# Components and Implementation Strategies for Effective Hazard Monitoring and Early Warning

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## Abstract

Effective monitoring of hazardous incidents for timely dissemination of notifications and warnings involves a thoughtful mixture and application of information, technology and intuitional processes. It starts with the identification of the right data – data to be used in decision making processes – from the right sources – authoritative sources that can be trusted and relied upon. Processes must then be developed to routinely and swiftly acquire, process, and ingest these data into an early warning system (EWS). Decision criteria – sometime referred to as "business rules" – must be established to transform these data into actionable information, including for the dissemination of warning messages. Finally, the warning messages must be quickly and securely transmitted to the intended recipients, often via redundant mechanisms to insure receipt. Of course, warning messages themselves, even if timely, accurate, and actionable, are not sufficient without an overall context in which to assess them as well as pre-established processes for taking actions, sometimes referred to as Standard Operating Procedures (SOPs). However, even the best SOPs will be ineffective if their users are not adequately skilled and knowledgeable. This generally means that a training and exercise program must be a key component of any successful monitoring and warning system. These elements of effective monitoring – and strategies for their implementation – are described and illustrated via the Pacific Disaster Center's DisasterAWARE™ all-hazards monitoring, early warning and decision support system.

## Introduction

An effectively implemented and operated hazard monitoring and early warning system (EWS) can reduce risks and lower impacts associated with "disasters" – be the hazards natural (e.g., typhoon, earthquake, tsunami, etc.), environmental (e.g., land and water degradation, over exploitation of natural resources, etc.), or man-made (e.g., industrial accidents, terrorism, etc.) The key to successful implementation includes three key components – information content, technology, and institutional processes – that are explored in this paper. Further, they will be illustrated by examples taken from implementation and operation of natural hazards early warning systems based on DisasterAWARE™ by Pacific Disaster Center. The general processes can be extended to any monitoring and early warning system, including those related to aquatic animal health.

## Components of Monitoring and Early Warning Systems

EWS include both technological and organizational. The former – including information content, and visualization, analysis and alerting technologies – are detailed below. The latter are discussed in the Institutionalization section.

### Information Content

At the heart of any early warning system is the information that drives the warning issuance and decision making. Correctly identifying the hazard signals from the ordinary, day-to-day signals is the starting point for all remaining actions. Normally, those directly involved in hazard monitoring and management activities are familiar with availability and applicability of critical information and the decision rules that are associated with their use. However, this knowledge may not be well documented or shared effectively, essentially skipping the first step in the development of an EWS. As described in more detail in the institutionalization section (below), the creation of a Concept of Operations (CONOPS) helps developers and implementers of an EWS to understand what information is needed for use in the decision-making process, what data are already available, who produces these data and information, who and how they are shared with those who need them, and what rules are associated with their use.

Once key information requirements are identified, developers of the EWS must seek authoritative sources for each information element. Generally, these include regional bodies, national agencies, universities, etc. In the case of natural hazards, PDC works with such agencies as the Pacific Tsunami Warning Center (PTWC), National Weather Services, NASA, and United States Geological Survey (USGS) to obtain natural hazard data. For national-level deployments of DisasterAWARE, authoritative sources extend to national hydro/met services, seismic and volcanic agencies, mapping, and census/statistics agencies. In the case of an aquatic animal health EWS, authoritative sources may include OIE WAHID and fisheries/coastal resource/environmental health ministries, as well as regional bodies and UN agencies.

Next, processes to routinely and efficiently obtain these data must be developed, often in collaboration with the cognizant agency that produces the data. A necessary step may be the execution of a data use agreement (DUA) or data sharing agreement (DSA), outlining the intended use of the data, any restrictions or limitations associated with their use, and a general means by which they will be shared by the producer with the EWS. For dynamic data and information that change quickly or regularly, automation procedures should be considered to obtain, condition (if needed), and incorporate the source data into the EWS. For the DisasterAWARE platform, PDC has developed such an automation mechanism called "Dynamic Data Processing and Publication" (D2P2) engine. D2P2 can be configured for the required context to automate key national, regional, and international incident data sets that are pertinent to the needs of the intended users. D2P2 rules govern incident severity categorization and, when conditions are met, notifications are automatically created within DisasterAWARE for dissemination to registered users. For PDC-operated instances of DisasterAWARE, D2P2 brings in typhoon locations and forecasts from Joint Typhoon Warning Center (JTWC), tsunami bulletins from PTWC, earthquake epicenters and shaking intensity from USGS, and wildfires and floods from NASA sensors. For customized versions of DisasterAWARE deployed within national EOCs, information sources include the Indonesian Agency for Meteorology, Climatology and Geophysics (Badan Meteorologi, Klimatologi, dan Geofisika, BMKG) for the Indonesian deployment, InAWARE; Viet Nam's

National HydroMet Forecasting Centre (NHMFC) for the Vietnamese deployment, VinAWARE; and ASEAN Specialized Meteorological Centre (ASMC) for the ASEAN-regional deployment, DMRS.

**Enabling technologies**

EWS users need to be able to quickly and easily view hazard data within their decision-making context. Generally, this includes being able to see the location and extent of the hazard in relation to a user's area of responsibility and the resources that must be protected from harm. In the case of natural hazards, this would include a map of the hazard location and impact area along with population and infrastructure data. For animal resource management, this would include breeding/nesting areas, catch/harvest areas, specific agriculture and aquaculture infrastructure and trade routes, and ports. The PDC-hosted version of DisasterAWARE, EMOPS, in fact, contains more than 4000 map layers. PDC's DisasterAWARE incorporates GIS technology to enable users to visualize these data together, at various scales, providing context and a common operating picture. Further, the system facilitates viewing time-series data and the incorporation of user data to support incident monitoring and the specific data needs of individual users.

Another key enabling technology is the ability to share information and analyses with other system users. This can include the ability to share an annotated version of the map display or to attach a report or assessment to a hazard detected by the system. As well as providing up-to-date incident information, the DisasterAWARE platform supports interagency cooperation and information sharing through its ability to add relevant non-geographical incident "products" to a specific event. This "one-stop" repository for incident products allows for quick and easy sharing of information between users.

It is well understood the timely warnings can help limit a hazard's impact and reduce the loss of lives and livelihoods. Placing easy-to-access, real-time hazard data in the hands of the decision makers is therefore a key element of any effective EWS. Through the DisasterAWARE Alert Service (DAS), registered DisasterAWARE users can subscribe to receive e-mail and SMS notifications when new Hazards are registered by the system or when a Hazard is updated to reflect a new hazard advisory or when additional information is received. Additionally, DisasterAWARE is capable of sending similar notifications via messaging applications such as Telegram or pushing alerts to social media channels such as Twitter and Facebook. As the DisasterAWARE platform is enabled for touch-screens, notifications receivers can instantly access additional information via their mobile phone or tablet, allowing them to make response decisions while in the field or in transit.

## Strategies for Effective Implementation of Early Warning Systems

**Risk-based Deployment of EWS**

Given the finite resources available for disaster management planning and preparedness activities, understanding high risk zones and priority areas is an important consideration in the deployment of an early warning system to maximize its impact. Risk and vulnerability assessments (RVA) can allow EWS developers and operators to make informed decisions such as where detailed data might need to be collected or where to deploy additional sensors to monitor a particular hazard. Additionally, RVA outputs can be incorporated into system, providing the wider user community – including planners and response teams – with data that can enhance their understanding of a particular incident within an overall risk and vulnerability context.

**Institutionalization for Effective Use and Sustainability**

When implementing an EWS, long-term use and sustainability planning must be key considerations. Users should feel confident in their abilities to leverage the system for their specific disaster management responsibilities. Additionally, such systems should be developed with the user needs and local context in mind. Understanding this, PDC places significant emphasis on the institutionalization of each DisasterAWARE application as part of the deployment process in an effort for it to achieve its full potential.

**Concept of Operations**

Development of an EWS should begin with a clear understanding of the current hazard monitoring, early warning, and preparedness and response

decision-making and operational process of the implementing organization. This understanding must include mechanisms for sharing hazard information and providing warnings, as well the intended role that the early warning system will play in the overall disaster management framework. With PDC's deployment of its DisasterAWARE systems - both regionally and within individual nations - a Concept of Operations (CONOPS) document is developed that identifies disaster management stakeholder organizations, and includes their structures, roles, responsibilities, information flows, and decision-making processes as they relate to natural hazard monitoring and early warning. This information is obtained through a literature review, stakeholder workshops, and individual stakeholder interviews. The CONOPS is used to guide the customization, deployment, and operational utilization of the system. The drafting of this document helps developers and implementers of the system to understand what information are needed for use in the decision-making process, how data and information could be shared with those who need them, and what rules should be associated with these sharing mechanisms.

**Standard Operating Procedures**

EWS users also require clear direction regarding the utilization of an EWS to monitor, alert, and report on disaster events. This can be effectively achieved through the development and implementation of Standard Operating Procedures (SOPs) which provide details of required user actions as they carry out their prescribed disaster management responsibilities. Multiple SOPs may be developed to guide various categories of user interactions with the EWS. With the deployment of national or regional-level DisasterAWARE applications, for example, SOPs are typically developed for Hazard Creation (aka Manual Hazards), Response Operations, and Exercise. The input of non-automated hazard notifications into the system is guided by the Manual Hazards SOP, allowing selected administrative users to assign severity and create hazards within the system. For aquatic health monitoring, this would allow administrative users to create hazards based on incident reports received from stakeholders, in turn leading to the automatic issuance of notifications to DisasterAWARE users. The Response Operations SOP details how users can most effectively utilize the system during hazard event, such as responding to an aquatic disease outbreak, while an Exercise SOP provides guidance on how to use DisasterAWARE to conduct or support scenario-based exercises and simulations.

**Staffing Plans**

With a focus on the sustainability of an EWS, it is also important to consider the staffing requirements to avoid having the EWS become inoperable or obsolete. Identifying key roles and outlining responsibilities allows the agency that administers the EWS to engage the services of staff and vendors to operate and maintain the system. The development of a staffing plan achieves this, providing leadership with guidance for resourcing the system appropriately. Generally, a customized version of DisasterAWARE requires a System Administrator, Map Server System Administrator, GIS and Hazard Information Analysis, and Database Administrator. These roles could be performed by multiple staff or can be combined into fewer full-time staff positions.

**Training and Exercise**

While the above processes and associated documents are essential components in the development and deployment of an EWS, the use of a system can only be effective if there is sufficient user capacity to effectively operate it and carry out approved SOPs. This capacity can be successfully built through training on, and exercising of, the EWS and its various SOPs. For DisasterAWARE deployments, PDC provides training to key system users to ensure that they have a working mastery of the system's functions to allow them to use it most effectively for their activities. Additionally, PDC delivers Train-the-Trainer programs to build internal capacity for future training requirements. PDC's training activities also extend to System Administration training, again with a focus on building internal capacity, helping to ensure the sustainability of the system.

Exercises are a useful and important way to test an EWS, provide an opportunity for users to practice their skills, and to review and refine SOPs. Additionally, an EWS-supported exercise offers an opportunity to test wider disaster management operations as it can be used to simulate an evolving hazard scenario and identify operational gaps. Globally, DisasterAWARE applications have supported numerous exercises, large and small, often

acting as the central information management tool during multi-country exercises. DisasterAWARE can be used to inject exercise-supporting data and map layers, providing a visual understanding of the scenario as well as supporting inter-agency information sharing throughout the exercise.

**Operational Policy**

While SOPs and training can provide the capacity needed to use an EWS, effective use of an early warning system ultimately requires high-level approval and direction. Such authority can be provided by agency leadership through the execution of a policy document (e.g. circular, decree, etc.) that provides users with authorization to use the system as part of the duties.

## PDC's DisasterAWARE™ Platform

PDC's disaster monitoring, early warning, and decision support platform is DisasterAWARE™ (All-hazard Warning, Analysis, and Risk Evaluation). This web-accessed resource provides situational awareness, decision support, and information sharing capabilities, and is operationally used by disaster managers around the world. DisasterAWARE is available through freely-accessible public versions, a password-protected version for those with disaster management or humanitarian assistance responsibilities, and various custom versions.

DisasterAWARE is an ever-evolving solution to the everyday challenges of hazard monitoring and the related urgent needs. When the critical—possibly life-saving—disaster information exists, it is often scattered across national and subnational agencies and lacking any risk context. If the information can be found, it will be at the cost of time (and sometimes money) disaster managers can ill-afford, and often security restrictions to which they cannot conform. Specialized solutions are difficult, expensive, and narrow. DisasterAWARE overcomes these and many other obstacles by incorporating international best-practice methodologies and technologies for data acquisition, hazard modeling, risk and vulnerability assessment, mapping, visualization, and communications into one system. Additionally, the system's interoperable base platform is adaptable to support secure environments.

PDC hosts and operates two distinct web-accessible versions of DisasterAWARE at its Hawaii-based headquarters: Disaster Alert and EMOPS (Emergency Operations). EMOPS, incorporating some special holdings and features for disaster management professionals, requires a registered account and password. A mobile app version, Disaster Alert, extends monitoring and alerting capabilities to iPhone, iPad, and Android mobile devices.

Custom systems "powered by DisasterAWARE," have been developed for PDC partners around the Pacific, and more are in development or under consideration. Deployed systems include DisasterAWARE for Thailand (2006); VinAWARE for Vietnam (2011); Disaster Monitoring and Response System for ASEAN at the AHA Centre (2012); and InAWARE for Indonesia (2014). Deployment of PhilAWARE for the Philippines is planned for 2019. Generally, these custom deployments include both hazard and baseline data from relevant national agencies, and localization of the user interface to support early warning, disaster relief, and humanitarian assistance missions.

## BioServ

In 2012, PDC was approached by key stakeholders in the disease monitoring and public health alerting community and asked if DisasterAWARE could be adapted to provide monitoring and warning for public health and infectious disease. The theory was tested in a small pilot project. After initial success, and in partnerships with the U.S. Navy Environmental Preventive Medicine Unit 6, Naval Medical Research Unit 2, and the Army Public Health Command, the BioSurveillance Information Service (BioServ) program was developed under funding from the US Navy's Advanced Medical Development program.

Expanding the partnership network to include authoritative U.S. and global health data sources, during subsequent years of the program, BioServ has been expanded under three major themes: disease outbreak and human security alerts, disease background information, and country/regional background information. All of these health data appear alongside PDC's global risk and vulnerability indices, infrastructure, climatic, demographic, economic, and geographic information layers.

## About the Pacific Disaster Center

Pacific Disaster Center (PDC) was created following the destructive Hurricane Iniki, which passed through Hawaii, heavily impacting the island of Kauai on September 11, 1992. Seeing the destruction, Hawaii's U.S. Senator Daniel K. Inouye realized that information resources with the potential to reduce hurricane damage were, in fact, available. He knew about space-based imagery libraries, for instance, and near-real time satellite observation. He also understood that these Cold War technologies could be repurposed for the civil-military needs of disaster management. It was not easy. It took four years, working on everything from funding channels to writing new software, but 22-1/2 years ago, in February 1996, Pacific Disaster Center opened.

Since then, PDC has actively applied information, science, and technology to enable effective evidence-based decision making and to promote disaster risk reduction (DRR) concepts and strategies. The Center provides multi-hazard monitoring, warning, and decision support tools to facilitate critical information sharing, supporting effective actions throughout the disaster management cycle. PDC also conducts advanced risk assessments that integrate hazard exposure with socio-economic factors to define vulnerability and resilience, so the disproportionate impact of events on various populations can be better understood, and then mitigated through improved preparedness and planning processes.

All this, however, can only be accomplished through working partnerships: working with stakeholders to understand gaps and needs, collaborating with a broad range of data providers to facilitate access to information, and partnering with scientists and technologists to develop solutions. PDC could not possibly hope for better partners in establishing disaster management best-practices for any place than the people that call that place "home."