CWB EARTHQUAKE EARLY WARNING SYSTEM
-- -- PLAN A

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ABSTRACT

At the January, 1993 Advisory Committee Meeting of the Central Weather Bureau (CWB), two plans were put forwarded for earthquake early warning purposes in Taiwan.Plan A is to implement a prototype early warning system using modern technology, and Plan B is to upgrade the existing CWB telemetered seismic network with an earthquake early warning capability. This paper reports the current status of Plan A.Professor T. L. Teng will report the status of Plan B in the next paper.

Of all the Taiwan earthquake program elements,an earthquake warning system has the potential for the quickest return of benefit to Taiwan. Such a system can provide the critical information needed (1) to reduce loss of property and lives, (2) to direct rescue operations, and (3) to prepare for recovery from earthquake damage.

The most effective use of earthquake warning is to activate automated systems to prepare for strong ground shaking. For example : slowing down rapid-transit vehicles and high-speed trains to avoid potential derailment, orderly shutdown of pipelines, gas lines, etc. to minimize fire hazards, controlled shutdown of manufacturing operations to decrease potential loss, and safeguarding computer information by saving vital information and retracting disk heads away from the disk surface.All the above can be accomplished to variable

but useful extent within several seconds of notification time.

Although human response may take more than a few seconds, personal safety can be greatly enhanced if several seconds of notification are available: school children can seek cover under desks and workers can move away from hazardous positions. More important, early earthquake notification will greatly reduce panic and confusion. Functions of a modern society, including civil and military operations, will be less likely to turn into chaos if an early earthquake notification is available and drills for appropriate actions have been performed.

With an earthquake warning system, we will be able to estimate quickly the maximum expected ground motion caused by an earthquake anywhere in Taiwan so that emergency response team scan be deployed where they are needed most. Because such a system monitors earthquakes in real time, information on the earthquake sequence (main shock and aftershocks) will be readily available while the events are in progress.

The physical principles of an earthquake warning system are simple : (1) strong ground shaking is caused by shear (S) and the following surface waves which travel at about half the speed ofthe primary (P) waves, and (2) seismic waves travel much slower than electromagnetic signals transmitted by telephone or radio.

If an earthquake is located at 100 km away from a city, the P-wave arrives in the city at about 17 seconds, and S-waves at about 29 seconds. If a dense seismic network is deployed in the earthquake source area and it is capable of locating and determining the size of the event in about 10 seconds, then there will be about 7 seconds to issue an warning before the P-wave arrives, and about 19 seconds before the more destructive S-waves and surface waves arrive at the city. Here, we have assumed that it takes very little time (say, less than 1 second) to send asignal from a seismic network to the city.

The above strategy may work for earthquakes located about 60 km or more away from a city. For earthquakes at shorter distances (say, 20 to 60 km), the time for detecting the event and issuing an warning must be reduced to about 5 seconds. For earthquakes within 20km of a city, there is just very little one can do other than installing automatic shut-off devices that can be triggered by the onset of the P-wave.

For the Taipei metropolitan area, the most likely destructive earthquakes may be those located in the Ilan and Hualien areas(at distances of about 30 to 120 km). Therefore, any earthquake warning system must be able to locate an earthquake and determine its size within 10 seconds after it occurs.

In the foregoing discussion, we have a basic assumption in mind, i.e., for earthquake warning to be practical, the earthquake must have a magnitude of $M >= 7$ at distance of 50 km or more away, and $M >= 8$ at distance of 100 km or more away. An empirical relationship that gives the practicality of an earthquake warning may be:

$$M = 4 \log D(km)$$

where M being the magnitude,and D being the approximate epicentral distance in kilometers. Furthermore, the empirical relationship:

$$M = 6.1 + 0.7 \log L(km)$$

relates magnitude M to the approximate length of fault rupture L. At a rupture velocity of 2.5 km/sec, we can construct the following table that relates the magnitude M, the maximum distance of consequences D(km), the estimated rupture length L(km), and the rupture duration T(sec) as follows:

M	D(km)	L(km)	T(sec)
7.0	50	20	8
7.5	75	100	40
8.0	100	500	200

From this table, in view of L and T,there is no practical need to know the earthquake hypocenter to better than 10 km, and origin time to better than 1 sec. In fact, the picking of P- and S- arrivals is not important, nor is it needed to go through the standard travel time inversion to locate the earthquake. For practical earthquake warning, the "epicenter" may be defined to be the location of maximum peak ground acceleration(PGA), and "origin time" to be the moment when the maximum PGA occurs.The crucial problem is to determine the magnitude to within 0.3 magnitude unit in as short a time as possible.

A practical way to determine the magnitude is to estimate the fault rupture length. If a number of stations spanning a region of 20 km all give a PGA of 0.5 g or higher, we may define the magnitude empirically to be 7 or larger. Since the requirement of early warning imposes the condition that the earthquake parameters be determined within a few seconds,these parameters must have "transient" values and should be updated as the rupture is developing, so that new "epicenter", "origin time", and "magnitude" will appear. If a later and higher PGA occurs,it will have similar propagation delay time before it reaches the metropolitan area. So, in the sense of early warning with a propagating rupture, only the outputs of a number of strategical placed strong-motion stations are monitored. As the rupture develops, "epicenter" and "origin time" are updated, and the "magnitude" is revised upward to correspond to the higher value of PGA,or the larger rupture length. This entire process is very similar to the hurricane warning of reporting the progress of the "eye" of the hurricane and its extent, which have found to be useful to the society.

From the above discussion, an earthquake early warning system is basically a realtime strong-motion monitoring system with quick decision capability and rapid communication links to users. It is comprised of four primary subsystems :(1) several digital telemetered strong-motion networks (capable of rapid "hypocenter"location and "magnitude" determination), (2) rapid communication from the networks to a central facility,(3) a central facility capable of quick decision, and (4) rapid communication from the central facility to users. The primary goal of the system is to detect a damaging earthquake and disseminate the information to various users as quickly as possible.

To reduce earthquake hazards in T·ipei,we are now implementing a prototype earthquake warning system under Plan A through a CWB-USGS cooperation program. During 1992-1993, a design with specifications of the prototype earthquake warning system was completed. A contract was awarded to Nanometrics to supply and install a digital strong-motion network in Hualien.This installation is on schedule and the network is expected to be completed by June, 1994.

During 1993-1994, a contract was signed with Nanometrics to provide the computer equipment for the Hualien node and the CWB Taipei Headquarters. Also, a contract was signed with Quanterrato provide three 6-channel, 24-bit broad band stations to be installed at Hualien, Ilan, and Anpu in order to give real time estimate of earthquake source parameters. Through the telephone links between Hualien and Taipei, we will test the prototype earthquake warning system in the summer of 1994.

Signals from the Hualien strong-motion network will be processed and analyzed by two independent realtime system simplemented by Nanometrics and USGS, respectively. At the Hualien node,the Quanterra system will also supply source parameter estimates. All three systems will be monitored by a supervising computer,which will be in realtime communication with the supervising computer in Taipei. To minimize false alarms,at least two of the three realtime systems at Hualien must report an earthquake. To further minimize false alarms and to provide monitoring capabilities at the Ilan area, a second digital strong-motion network will be established at Ilan during 1994-1995.

In summary,implementation for Plan A has been progressing on schedule. The goal,is to develop a prototype that provides timely warning messages in about 10 seconds for strong earthquakes that have occurred under the monitoring arrays. It will not provide useful information for earthquakes that have occurred too far outside the monitoring arrays. Fortunately, Plan B is designed to supplement Plan A to cover the entire Taiwan, but with some additional delays of about 10 to 50 seconds. Therefore, the combination efforts of Plan A and Plan B will provide a useful early warning system for Taiwan in a few years.