maps or diagrams that clearly identify the existing hazards and the areas that might be affected.

The results of the physical vulnerability analysis of the system's components can thus be represented in diagrams specifying the most vulnerable or critical components. These diagrams should be produced with the assistance of the most experienced and technically capable personnel of the company, and of external consultants, private or academic, if needed.

When the system's plans are annotated to indicate the most vulnerable components and superimposed on the hazard maps, a system risk plan can be produced for each of the likely hazards.

In addition to the above, it is customary and advisable to procure hazard maps produced by universities, civil defense institutions, national emergency commissions, or professionals in each of the relevant fields.

The following is a summary of the steps that must be taken to carry out a vulnerability analysis. Although reference is made to the drinking water supply system, the steps are also applicable to sewerage systems.

1. Identify the relevant national or regional disaster reduction institutions, as well as the legislation and standards regarding emergencies and disasters.
2. Describe the area under study: location, climate, urban infrastructure, public health services, geological, geomorphologic and topographic data, level of socioeconomic development, etc.
3. Identify and describe each of the components of the system and their subcomponents.
4. Identify and provide a functional description of the system (flow volume, level, pressure, quality of the service).
5. Identify the system's operational aspects (capacity, demand, deficit or surplus volume).
6. Identify and describe the administration and response capacity of the company or agency responsible for the system under study.
7. Determine hazard parameters and hazard assessment, taking into account the likely impact on the system.
8. Estimate the system's vulnerability based on the determination of the likely effects of the emergency on the system's components.
9. Quantify the capacity of each component and subsystem to operate in certain conditions, bearing in mind quantity, quality, and continuity (operational vulnerability).
10. Identify the critical and vulnerable components of the system that may

affect capacity to meet basic demand, and of the priority points of supply (physical vulnerability).

11. Estimate the organizational response capacity (organizational vulnerability).
12. Determine the mitigation, preparedness and emergency measures required to reverse the impact of the hazard on the system's components in administrative, operational, and physical terms.
13. Determine the minimum demand of the population in priority supply points, both during and after the impact of a disaster.
14. Draft the final report and vulnerability maps. Several reports can be produced to cover the various hazards that can affect the system.
15. Develop the Emergency Plan and the Prevention and Mitigation Programs.

For each of the hazards, steps 7 through 13 should be repeated.

The vulnerability of a drinking water supply or sewerage system is analyzed from three points of view:

- **Physical:** Estimation of the possible damage to infrastructure components;

- **Operational:** Assessment of the surplus or remaining capacity to provide the needed services, including an estimate of the time required to rehabilitate the systems.

- **Organizational:** Determination of the institutional or company response capacity, bearing in mind the organization, its expertise, and its other resources.

In some cases it may prove necessary to consider the cultural and socioeconomic characteristics of the community that benefits from the water supply and sewerage services, since improper use of the systems contributes to their vulnerability.

Each vulnerability analysis is related to a specific hazard, and this determines the structures and equipment that are susceptible to direct damage (for instance, the flooding of a pumping station) or indirect damage (failures in power supply).

The internal features of the company that support operations and maintenance (for instance, transportation, communications, and the supply of materials) must be analyzed, as well as features outside of the company (electrical power, telephone services, firefighters, and so on).

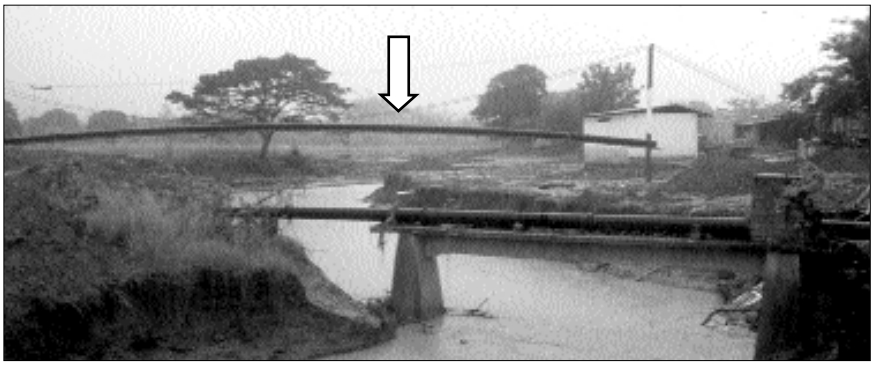
The organization of the company or institution is often the most vulnerable element to hazards if there is a lack of effective preparedness and training to confront emergency situations. Other factors are the obstacles to rapid response, such as bureaucratic barriers to prompt outsourcing or direct purchasing.

Within the organization, operations and maintenance activities are the most important during an emergency, since it will be necessary to work at a fast pace, with additional burdens and under pressure.

In order to systematize the key facts needed to produce a qualitative estimate of current vulnerability based on the information mentioned above (both regarding hazards and the water supply and sewerage systems), one option is to produce tables or diagrams regarding such matters as rehabilitation times, immediate surplus or remaining capacity, and the impact of potential disasters on the services in the area under study.[7]

Prevention and Mitigation Measures

The correct application of prevention and mitigation measures requires strong corporate or institutional will to support emergency planning. The effects of a hazard cannot be reduced without allocating the necessary resources. Even a modest, but continuing, budgetary allocation can produce significant results.



This photograph shows the effects of flooding during El Niño in Ecuador in 1999. The construction of a river overpass is a mitigation measure for piping.

C. Osorio, 1998

After carrying out the vulnerability assessment, the next step is to identify the most effective prevention and mitigation measures. This will make it possible to program the necessary actions to reduce the potential impact of any given hazard on the system. Such measures must include devising emergency operations, signing agreements with other institutions, preparing and carrying out the necessary training activities, allocating material and other resources, and choosing the most important retrofitting projects to reinforce the current system components.

[7] PAHO, *Natural Disaster Mitigation in Drinking Water and Sewerage Systems: Guidelines for Vulnerability Analysis*, Washington D.C., 1998.

Preventive measures reduce the vulnerability of systems. Exposed piping in Ecuador.

A. Rodriguez, 1998

Operations and maintenance activities provide an outstanding opportunity to incorporate mitigation measures into daily, routine actions.

The efficient use of resources calls for good administrative practices based on up-to-date staff training, particularly if new techniques or equipment are to be used. Training must take place at all levels of the company so as to maximize the use of resources.

The execution of a prevention program in companies responsible for water supply and sewerage systems will be effective if the following issues are borne in mind:

- The timely application of preventive measures based on the most likely and severe potential disasters and the availability of appropriate information in the short term;
- Integration of measures in a single program containing different levels or areas of execution based on existing resources;
- The identification of the key areas where the application of preventive measures is most needed and hence most urgent;
- Appropriate management of resources and their timely application;
- The introduction of preventive measures in the everyday activities of the agency or company.

Measures involving physical actions and establishment of standards require the greatest financial investment. They include improvements to existing infrastructure, new construction, and the implementation of improved design and building codes.

The creation and promotion of a culture of prevention and mitigation in the workplace ensures that the adoption of measures to improve potentially vulnerable structures can be carried out in a planned, progressive fashion, both in times of calm and during states of alert.

Other measures—particularly preventive ones—involve the institutional actions needed to respond to emergency situations (including the drafting of an emergency plan). Preventive maintenance, professional training in new operational methods, and the signing of agreements with other bodies are some of these actions. Such measures ordinarily do not demand major investments.

Even as the prevention and mitigation measures are being implemented, the components identified as most vulnerable should be included in the emergency plan, so that the company has a clear idea of how to respond in an emergency or disaster.

The Road to Disaster Mitigation

A proactive program enables a company to organize its activities in such a way as to begin planning for emergencies and disasters long before they occur, for instance by designating who should be in charge of this effort.

As noted elsewhere, responding to emergency situations in water supply and sewerage systems calls for the participation of the company's technical and operational units and the various support units, as well as from representatives of other organizations involved in environmental health and hazard management.

An obvious first step is to appoint a Central Emergency Committee (described in greater detail in Chapter 2), which would focus on strategic decision making both before, during, and after an emergency or disaster, as well as an emergency and disaster response office or unit, and/or some other technical committee, to serve as a tactical coordination mechanism under the guidance of the Central Emergency Committee. The second task is to become familiar with the hazards in the region, the weaknesses of the systems, and the goals that are to be pursued, keeping in mind the available resources.

The following section describes key activities, organized in four sequential stages, for developing and applying the emergency and disaster prevention, mitigation and response program.

A. Design of the Emergency and Disaster Prevention and Response Program

As the preliminary results of the vulnerability analysis become available, it is possible to start working on the Emergency and Disaster Prevention and

Response Program. Such a program must include:

- National and institutional standards for emergency situations;
- Description of the water supply and sewerage systems;
- Vulnerability analyses;
- Prevention and mitigation measures;
- Emergency operations plans;
- Annexes and supporting documents.

These components of the program must be incorporated sequentially, based on the information obtained and the resources available. It should be apparent that such a program covers all aspects of emergency and disaster situations, from the legal framework to the vulnerability assessments, as well as the Emergency Operations Plans. Once the program has been drafted, it must be approved by company or agency authorities and immediately released to all employees.

It must be stressed that such a program has to be carried out immediately after the weaknesses of the components and the system as a whole are known in sufficient detail, with the resources available at that time. As the program is being designed, the various operational levels should draft their own operative emergency plans, specifying the procedures for their application, as will be shown below.

The water supply and sewerage agency or company should include in this program administrative and normative aspects, the terms of reference for the vulnerability analyses, the prevention and mitigation measures to be taken, and the Emergency Operations Plans—all this in order to provide the greatest possible degree of security in the provision of water supply and sewerage services—in terms of quality, quantity and continuity—in the event of an emergency or disaster.

All actions outlined in the program must be mandatory for each of the departments of the company or agency to which they apply. The Emergency and Disaster Prevention and Response Program is, in general terms, a strategic document that should specify exactly who within the company or agency will carry out which actions when responding to emergencies and disasters. Once again, the operative program must consider the concrete, specific aspects of each of the potential hazards identified in the vulnerability analyses.

Finally, we should mention that it is important for the organizational structure of the company or agency to change as little as possible in the event of an emergency, so that employees can continue to carry out routine activities, even though the pace of work will increase in order to respond to the disaster situation.

B. Compiling and Evaluating Necessary Information

Given the nature of the work normally carried out by a water supply and sewerage company or agency, its response to an emergency or disaster is often considered adequate. However, there is no assurance that the decisions taken are the best ones. Even if the affected systems are brought back into operation, the facilities will not necessarily be more secure or able to withstand future disasters in the most cost-effective fashion.

The emergency and disaster plan must be based on the most reliable and up-to-date information available. Only then will there be a reasonable degree of certainty that the decisions taken in an emergency or disaster are the most appropriate, both technically and financially. The following is a checklist of the basic information needed to plan emergency response in water supply and sewerage systems.

Company or Agency Information

1. Technical information
   - Up-to-date description of the systems, including manuals, tables, figures, plans, maps, flow charts, etc.;
   - Official register of water supply and sewerage networks and up-to-date technical files;
   - Operational procedures, make-up of maintenance and other teams, fields of specialization of staff, etc.;
   - Background information on previous disaster experiences, rupture of mains, major maintenance jobs, labor strikes, etc.;
   - Projects under development and technical studies.

2. Administrative information
   - Description of human, material, and financial resources of the company or agency;
   - Organization of the company or agency (objectives, goals and strategies);
   - Legal framework;
   - Current technical and business plans;
   - Commercial information, including information on the expansion of the service;
   - Personnel training programs.

3. Operational information
   - Availability of heavy machinery;
   - Inventory and condition of vehicles;
   - Inventory of equipment (pumps, compressors, soldering equipment, etc.);
   - Personal protection equipment;
   - Stock of spare parts and chemical products.

Information from other institutions and bodies

1. Legislation and regulations pertaining to disasters at the local level (provincial, departmental) and the national level;

2. Information on hazards, including:
   - Earthquakes, hurricanes, floods, landslides, etc. (provided by civil defense, firefighters, municipalities, universities and other institutions);
   - Land use, urban planning (provided by environmental groups, universities, etc.).

3. Information on support and rehabilitation projects.
   - Construction companies, equipment and material suppliers, consultants;
   - Fuel suppliers, owners of water trucks and privately owned drinking water wells;
   - Information on other water supply and sewerage companies, both national and international;
   - Information on priority supply points, including:
     - Hospitals, health centers, Red Cross, firefighters, the police;
     - Shelters, military barracks, prisons, markets, schools;
   - National emergency commission or civil defense.

Since this information cannot be improvised, enough time should be assigned to collecting it, verifying its reliability, and analyzing it.

C. Vulnerability Analysis of Systems and Mitigation Measures

Once the components of the water supply and sewerage systems have been identified and described, as well as the potential hazards prevalent in the region, the process of vulnerability analysis should begin.

Some practical aspects to bear in mind at this stage are the following:

- Those responsible for the analysis must be identified;
- While the information is being analyzed, any gaps in the information must be identified and filled through additional data collection;
- The relevant human resources involved in the analysis must be identified, both those within and outside of the company;
- The training needs of the staff must be defined;
- The hazards must be described;
- The strengths and weaknesses of the system and its components must be identified;
- Prevention and mitigation measures and works must be defined, based on the early draft of the vulnerability analysis regarding each of the major hazards;
- Specialized studies (such as risk maps of the region) must be ordered, if needed;
- A financial assessment of the costs of prevention and mitigation measures must be undertaken.

D. Implementation and Evaluation of the Program

The directors of the company or agency must approve the Emergency and Disaster Prevention and Response Program so that it can be implemented as soon as necessary. They must also approve the budgetary allocations required to carry out the prevention and mitigation measures specified in the program, as well as to support the professional training process and follow up on it to make sure it achieves its objectives.

The directors should also establish a periodic review and evaluation process regarding the Emergency Operations Plan, for which they can use emergency drills and simulations at the relevant levels of participation. They must also review regularly the legal framework in order to propose the necessary adjustments to the relevant national, provincial, or municipal legislative bodies.

Since each prevention and mitigation measure that is carried out modifies the conditions that are the basis of the program, it must be revised as often as needed to make sure it remains up-to-date and reflects the current situation.