTER


Avant l'aménagement
Après l'aménagement
Aménagement de l'Oued Ourika
Aménagement de Kamikochi


AMENAGEMENT DE L'OUED
SEUIL A NIVEAU
REVETEMENT


Revetment





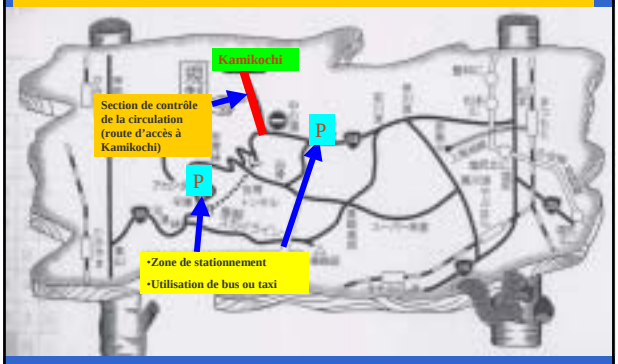
## INTRODUCTION DU CONTROLE DE LA CIRCULATION DEPUIS 1975

La principale raison en est la prévention des désastres, mais elle sert également à la préservation d'un environnement meilleur

## LES PRINCIPAUX ELEMENTS DU CONTROLE DE LA CIRCULATION

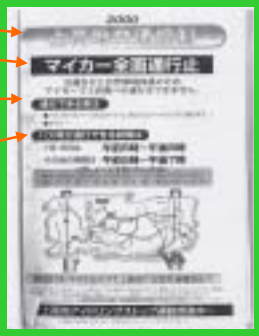
- Interdiction de l'accès à Kamikochi pour les voitures particulières
- Les voitures particulières doivent stationner dans des espaces de stationnement désignés
- Les touristes utilisent des bus publiques ou des taxis pour entrer en Kamikochi.

## UNE AFFICHE DE CONTRÔLE DE LA CIRCULATION




## UNE AFFICHE RELATIVE AU CONTROLE DE LA CIRCULATION

- Contrôle de la circulation en Kamikochi
- Interdiction d'accès aux voitures particulières
- Les bus et les taxi sont les seuls a avoir libre accès
- L'accès en taxi ou en bus n'est permis qu'entre 5:00 et 20:00



## COMMENTAIRES SUR LE CONTROLE DE LA CIRCULATION A KAMIKOCHI

- Au début, les personnes concernées se sont fait des soucies quant à la réduction du nombre de touristes.
- Quelques-uns se sont opposé au contrôle de la circulation.
- En fin tout le monde a compris et s'est montré coopératif.
- Après 20 ans, ce système de stationnement et d'utilisation de s transports en commun est complètement établi.
- La bonne réputation de Kamikochi pour sa sécurité contre les désastres et son bon environnement a été mise en valeur.

## Sustainability of FFWS

- People may forget the flood disaster after a long period. But flood disaster surely will repeat again.
- It is essential to well maintain the FFWS to cope with the disaster, whenever it may attack.
- Cooperation and understanding of people as well as officials concerned are necessary.
- The pilot project was completed and the operation just begins.
- The the sustainability of FFWS is significant.
- We appreciate your further cooperation to operate and maintain your and our pilot project and toward to implementation of the Master Plan.
- Thank you very much for your attention.

**The Master Plan Study on Flood Forecasting and Warning System in the Atlas Region**

# EVALUATION OF PILOT PROJECT

M. KATAYAMA

## Topics

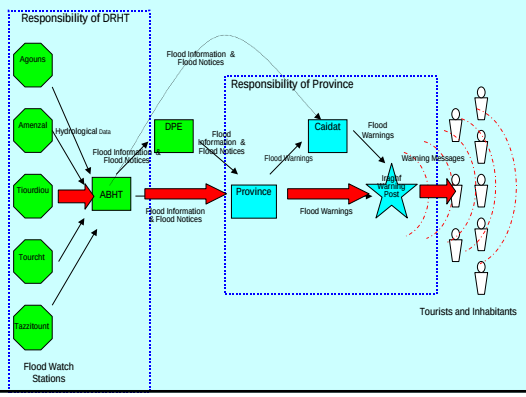
- *Description of Pilot Project:*
  - *Components of Pilot Project*
  - *Installation of Pilot Project*
  - *Preparation of Guidlines*
  - *Technology Transfer Progemas*
  - *Simulation Drills*
- *Experimental Operation:*
  - *!4 June 2003 Flood*
  - *8 August 2003 Rainstorm*
- *Evaluation of Pilot Project*
  - *Criteria of Evaluation (Effectiveness and Sustainability)*
  - *Adequacy of Equipment*
  - *Adequacy of Manual Operation(Guidelines)*
  - *Adequacy as a Total System*
  - *Conclusion*

## Components of Pilot Project

| Subsystem | Phase I (Completed in Dec. 2001) | Phase II (Completed in July 2003) |
|---|---|---|
| Hydrological Observation and Data Collection | Automation at 5 flood watch station | Automation of data transmission (VHF radio with 2 repeater stations) |
| Data analysis, Forecasting, Distribution of Information | Establishment of Master Information Center at ABHT (DRHT) and Monitoring Stations at DGH and so on | Upgrading of data processing system along with introduction of telemetry system |
| Issuance of Flood Warning | Preparation of Guidelines and Experimental Operation | |
| Dissemination of Flood Warning | Establishment of Iraghf Warning Post | Provision of selective call system among Iraghf Warning Post, Al Haouz Province and Ourika Caidat |
| Execution of Evacuation | Preparation of Guidelines | |

## Installation Work

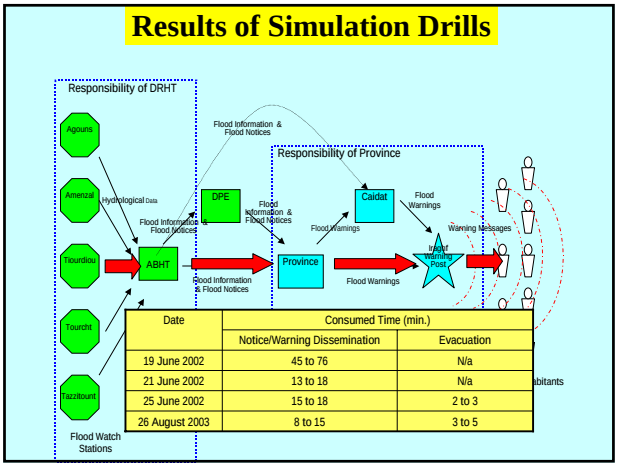
## Preparation of Guidelines




## Technology Transfer Programs

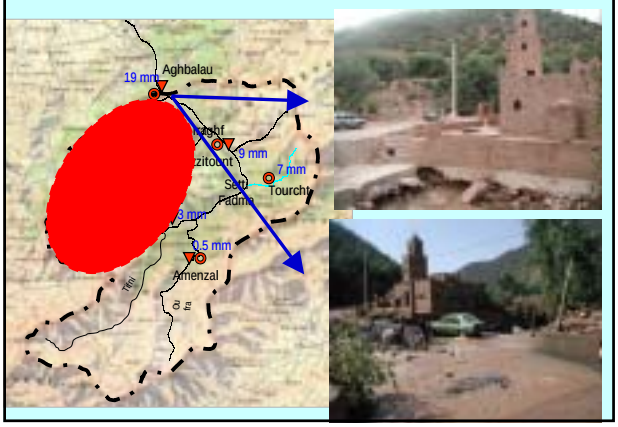
## Simulation Drills

## Results of Simulation Drills

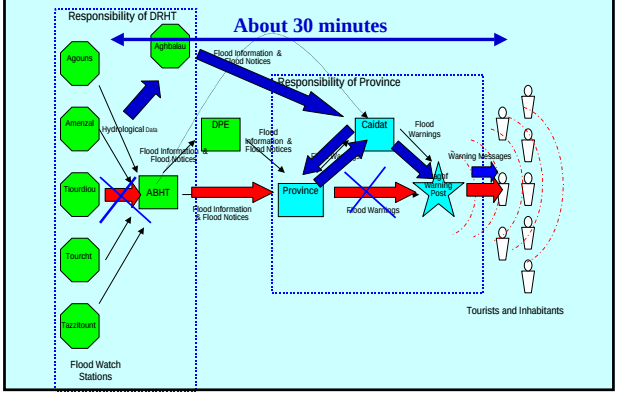



| Date | Consumed Time (min.) | |
|---|---|---|
| | Notice/Warning Dissemination | Evacuation |
| 19 June 2002 | 45 to 76 | N/a |
| 21 June 2002 | 13 to 18 | N/a |
| 25 June 2002 | 15 to 18 | 2 to 3 |
| 26 August 2003 | 8 to 15 | 3 to 5 |

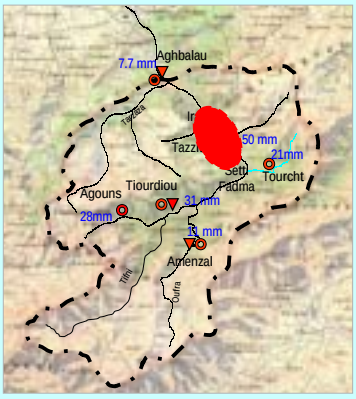
## 14 June 2003 Floods



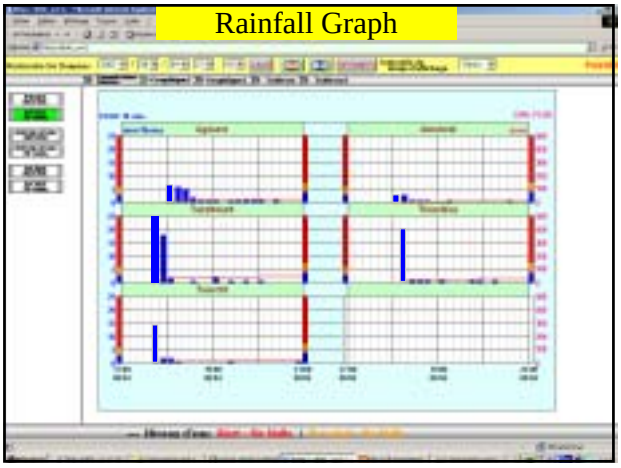

## Actual Operation during 14 June 2003 Flood

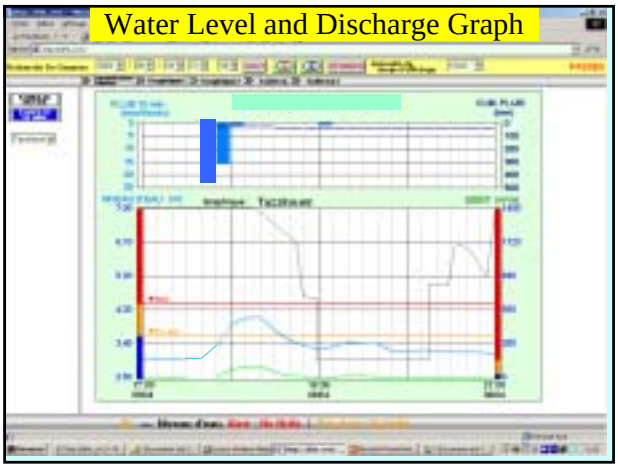



## 4 August 2003 Rainstorm




## Rainfall Graph



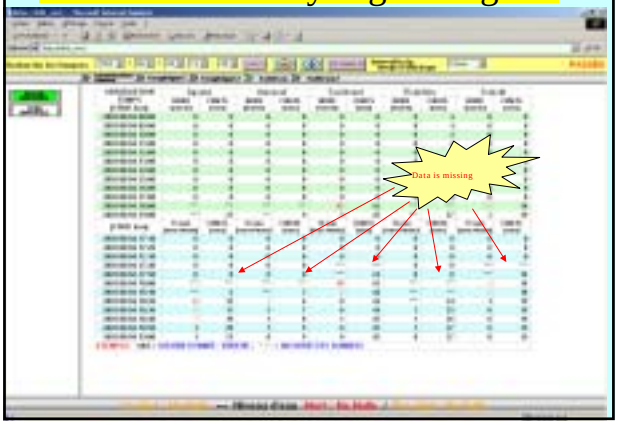

Water Level and Discharge Graph

## Gap of Rainfall Data Between Automatic and Manual Gauges

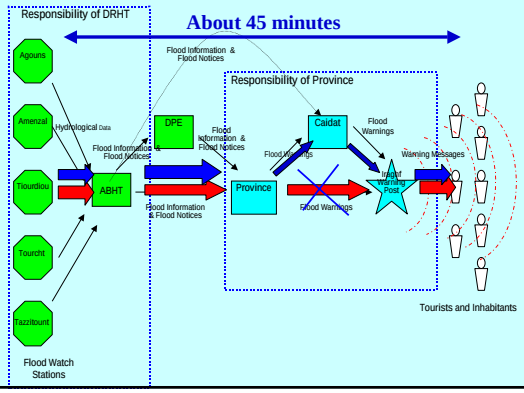

Observed Rainfall Data (mm)

| Gauge | Tourcht | Tazzitount | Tiourdiou | Amenzal | Agouns |
|---|---|---|---|---|---|
| Automatic | 21 | 50 | 31 | 11 | 28 |
| Manual | 205 | 91.5 | 25.8 | 14.9 | 21.3 |
| Difference | 0.5 | -41.5 | 5.2 | -3.9 | 7.7 |

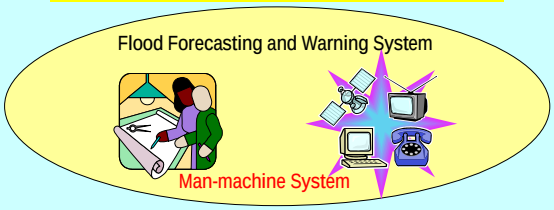
## Interference by Lightening




## Actual Operation during 4 August 2003 Rainstorm




## Evaluation of Pilot Project




Criteria of Evaluation

| Criterion | Criterion | Consideration |
|---|---|---|
| Adequacy of Equipment | Effectiveness | Equipment are effective against disasters? |
| | Sustainability | Equipment are sustainable (durable)? |
| Adequacy of Manual Operation (Guidelines) | Effectiveness | Guidelines are effective against disasters? |
| | Sustainability | Guidelines are sustainable (accepted by personnel concerned)? |
| Adequacy as Total System | Effectiveness | Total System is effective against disasters? |
| | Sustainability | Total System is sustainable? |

## Effectiveness of Equipment Against Disasters

- *In general equipment worked properly during the recent floods.*
- *In particular, effectiveness of the telemetry system is remarkable. The system automatically alarmed ABHT , and then they could for the first time inform Province of the occurrence of the August rainstorm earlier than local authorities.*
- *On the other hand the following problems were identified:*
  - *Interference by Lightening:*
  - *Big gap between rainfall data of Automatic and Manual Gauge.*

- *Countermeasures against interferences by lightening:*
  - *To increase the number of the times of recalls from the repeater station to the flood watch stations.*
  - *To obtain data through radiotelephone*
- *Countermeasures against big gap between automatic and manual gauges:*
  - *To continue to compare the rainafalls.*

## Sustainability of Equipment

- *Several troubles occurred during the experimental operation, but all the troubles were solved within a month. Neither fatal nor chronic problems were found.*
- *Since most of troubles were solved by JRC and Study Team who happened to stayed in Marrakech, the capacity of the oraganizations concerned for handling such troubles has not been practically challenged.*

Major Troubles of Equipment

| Trouble | Station | Cause | Treatment |
|---|---|---|---|
| No connection between Server and Client PC | ABHT | Mis-operation | Restoration by Sohime under direction of JRC |
| Failure of Switching Hub | ABHT | High temperature | Naturally restored |
| Breakdown of DC/CD Concerter | Agouns, Amenzal | Low unstable power supply | Replacement of parts with new modified ones by JRC |
| No-charging of DC UPS | Iraghf | Low unstable power supply | Provision of AVR |
| Unstable communication by radiotelephone | Iraghf | Low signal strength | Replacement of non-directional anntena with directional one by Study Team. |

## Effectiveness of Guidelines

- *Due to simple errors, effectiveness of guidelines were not examined in the actual recent floods.*
- *However, the results of the simulation drills showed a high possibility of the proposed guidelines.*
- *Between July and August 2003 DMN issued in total 8 pre-alert or alert messages over Atlas Region. Among them 3 messages guessed right flood situations over pre-alert levels, but the others failed. Although accuracy of DMN messages is not so high, they are still worthy of listening to.*
- *As far as 21-month hydrological data are concerned, no reason to change the values of rainfall and water level of pre-alert and alert level.*

**Number of days Reaching Pre-alert and/or Alert levels**

| Cause | Pre alert | Alert |
|---|---|---|
| Rainfall | 12 | 4 |
| Water level | 3 | 0 |
| Total | 12 | 4 |

Note: Data period is about 21 months from Dec. 2001 to Sep. 2003

## Sustainability of Guidelines

- *The effect of the simulation drills is beyond question. Through them, understandings of personnel concerned were improved very much.*
- *As seen in the simple errors experienced during the recent floods, however, the guidelines have not been soaked into the personnel sufficiently.*
- *Lacking of necessary tools (telephones, faxes, etc.) and weak permanence system also discourage the personnel to follow the guidelines.*

## Effectiveness of Total System

- *The Pilot FFWS has a high possibility if the results of the simulation drills are taken into consideration.*
- *On the other hand it was revealed in the recent floods that it is difficult for FFWS to cope with rapid disasters such as flash floods and debris flows from tributaries.*
- *There are still many problems in the atlas region that cannot be solved by FFWS alone.*

## Sustainability of Total System

Machinery to institutionally, financially and technically support the Pilot FFWS is indispensable.

- *Institutionally: An ad hoc meeting on flood risk management was held in May 2003, presided by the Governor of Al Haouz Province with the presence of representatives from ABHT, DPE, Royal Mounted Police, etc. This meeting is expected to develop into an permanent coordination committee.*
- *Financially: Assisted by DGH, ABHT made a 120,000 Dh maintenance contract with a local agent for this year. DGH is preparing 200,000 Dhs for the next year.*
- *Technically: ABHT who were trained by the Study Team is requested to further train personnel of the other organizations.*

# Conclusion of Pilot Project

| Criteria | Considerations | Evaluation | Issues |
|---|---|---|---|
| Adequacy of Equipment | Effectiveness | B | • Measures against lightening should be considered. |
| | Sustainability | B | • Maintenance works should be assured. |
| Adequacy of Guidelines | Effectiveness | B in drills but practically unknown | • Guidelines should be examined in actual floods. |
| | Sustainability | C | • Strengthening of permanence system and provision of necessary tools is indispensable.<br>• Training and simulation drills should be executed regularly. |
| Adequacy as Total System | Effectiveness | B | • Effectiveness against flash floods and debris flows is insufficient.<br>• There are still many problems that cannot be solved by FFWS alone. |
| | Sustainability | B | • Machinery to support Pilot FFWS is indispensable. |

# COPING CAPACITY TO FLOOD DISASTERS IN MOUNTAIN REGIONS

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**1. Coping capacity to flood disasters consists of the factors as follows:**

a) solidarity among the people in a community at risk,
b) leadership to direct people of a community at risk,
c) knowledge, technology and skills based on the local wisdom, lessons learned from the past disaster events,
d) materials and equipment to be used for education, warning, flood fighting and maintenance practices and fruits of academic research,
e) financial resource to be allotted for prevention/mitigation, preparedness, rescue, relief, rehabilitation, reconstruction and compensation,
f) sense of ownership for every items for disaster prevention and preparedness is the key factor for resilient capacity of a community at risk.

**2.Role of parties concerned with disaster prevention and preparedness**

The role of parties concerned varies from party to party as follows:

**Local community**---community to village level

a) Solidarity based on commons, spirit of self reliance and mutual help
b) Common awareness based on local wisdom and knowledge

**Autonomous body**---municipality level

a) function beyond the capacity of a community and village covering all the communities in a democratic manner under the aegis of a municipality
b) warnings and their transmission, sheltering, emergency rescue and relief
c) coordination among local communities on the practices for mutual assistance
d) mechanized functions for disaster prevention, rescue, relief, sheltering and rehabilitation
e) material stock
f) insurance

**Regional body**---state, provincial level

a) function beyond the capacity of municipality level
b) hazards watching, early warnings and their transmission
c) coordination among municipalities on the practices for mutual assistance
d) much more mechanized functions for disaster prevention, rescue, relief, sheltering and rehabilitation
e) material stock
f) damage assessment
g) financial supports for disaster prevention, preparedness, rescue, relief, rehabilitation and reconstruction
h) insurance

i) education and research

**State and international body**

a) function beyond the capacity of regional body
b) regional and global cooperation and coordination in the field of monitoring, information services, early warning and technical cooperation to spread technologies and know-how,
c) emergency rescue and relief,
d) development and promotion of disaster-related industries
e) funding for disaster prevention projects for both non-structural and structural,
f) research and training
g) awarding

**3. Land-use regulation**

Disasters due to mudflow is refereed to as “the second son’s disaster” in Japan.

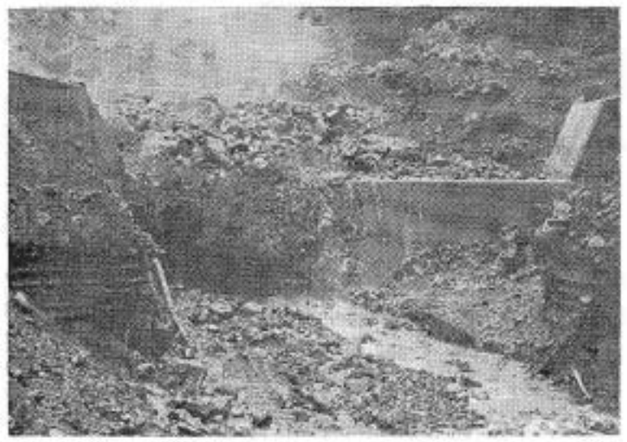
The eldest son had been assured to inherit father’s land and houses which had been handed down from generation to generation because father’s house had been built at the safest location.

The second and younger brothers are obliged to develop new field and housing lots on the land which had been left undeveloped because of high vulnerability to hazards.

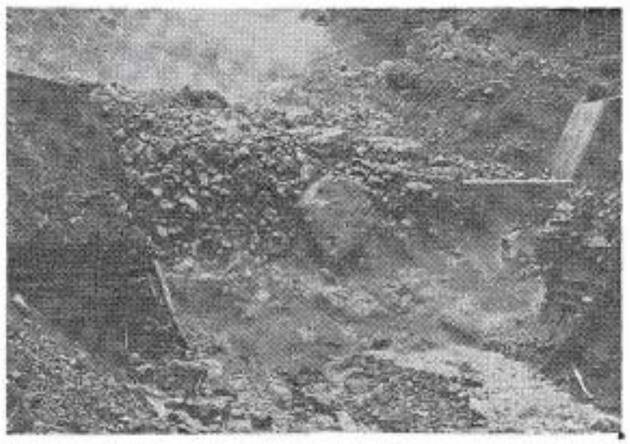
Land-use regulation must be the most efficient and effective step for disaster prevention. They say that fools rush in where angels fear to tread.

In a society with high disaster coping capacity, those who violated the law and regulations for land-use are punished.

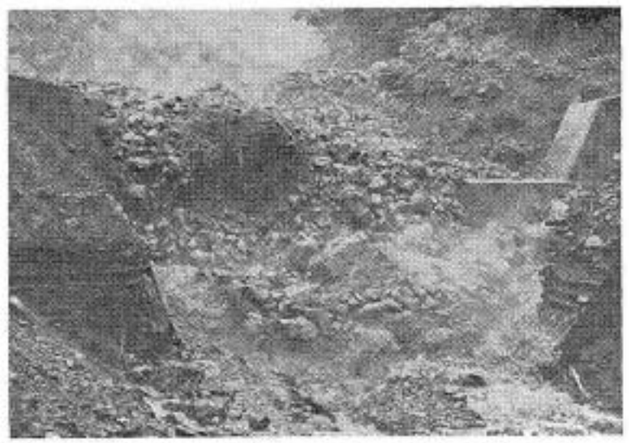
| Type of Movement | Material before Movement | | | |
|---|---|---|---|---|
| | Bedrock | Rough-grained Soil | Ununited Layer: Debris | Sand and Soil / Weather Soil / Topsoil |
| I. Falls | 1) rock fall a | | 2) debris fall b | 3) sand and soil fall c; 4) surface fall d |
| II. Toppling | 5) bedrock toppling; 6) bedrock toppling; 8) toppling slump e | | 7) debris toppling f | g; h |
| III. Slide — Slump | bedrock slump 9); 10) multiple bedrock slump i | | 11) debris slump j | 12) sand and soil slump k; 13) surface slump l |
| III. Slide — Translational Slide | multiple step mountain ridge slide 14); 15) wedge-like cave-in slide; 16) bedrock stray slide m | | 17) debris stray slide n | 18) block slide o; p |
| IV. Lateral Spread | 19) cave-in lateral spreading; 20) bedrock lateral spreading (200 m, 0) q | | 21) wedge-like cave-in by freeze r | 22) lateral spreading s; t |
| V. Flowage<br>A: Bedrock<br>B: Soil | A: 23) deep-seated bedrock creep; 24) deep-seated bedrock creep; 25) deep-seated bedrock creep (1700, 1400 m); 26) floor expansion and elevated creep; 27) shallow-seated bedrock creep; 28) upheaval slide u<br>B: 31) talus creep | | 29) debris flow; 30) debris avalanche; 32) rock avalanche; 33) solifluction; v wet; dry | fluidized debris flow w; 34); 35) quick debris flow; 36) dry debris flow; 37) loess flow; 38) subaqueous slide; 39) spreading; 40) surface creep x |
| VI. Others | | | | 41) front penetrate slide |



(1) the moment of overcoming a check dam



(2) 2 - second later



(3) 3 - second later
(Boulders are overcoming a check dam)

(4) 6 - second later
(The boulders piled up the bottom of the dam)

(5) 8 - seond later
(following including much water)

(6) 11 - second later
(turned into mud flow)

Debris overcoming the check dam, 3 Aug.1976 , Mt. Yakedake