Assessment Report and Implementation Plan for Early Warning and Monitoring Systems

DIPECHO III

August 2006

Table of Contents

I. Introduction

1.1 Background

Since the DIPECHO project was started in 2003, FOCUS has done an outstanding job in assessing the risks of natural disasters, developing Village Disaster Management Plans (VDMP), training the citizens of each village on how to respond to disasters, and working with the communities on various mitigation projects. In the latest phase of this project, DIPECHO III, there is a need to build on existing capabilities by developing early warning and monitoring systems (EWMS).

Effective early warning and monitoring systems for natural disasters can save lives. The people of GBAO are exposed to five natural hazards, but currently do not have any type of early warning or monitoring systems aside from those provided for the Lake Sarez Risk Mitigation Project (LSRMP). There is a need to integrate these existing systems with new community based early warning and monitoring systems to further prepare the citizens of GBAO for natural disasters. The recommended framework for implanting this plan is based on a report from the United Nations publication entitled “Global Survey of Early Warning Systems” released in 2006. This report points to four elements required for an effective, community based early warning system. They are (i) knowledge of the risks faced; (ii) a technical monitoring and warning service; (iii) the dissemination of meaningful warnings to those at risk; and (iv) public awareness and preparedness to act.

1.2 Aims and Objectives

The overall goal of this project is to develop an early warning and monitoring system that is community centered, meaning the people of the villages in GBAO will be active participants in the monitoring/warning process. For this reason, the technical aspects of this project will be kept basic enough to be able to be taught to a person without any education in hydrometeorology.

The objectives of this project are:

- To train village members to monitor and record factors related to natural hazards.
- To ensure recommendations for early warning and monitoring systems provided by village assessments are integrated into VDMPs.
- To provide an alarm system with trained operators within each village.
- To provide signs to warn against natural hazards.
- To provide signs that show the location of CODAN radios.
- To standardize warning messages that are broadcast over the CODAN radio system.
- To build a centralized database that will store the information from all the villages and can also be used to look at environmental trends over extended periods of time.

- To recommend specific equipment that should be purchased for an effective early warning and monitoring system.

1.3 Target Audience

This system will be implemented in the 15 villages that the DIPECHO III project is concerned with. As the system is then refined, it is hoped that it will be able to be taken to all the villages that DIPECHO I and DIPECHO II worked with.

II. Community Based Early Warning and Monitoring Systems

2.1 Risk Knowledge

Currently, FOCUS performs Hazard Vulnerability Risk Assessments (HVRA) in each village to gain an understanding of the specific risks that community faces. Now, in addition to the HVRAs, the field teams must also assess the type of monitoring and early warning systems that would be appropriate for that region. It would be helpful if they could locate specific areas (such as a critical rock crack) that should be monitored. Once the monitoring systems are in place, there will also be a need to gather the data from the villages at a centralized location. Then, all of the data that has been recorded can be observed over time to look for trends which may point to signs of a potential disaster that needs additional observation.

2.2 Technical Monitoring and Warning Service

For the purpose of this project, the recommendations for the early warning and monitoring system are to be kept simple so that the local population can be trained to use them. Not only is the cost kept low, but community based early warning systems allow the villagers to take a more active role in their own protection. This also increases their awareness and preparedness for disasters. More advanced monitoring systems would also be useful and some have been mentioned in this report. Once a basic system has been implemented, it would be practical to look into more sophisticated systems that utilize additional technical equipment.

1) Flooding

The most serious type of disaster the people of GBAO are at risk for is a Glacial Lake Outburst Flood (GLOF). Monitoring for this type of flood requires advanced equipment which has been implemented as part of the Lake Sarez Risk Mitigation Project (LSRMP). There are also local floods and underground floods which can be monitored in the villages with simple equipment.

One example of a successful community based flood monitoring system was carried out in Honduras. The project was started in 1995 through the Organization of American States, Unit for Sustainable Development and Environment, and ECHO. Rainfall and river levels are measured and once the critical river level is surpassed, a public warning is issued.

The following devices are used for flood EWMS:

Pluviometer

A pluviometer is a simple device that measures rainfall. The gauge shown above is the WS-7038UF La Crosse Wireless Rain Gauge. The advantage of using a digital wireless device is that the data is more accurate and it can be transmitted to an indoor location up to 80’ away. This particular model also records rainfall for 7 months and can provide graphs to show hourly, weekly, or monthly trends. It is also useful because it can monitor daily rainfall for dry weather, or hourly rainfall when more intense observation is necessary. The unit requires no maintenance once the simple set up is complete and it runs on standard AA and AAA batteries.

Current Meter

Current meters are simple devices that can be used to measure the current speed in ft/s or m/s. It is accurate within 1% and is powered by a single 9 V battery. This device would be used best by lowering it from a bridge to take periodic measurements. Alternatively, it could be permanently affixed to the underside of a bridge to take continuous measurements. It is possible to purchase a cable up to 1000’ in length so the information could be collected indoors and at quite a distance form the measurement site.

Water Level Sensor


Water level sensors can accurately measure any change in river levels. The device is connected to a simple display by a wire up to 500’ away from the sensor. The device runs on a simple 12 V DC battery. A water level sensor could be used to measure river levels as well as subsurface water levels in wells and holes. This is important to also monitor for underground flooding.

Water Level Pole

The simplest and most cost efficient way to measure water levels is to simply use a pole with measurement markings. Normally, wood or tubular aluminum poles are used, but fiberglass poles can also be used. It would be useful to also use different colors on the pole to indicate caution or critical water levels. The disadvantage of using this device is that it someone must physically go to the site to take the measurement. As with the water level sensors, a water level pole could also be used in wells and holes to monitor for underground flooding.

Water Sensors

These water sensors are activated when completely submerged in water. They are designed to be used as child safety devices in case a child falls into a pool. However, they would be useful for flood warnings as well because they have been tested along freshwater shorelines. These devices could conceivably be attached to the poles used to measure water levels. Then, when the water reaches the critical level and submerges the sensor, a signal is sent to the base station which can then trigger an alarm. The sensor itself has a battery life of 4 years and multiple sensors can be used for the same base station. The base station can be powered by electricity or a solar-charged battery unit. The base station itself has an alarm which will sound, or a secondary, more powerful alarm can be connected. The standard range of the equipment is 100', but with additional equipment, a range of 1000' can be reached.

2) Landslides, Debris Flows and Rock Falls

After flooding, the second most dangerous natural hazard the people of GBAO are exposed to is a landslide. Debris flows, also referred to as mudslides, are common types of landslides. Rock falls are included in this section because early warning devices for landslides and debris flows are also employed for rock fall early warning. Once the initial assessment has been completed and a landslide hazard has been identified in a particular region, there are a number of steps people can take to monitor for landslides. The most difficult issue which requires geological expertise is identifying precisely where the monitoring should occur.

The following devices are used for landslide, debris flow, and rock fall EWMS:

Digital Tape Extensometer

Extensometers are simple devices that are used to measure the distance between two reference points. For the study of landslides, extensometers are generally installed across the main scarp, at transverse crack and transverse ridges near the toe or front portion of the slide and parallel to the suspected slide movement.

Tiltmeter

Tiltmeters are useful in showing the changes in inclination, or deformation of the ground. They can be connected to data loggers which may transmit wireless information to an alarm system. Therefore, if the tilt passes a critical point, an alarm would sound immediately.

Vibrating Wire Crackmeter

A crackmeter is a device that can be used to monitor movement over a crack in the rock. The ends of the device are anchored in the rock and a transducer is mounted across the anchors. If the distance across the crack changes, a signal is produced which is recorded by a data logger.

Inclinometer

An inclinometer is a device used to monitor slopes and landslides. It can detect whether movement is constant, accelerating, or responding to any mitigation measures. A series of fixed sensors (shown above) can be implanted into the hazardous region. The sensors measure a change in inclination and can trigger an alarm when a preset inclination value, or rate of change value, is exceeded.

Vibrating Wire Piezometer

A Piezometer is used to measure pore water pressure. This is useful in determining slope stability as an early indicator for a landslide. The vibrating wire piezometer converts water pressure to a frequency via a diaphragm, a tensioned steel wire, and an electromagnetic coil. The piezometer is also equipped to measure temperature. The signal can be transmitted great distances with a properly shielded cable.

Observation

There are also simple observations that can be performed by everyone in the community for an early warning sign of a landslide or debris flow. The following list, provided by the Federal Emergency Management Agency, offers some great examples:

Recognize Landslide Warning Signs

- Changes occur in your landscape such as patterns of storm-water drainage on slopes (especially the places where runoff water converges) land movement, small slides, flows, or progressively leaning trees.

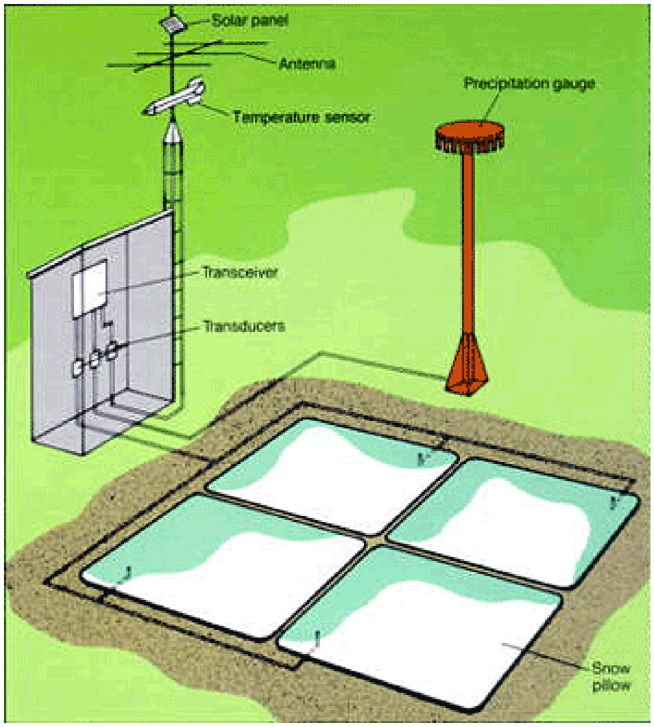
- Doors or windows stick or jam for the first time.
- New cracks appear in plaster, tile, brick, or foundations.
- Outside walls, walks, or stairs begin pulling away from the building.
- Slowly developing, widening cracks appear on the ground or on paved areas such as streets or driveways.
- Underground utility lines break.
- Bulging ground appears at the base of a slope.
- Water breaks through the ground surface in new locations.
- Fences, retaining walls, utility poles, or trees tilt or move.
- A faint rumbling sound that increases in volume is noticeable as the landslide nears.
- The ground slopes downward in one direction and may begin shifting in that direction under your feet.
- Unusual sounds, such as trees cracking or boulders knocking together, might indicate moving debris.
- Collapsed pavement, mud, fallen rocks, and other indications of possible debris flow can be seen when driving (embankments along roadsides are particularly susceptible to landslides).

3) Avalanche

Avalanches are very difficult to predict, especially with a basic early warning system, but there are some precautions that can be taken. There is an increased chance of avalanche with heavy snowfall (greater than 2 cm/h), rain, blowing snow, and rapidly warming temperatures, especially above 0º C.

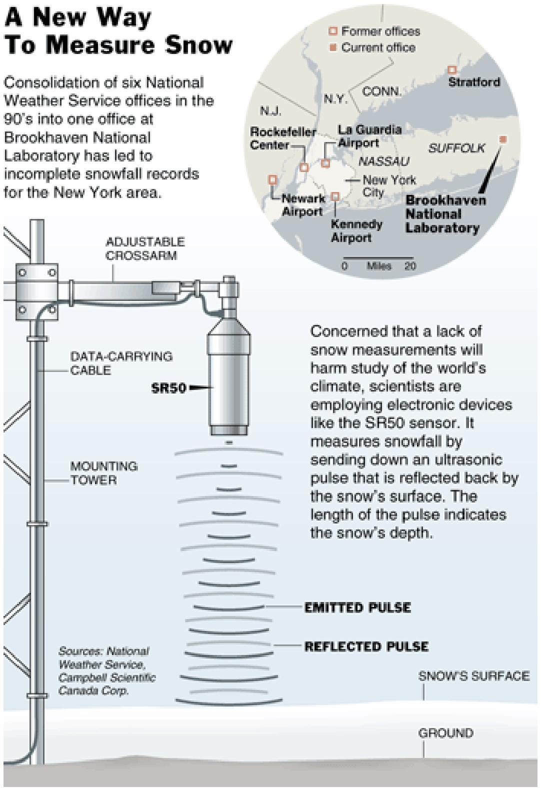
The following are three types of monitoring systems for snowfall:

SNOTEL System



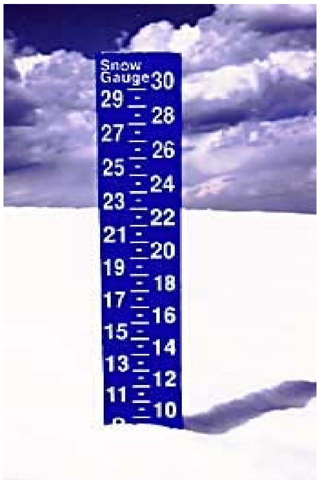
The SNOTEL system is the most advanced system to measure snowfall automatically. The system relies on specially designed snow pillows which rest on a solution of antifreeze. As snow accumulates on the pillows, special weight sensors convert the snow mass into the snow's water equivalent. This information is transmitted via antenna great distances and the batteries of the system are kept charged with a solar panel.

Automatic Snow Depth Sensor



A snow depth sensor is device that employs an ultrasonic pulse to measure snow depth. It can measure snow fall from 0.5 m to 10 m and is effective between –45 ºC to 50 ºC. It is accurate to ± 1 cm. It requires a mounting mechanism and a data-carrying cable. This length of the cable can be custom made and the other end is connected to a data logger for automatic data acquisition. Both the data logger and the sensor are powered by a standard 12 V DC battery.

Snow Gauge



A snow gauge is a very simple, inexpensive device that measures snowfall accumulation. It has spring steel legs which allow it to withstand strong winds and the numbers are large enough that it can be read at a distance (from indoors).

Observation

There are also observations that can provide an early warning sign for an avalanche. The following list is provided by the Scottish Mountain Safety Group.

1. Rapid slab/new snow build up (more than 2cm per hour) may produce unstable conditions. More than 30 cm build up is considered very hazardous.
2. Slab lying on ice or neve, with or with out aggravating factor such as thaw.
3. Discontinuity between layers, usually caused by loose gravel pellets or airspace.
4. Sudden temperature rise - the closer to 0 degrees the greater the risk, even if there is no thaw.

2.3 Dissemination of Warnings

The ADPC recognizes that the greatest challenge with early warning systems is the “translation of geo-physical forecasts into useful warnings which are understood and acted upon”. Therefore, it is necessary that any early warning signal that is triggered must be converted into a standardized, easy to understand alarm so the public is aware of the danger. There are two types of warnings that should be implemented. The first should instantaneously alert the village of an immediate threat. The second type of warning would be delayed because there is no immediate threat to the community. Based on measurements and data collection with various equipment the villagers will be trained to use, they will also be trained to look for certain levels (crack width, river velocity etc) which exceed normal values. They can then relay this information to a centralized agency for further investigation.

The following devices could be used in an emergency situation:

Sirens

Electromechanical sirens emit a very powerful sound in all directions due to a rotating head. This particular model has a sound output of 128dBC and has an effective range of 5,600 feet. Most electromechanical sirens run on AC power but some models are available that can use rechargeable batteries, or even solar power.

Gongs

Gongs can also be used as alarms to alert people of danger. The main advantage of using a gong over a siren is cost. The main disadvantage is that gongs cannot be connected to sensors like sirens can, and therefore need someone to physically strike the gong.

Air Horn

Air horns can also be used as alarms. In the past, air horns were a costly option because the compressed air canisters needed to be replaced. Now some air horns, such as the one pictured above, are rechargeable with a hand held pump. This air horn emits a 120 decibel blast.

Search Light

In the event of an emergency it is also vital that a search light be available. These are inexpensive devices that can greatly aid in finding people moments after a disaster. The light pictured above has 1,000,000 Candle Power and runs on a 6 V battery. It can also be run on rechargeable batteries.

Flares

Flares are simple, effective signaling devices that can be used anywhere. A parachute flare, like the one pictured above, rockets to 1,500 feet and deploys a parachute. It emits a very bright light that can be seen for many miles and lasts about 60 seconds.

2.4 Public Preparedness to Act

Of the four elements required for an efficient early warning system, public preparedness is probably the most developed under FOCUS and previous DIPECHO projects. FOCUS conducts comprehensive village training sessions to ensure communities know how to respond if and when a disaster strikes. One way to build on this capacity, however, is to develop signs and standardized messages to prepare each community. Currently there are no standard warning signs so there is a great need to implement them. Based on ADPC guidelines, it would be useful if these signs contained symbols.

Safe Haven Signs

Currently the only type of sign present in each village to indicate a safe haven is pictured above. These signs are designed on rocks and therefore cannot be seen from centralized locations. The arrows are simply painted on the rocks and are vulnerable to weathering. New signs need to be more visible and durable. The following sign would be suitable because it is simple and clear. This sign, as well as the others depicted below, have English text, but the final version will most likely have to be in Tajik. Blue was chosen as the color because the existing safe haven signs are blue arrows.

CODAN Radio Signs

Above is an example of the sign that is posted on top of the Pamiri home that houses the CODAN radio in the village of Basid. This sign offers no indication of what the 'Early Warning System Project' is. A much better alternative would be to use a simple sign (shown below) that gives a clear message that a CODAN radio is available there. Also, since CODAN radios are not available in all villages, it would be helpful to have road signs with kilometer markings in case of a disaster away from a village with a CODAN radio.

Natural Hazard Signs

Road signs are helpful to alert motor vehicles to possible dangers. For example, the Ministry of Transportation in British Columbia employs "No Stopping" signs as a precaution for avalanches. It would also be helpful to have a general sign that warns against landslides, debris flows, and rock falls.

III. Implementation Plan

3.1 General Information

It would be beneficial if all of the equipment discussed in this report could be implemented. However, due to financial restrictions and lack of geotechnical expertise in the villages, this would be impossible. A single electro-mechanical siren costs more than $3,000 and a fully automated landslide warning system would cost between $10,000 and $80,000. Since the financial resources need to be distributed across fifteen villages, it is necessary to make recommendations for systems which will be effective and cost-efficient. It is also important to keep in mind that the goal of this project is to develop community based early warning and monitoring systems so the recommended devices are ones that are simple enough for anybody to use.

The conclusions reached in this report are drawn from extensive research and from recommendations provided to FOCUS from geologists who have visited the fifteen villages of DIPECHO III. This report contains hazard specific recommendations for early warning and monitoring in each village.

At the time this report was written, 13 villages had been assessed. The following chart shows the specific hazards each of these villages is at risk to. Flooding includes both river floods and underground flooding.

District	Village	Flooding	Landslide	Debris Flow	Rock Fall	Avalanche
Murgab	Murgab	☒		☒		
Roshtkala	Vezdara *	☒	☒		☒	
Roshtkala	Rozhdara *			☒	☒	
Roshtkala	Kala *			☒		☒
Roshtkala	Rimvodzh *	☒		☒	☒	☒
Roshtkala	Kurtsboghen *			☒	☒	☒
Roshtkala	Siev *				☒	
Rushan	Derdeh	☒		☒	☒	☒
Rushan	Baju	☒				☒
Rushan	Bardeh					☒
Darvaz	Luhch *			☒		
Darvaz	Kalaihusseyn			☒		☒
Darvaz	Sabziharv			☒		☒

Tab. 1: Hazard risk for the DIPECHO III villages.

3.2 Monitoring Systems

Of the 13 villages assessed to date, only 7 have some type of monitoring system in place (indicated with a star on Table 1). The current systems, however, are extremely basic and only involve seasonal, visual observations by the local populations. There is a strong need to incorporate a more technical and precise system that can be used to monitor for hazards throughout the year.

For flooding, the two most important measurements are river levels and rainfall. The easiest way to measure the river level is to use a water level pole. A water level pole should also be used to measure subsurface water levels in wells and holes to monitor for underground flooding. Even if a village has not been assessed as at risk for flooding, simple monitoring of river levels should be implemented. This data may eventually show gradual changes over time that could put the village at risk for a flood. The second factor, rainfall, should be monitored in each of the villages. Rainfall is an important measurement not only for flooding, but also for landslides and debris flows. Since all of the villages are at risk to at least one of these three hazards, rainfall must be monitored in all villages. It is possible to use a simple cup with gradations showing the amount of rainfall, but because of the simplicity, accuracy, low cost, and ease of use especially during heavy rainfall, a digital pluviometer would be the best instrument to use. The geologists also recommend purchasing three current meters to measure river flow rates in various locations.

Landslides, debris flows, and rock falls also require specialized monitoring. The most basic type of monitoring is simply visual observation while the most advanced type of monitoring would include crack meters, inclinometers, piezometers, and extensometers. For this project, a medium between these extremes is recommended. According to some experts in the field, the two most critical factors that cause landslides are rainfall and soil pore moisture pressure. However, the FOCUS geologists recommend measuring crack width instead of pore pressure. Therefore, each village that is at risk to a landslide, debris flow, or rock fall should have a pluviometer and an extensometer. One limitation, however, is that a single digital extensometer costs upwards of $2000. Therefore, our geologists say that this money would be better spent elsewhere (on satellite phones for example). Instead of using an extensometer it is possible to use a much more basic system that can measure and show changes in crack width. Simply using 2 sticks or poles and measuring the change in distance between them over time is sufficient.

A monitoring system for avalanches must involve a measurement of daily snow depth. The SNOTEL system is a great device, but it is extremely expensive costing more than $15,000. The automatic snow depth sensor costs only $850.00 and our geologists recommend buying three of these devices for the most high risk villages. For the rest of the villages a snow depth gauge is recommended.

Based on the FOCUS report from our geologists, it is recommended that the villages of Murgab and Rimvodzh also monitor for river bed erosion. This can be done by installing a series of benchmarks at various distances from the edge of the riverbank. Daily measurements can then be taken and recorded.

Finally, there must be a recording and reporting system for all of the data that is gathered. Each village should have an organized system of specific people to monitor each of the instruments. The data should be recorded and kept by one person in the village and then, as often as possible, this information should be relayed to the Hydro Meteorological Center in Dushanbe or a similar organization. The data can then be computerized and if any of the measurements are outside of the normal range, either a team can go to the village for further assessment, or an evacuation can be issued.

3.3 Early Warning Systems

According on the FOCUS report provided by our geologists, there are currently no early warning systems in place in any of the villages. The geologists have, however, recommended various systems that should be in place based on the hazard. The most common recommendation is a gong. They have also recommended a siren, flares, a vehicular horn, and a vocal method. Basically, there needs to be an audible and visual warning when a disaster is about to occur or is occurring. Taking into consideration ease of use, availability, cost, and effectiveness, the best system to use would be a combination of an air horn and signal flares and these should be available in all of the villages. Sirens are too costly to implement in all the villages and air horns are a much better alternative to gongs or vehicular horns. They are loud, easy to use, and reusable. Combined with signal flares, air horns would be the best warning to use in the villages. Searchlights are not recommended by the FOCUS geologists as part of this system because of the limited battery life.

In addition to the general early warning systems that need to be implanted in all of the villages, some villages need specific early warning systems. As shown in Table 1, the villages of Murgab, Vezdara, Rimvodzh, Derdeh, and Baju are all at risk for flooding. These villages, therefore, need a flood warning system in place. The best system to use for these villages is the flood sensor system which will set off a remote alarm when the sensors are submerged.

As part of the entire early warning system, there will need to be communication with the Hydro Meteorological Center in Dushanbe. Once they receive and process the monitoring data they may need to issue warnings to prepare villages for a disaster. This is why it is absolutely necessary that a set of standardized messages be developed for use across the CODAN radio system. For villages without a CODAN radio, the standard telephone system must be used. There are currently 7 villages (1 in Roshtkala, 3 in Rushan, and 3 in Darwaz) without a CODAN radio and that are outside the telephone system. It is recommended that three satellite phones be purchased to test in some of the villages. If they are successful then additional satellite phones can be purchased for the other villages.

The signs described in this report are also a very important part of the early warning system. There needs to be an assessment done to see exactly how many signs are required, and where they should be located. Once this assessment is complete, the new signs can be implemented in the recommended locations.

IV. Financial Summary

Based on the final recommendations of FOCUS geologists and engineers, the approximate costs associated with the recommended equipment are shown below. The transportation cost is an estimate based on goods from the United States. If similar items can be found in Russia or China, then the transportation costs would be significantly lower.

Item	**Quantity**	**Unit Price**	**Total**
Air Horn	15	$35.00	$525.00
Flares	45	$11.00	$495.00
Pluviometer	15	$50.00	$750.00
Snow Depth Gauge	15	$10.00	$150.00
Water Depth Pole	15	$10.00	$150.00
Safety Turtle Flood System	5	$800.00	$4,000.00
Current Meter	3	$2,000.00	$6,000.00
Satellite Telephone	3	$1,000.00	$3,000.00
Snow Depth Sensor	3	$850.00	$2,550.00
Subtotal			$17,620.00
Estimated Transportation Costs			$2,000.00
Total			**$19,620.00**

Tab. 2: Financial Summary.

V. Conclusions and Recommendations

Of the 13 villages that have been assessed so far many different devices would be useful for the EWMS. The following chart gives a summary of each of the devices that should be implemented in each village. For snow depth sensors, current meters, and satellite phones, further assessment needs to be done to see which of the villages indicated in red should receive the equipment. The number of available units is indicated in parentheses.

Village	Air Horn	Flares	Pluviometer	Snow Depth Gauge	Snow Depth Sensor System (3)	Current Meter (3)	Water Depth Pole	Satellite Phone (3)	Flood Sensor System
Murgab	☒	☒	☒	☒		☒	☒		☒
Vezdara	☒	☒	☒	☒		☒	☒	☒	☒
Rozhdar	☒	☒	☒	☒			☒		
Kala	☒	☒	☒	☒	☒		☒		
Rimvodzh	☒	☒	☒	☒	☒	☒	☒		☒
Kurtsboghen	☒	☒	☒	☒	☒		☒		
Siev	☒	☒	☒	☒			☒		
Derdeh	☒	☒	☒	☒	☒	☒	☒	☒	☒
Baju	☒	☒	☒	☒	☒	☒	☒	☒	☒
Bardeh	☒	☒	☒	☒	☒		☒	☒	
Luhch	☒	☒	☒	☒			☒	☒	
Kalaihusseyn	☒	☒	☒	☒	☒		☒	☒	
Sabziharv	☒	☒	☒	☒	☒		☒	☒	

Tab. 3: Recommended Early Warning and Monitoring Systems

According to research and feedback from FOCUS geologists and engineers, the following recommendations are made:

1. Each village should be equipped with an air horn and flares in case of emergency.

2. Each village should engage in hydrometeorological data recording and this information should be transferred to the Hydro Meteorological Center in Dushanbe.

- Daily rainfall should be measured by a pluviometer. Heavy rainfall should be monitored hourly.
- Snowfall should be measured daily with a snow depth gauge or snow depth sensor if available.
- River and well levels should be measured daily with a water depth pole.
- River current should be measured daily where a current meter is available.

- High risk rock cracks, as deemed so by the geologists, should be monitored weekly by the villagers using sticks and a measuring tape across the crack.

- The villages of Murgab and Rimvodzh should implement the benchmark system of monitoring for river bed erosion once per week.

3. Three automatic snow depth sensor systems should be installed in three of the eight villages at risk for an avalanche. The villages should be selected based on geologist recommendations.

4. Three portable current meters should be used in three of the five villages at risk for flooding. The villages should be selected based on geologist recommendations.

5. Each of the villages at risk for flooding should have a flood sensor system installed which includes a remote alarm.

6. Of the seven villages that do not have CODAN radios, or regular telephones, satellite phones are recommended. It is recommended three phones be tested first, and if successful, then the remaining villages should have them as well.

7. A detailed assessment of the quantity and location of hazard, CODAN radio, and safe haven signs is recommended. Once this is complete, these sign can be implemented.

8. Any new Hazard Vulnerability Risk Assessment should include recommended early warning and monitoring systems.

9. Any new Village Disaster Management Plan must include implementation and training for EWMS equipment.

10. All villagers should be trained in visual monitoring techniques to observe early warning signs for each of the natural disasters.

VI. References

2001DC Outdoor Warning Siren. Audtiotech Outdoor Warning Sirens and Siren Controllers. 5 July 2006. <http://www.adsig.com/sirens.htm#Electronic>.

"Avalanche Warning Signs". The Scottish Mountain Safety Group. 21 July 2006. <http://www.scottishsport.co.uk/walking/avalanche.htm#shovel>.

"Avalanches – A Safety Hazard". Ministry of Transportation. Government of British Columbia. 19 July 2006. <http://www.th.gov.bc.ca/mot_org/const_maint/snowavalanche/snow_av.htm>.

"Before a Landslide or Debris Flow". 6 April 2006. Federal Emergency Management Agency. 9 July 2006. <http://www.fema.gov/hazard/landslide/ls_before.shtm>.

Bernstein, Fred. "Flawed Snowfall Data Jeopardize Climate-Change Research". 11 February 2003. The New York Times Company. 20 July 2006. <http://www.weather2000.com/nytimes_20030211.html>.

Comet Rocket Parachute Flare. BTP Arms. Keepshooting.com. 14 July 2006. <http://www.keepshooting.com/militarysurplus/flares/cometrocketflare.htm>.

Digital Tape Extensometer. Durham Geo Slope Indicator. 14 July 2006. <http://www.slopeindicator.com/instruments/ext-tape.html>.

"Early Warning". 33rd Disaster Management Course. Module 10. Asian Disaster Preparedness Center Presentation. 16 January – 3 February 2006.

Eco Blaster Air Horn. Taylor Products. Amazon.com. 25 July 2006. <http://www.amazon.com/gp/product/B0000AXRIG/ref=pd_sbs_sg_2/104-0137064-7675149?%5Fencoding=UTF8&v=glance&n=3375251>.

EI In-Place Inclinometer Sensors. Durham Geo Slope Indicator. 14 July 2006. <http://www.slopeindicator.com/instruments/inclin-el-ipi.html>.

EL Electrolevel Tiltmeter. Durham Geo Slope Indicator. 14 July 2006. <http://www.slopeindicator.com/instruments/tilt-eltiltmeter.html>.

"Engineering and Design – Hydrographic Surveying." 1 January 2002. US Army Corps of Engineers. 3 July 2006 <http://www.usace.army.mil/publications/eng-manuals/em1110-2-1003/c-8.pdf>.

"Frequently Asked Questions". Canadian Avalanche Association. 26 July 2006. <http://www.avalanche.ca/default.aspx?DN=19,15,3,Documents>.

"Global Survey of Early Warning Systems". Bonn. March 27-29, 2006. United Nations Third International Conference on Early Warning. 2 July 2006. <www.ewc3.org/upload/downloads/global_survey.pdf>.

Hansen, Michael C. "Landslides in Ohio". Geofacts No. 8. September 1995. Ohio Department of Natural Resources. 5 July 2006. <http://www.ohiodnr.com/geosurvey/geo_fact/geo_f08.htm>.

"Hydroacoustic Current Meters for the Measurement of Discharge in Shallow Streams and Rivers". 9 May 2001.U.S. Geological Survey. 24 July 2006. <http://in.water.usgs.gov/hydroacoustics/acoustic_wading_rod_measurements.shtml>.

Irrometer Tensiometers. Spectrum Technologies Inc. 14 July 2006. <http://www.specmeters.com/Soil_Moisture/Irrometer_Tensiometers.html>.

Jenne, Roy. "Snowpack Data". 22 February 1991. Computational and Information Systems Laboratory. 5 July 2006. <http://dss.ucar.edu/docs/papers/snowpack>.

"Landslides in Japan". The Japan Landslide Society. 7 July 2006. <http://www.tuat.ac.jp/~sabo/lj/index.htm>.

Large Bronze Chau Gong. Chopa Imports. 12 July 2006. <http://www.chopa.com/ShopSite/Woodstock_Hanging_Chau_Gong.html>.

"Living with Risk: A global review of disaster reduction initiatives". International Strategy for Disaster Reduction. Geneva, Switzerland. July 2002.

Programme for Flood Vulnerability Reduction and Development of Early Warning Systems in Minor River Basins in Central America. Organization of American States, Unit for Sustainable Development and Environment. 14 July 2006. <http://www.crid.or.cr/crid/CD_EIRD_Informa/ing/No4_2001/pagina20.htm>.

Ready-SAT-Go! Pre-Paid Package. Model GSP-1600-RSG. Globalstar.com. 9 July 2006. <http://www.readysatgo.net/index.php?main_page=product_info&products_id=19>.

Rechargeable Spotlight. Optronics. Shipstore.com. 27 July 2006. <http://www.shipstore.com/SS/HTML/OPT/OPTGR100B.html>.

"Remote Geohazards in South-Western Pamir GBAO, Tajikistan". Summary Report. Swiss Agency for Development Cooperation (SDC). 2005.

Safety Turtle Alarm System. Terrapin Communications. 7 July 2006. <http://www.safetyturtle.com/>.

"Snow Surveys and Water Supply Forecasting". 13 March 2006. National Atlas of the United States. 19 July 2006. <http://nationalatlas.gov/articles/climate/a_snow.html>.

Solinst Model 616 Drive-Point Piezometer. GroundwaterSoftware.com. 6 July 2006. <http://www.groundwatersoftware.com/Equipment/solinst_model_615_order.htm>.

Sonic Ranger 50 kHz. Campbell Scientific Canada Corp. 21 July 2006. <http://www.campbellsci.ca/CampbellScientific/Catalogue/SR50.html>.

Swoffer 2100 Current Meter. Geo Scientific Inc. 20 July 2006. <http://www.geoscientific.com/flowcurrent/Swoffer2100_CurrentMeter.html>.

Vibrating Wire Crackmeter. Durham Geo Slope Indicator. 14 July 2006. <http://www.slopeindicator.com/instruments/jmeter-crack.html>.

Vibrating Wire Piezometer. Durham Geo Slope Indicator. 14 July 2006. <http://www.slopeindicator.com/instruments/piezo-vw.html>.

WL400 Water Level Sensor. Global Water Instrumentation Inc. 20 July 2006. <http://www.globalw.com/products/levelsensor.html#Description>.

WS-7038UF La Crosse Wireless Rain Gauge. Ambient Weather. 7 July 2006. <http://www.ambientweather.com/wslacrwiraga.html>.