SEISMIC RISK OF KATHMANDU CITY WATER SYSTEM

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ABSTRACT

A study for the assessment of seismic vulnerability of the drinking water supply system of Kathmandu city was undertaken in view of high level of earthquake risk. A practical methodology for assessing the seismic vulnerability of network system, its components and institutional capacity was developed by adapting the Applied Technology Council ATC-25-1 tool with appropriate adjustment for Kathmandu context. Assessment results in the form of network system damage for scenario earthquake are presented using Geographic Information System (GIS). Based on possible maximum enhancement of the present intuitional capacity and spatial distribution of the possible damage extent, optimum routes for speedy restoration of water supply services to meet a minimum level are identified under two different scenarios i.e. as it is and improved system. Spatial distribution of emergency water demand in case of earthquake event is also presented.

The paper aims to present the methodology and results to a wider group of urban water system infrastructure planner and operation managers and provides necessary motivation for improving the general prop situation in developing countries. The paper concludes that the increased vulnerability of the water system largely due to non-recognition of earthquake risk in design and construction of water system could be reduced by implementing emergency response system in short term and with physical intervention in long run.

1. INTRODUCTION

During earthquake events, the water supply system is found to be seriously affected. A rapid restoration of this critical facility is imperative for assisting the society to return to normalcy. The impact of earthquake can cause contamination of water and breaks in pipelines leading to water shortage, damage to structure, and collapse of the entire system. As the water supply system is usually an extended network of linear infrastructure, a physical break at any point along the system could interrupt the services in the areas served by the network further down from the break.

Though the seismicity of Kathmandu valley is very high as suggested by historical accounts and geological studies(HMGN, 2002), specific detailed study was not done to assess the seismic vulnerability of the city water system. As a result, the necessity of risk consideration in planning, development and operation of the system were not known to the decision-makers and the stakeholders. To bridge this gap, the present study was undertaken for the assessment of the drinking water supply system of Kathmandu city against seismic hazard to locate the weak points in the network, to identify the system deficiencies, and also to suggest the remedial measures based on the observed status of the system.

Lack of information on built structures and absence of valid damage functions for the prevailing condition of infrastructure components make the vulnerability assessment of urban lifeline in developing countries complicated. It is important to develop a suitable methodology to address the situation so as to perform the assessment with the use of limited available data. In this study, the Applied Technology Council tool (ATC 25-1) with proper adaptation, which included the adjustment of the vulnerability function of system components and also modification in procedural steps in order to address the Kathmandu context.

The study covered the three municipalities of Katmandu Valley viz. Kathmandu Metropolitan City (KMC), Lalitpur Sub-metropolitan City (LSMC) and Bhaktapur Municipality (BM). An earthquake, generating shaking intensity of IX MMI, was taken as the Scenario Earthquake for the analysis. This level of shaking is roughly equivalent to the ground shaking of a larger part of the urban areas of Kathmandu during the Great Nepal Bihar Earthquake of 1934 (NSET, 1999). In the study, vulnerable links of water supply network were identified and the likely level of demand for water supply in emergency shelters that would be established in open spaces in the city following an earthquake was estimated. An assessment of water organizations, their strategies and programs for earthquake emergency response was also undertaken, and appropriate measures were recommended for improving the earthquake resilience of existing water supply system through mitigation measures, preparedness and response planning. Figure 1 shows the flow diagram of the study concept and methodology.

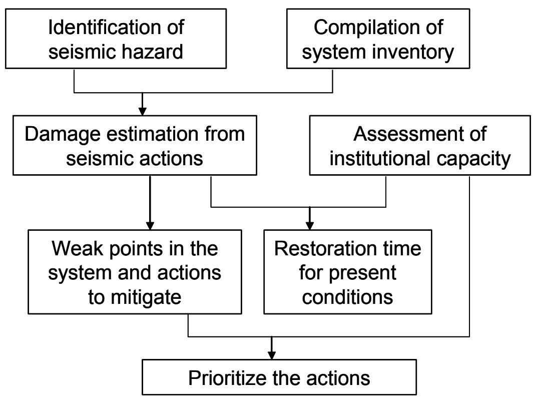

Figure 1: Flow diagram of the study

2. SYSTEM INVENTORY

In Kathmandu valley, most water supply systems are gravity flow system supplied from in-valley sources of water that have small storage facilities, streams, springs and spouts, and ground water as the source. Limited number of storage facilities is also used as the source of the network. The distribution system is complicated since the network has been constructed over many different periods, some parts of which date back to 100 years. Figure 2 presents the current network of the Kathmandu water system. The expansion of the distribution network is being done largely without demand-supply assessment (MPPH,1993).In the newly developed areas, the network is extended with dead ends. So, there is almost no redundancy in the distribution network

Pipe material used in the water system of Kathmandu valley comprises cast iron, ductile iron and Polyvinyl Chloride (PVC). Pipes installed more than 15 years ago are mostly made of cast iron with conventional lead joints. Pipeline constructed in recent years are mostly ductile iron with flanged joint. As the water system has very old pipes all around valley, repairing works for body breaks and joint breaks are frequent and new ductile iron pipe is laid at such repair points. It was observed that a major portion of the distribution network has cast iron pipes and transmission lines constructed in recent years employed ductile iron pipe conduits. The pipes are located mostly underground. Pipe sizes vary in range from 50 to 600 mm in diameter. Seismic consideration has not been taken in laying and joining the pipe segments.

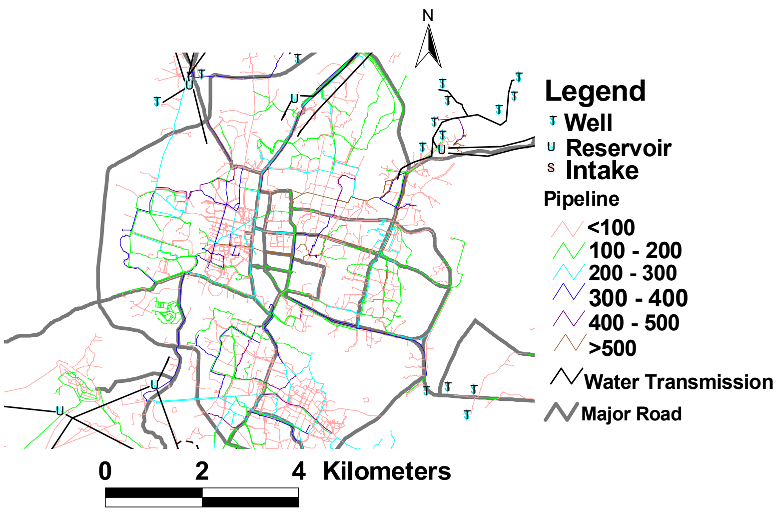

Figure 2: Water supply system of a part of Kathmandu Valley

3. SEISMIC HAZARD

Two kinds of seismic hazards are considered for the assessment: (a) ground shaking hazard and, (b) liquefaction hazard. In this study, intensity scale, which is a more general way to measure the effect of shaking, was used to describe the ground-shaking hazard. The intensity distribution of “scenario earthquake” – the 1934 earthquake in Kathmandu Valley was taken as basis to analyze the extent of damage to water supply system. The seismic intensity in the Modified Mercalli Intensity (MMI) for the scenario earthquake would be MMI VIII in most part of the valley and MMI IX in most of the urban area. Liquefaction hazard of Kathmandu Valley was from the publication of Seismic Hazard Mapping and Risk Assessment for Nepal, National Building Code Development Project (MPPH/HMGN, 1994). MPPH/HMGN considered the following criteria while assessing the level of liquefaction hazard.

1. Areas known to have experienced liquefaction during historic earthquakes.
2. Field studies following past earthquakes indicate liquefaction tends to recur at many sites during successive earthquakes.
3. All areas of un-compacted fills containing liquefaction susceptible material that are saturated, nearly saturated, or may be expected to become saturated.
4. Areas where sufficient existing geotechnical data and analyses indicate that the soils are potentially liquefiable. The vast majority of liquefaction hazard areas are underlain by recently deposited sand and/or silty sand.

About one third of the Kathmandu Valley is considered as high to moderate level of liquefaction susceptibility. The liquefaction susceptibility in Kathmandu Valley is presented in Figure 3.

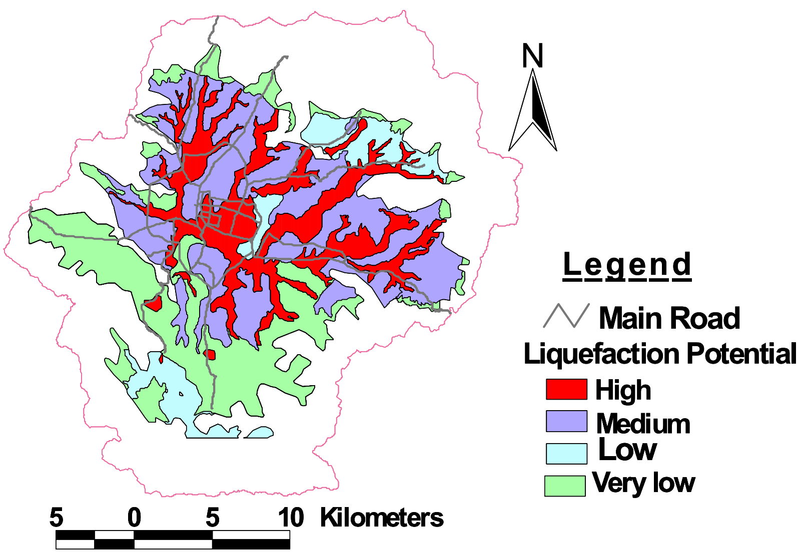

Figure 3: Liquefaction Susceptibility in Kathmandu Valley

4. DAMAGE ESTIMATION TO THE PIPELINE SYSTEM

4.1 Damage Assessment

To estimate the probable damage in pipeline system by the different forms of seismic hazard the ATC 25-1 methodology (ATC, 1992) was adopted. The methodology is intended to conduct a preliminary or "first phase" examination of the potential impacts of earthquakes on water system functionality. This study was firstly, to better understand the seismic vulnerability and impact of disruption of water systems, and secondly, to assist in identification and the prioritization of hazard mitigation measures and policies. Primarily, ATC methodology was intended to be applicable in United States. However, it began getting application in other regions of the world including developing countries but with due considerations of site specific situations. To use the methodology in case of Kathmandu, vulnerability functions are required to be adjusted to account for the material and poor installation of the pipe line system. It is observed, during this study, that the material used and type of connection of pipeline do not correspond to the seismic requirements. To adjust the vulnerability function presented in ATC-25-1, the damage from shaking intensity was supposed to be increased as exposed to one scale higher intensity level (Figure 4). Digital maps of seismic hazards and that of the water supply system were overlain to estimate the extent of damage to different pipelines in the water supply system.

In order to estimate the potential damage in pipes due to liquefaction hazard, assumption was made that any pipeline link that intersects the boundary of (1)high (2) moderate and (3) lesser than moderate liquefaction potential zone will be broken at the intersection with boundary. Pipeline with zones of high liquefaction potential will be assumed broken at mean break rate of 6.5 breaks per kilometer and of 5 breaks per kilometer in moderate liquefaction potential zone. No liquefaction caused break was assumed in other zones.

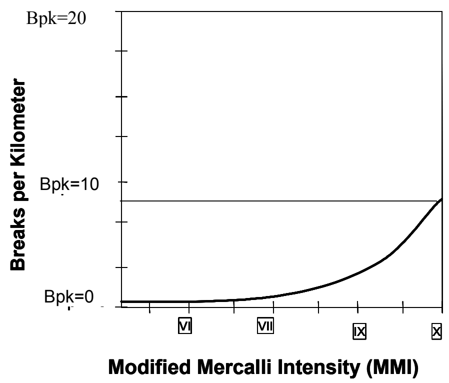

Figure 4: Damage percent by intensity in pipelines (reproduced after ATC 25-1)

4.2 Potential Damage

Table 1 and 2 present the damage extent to the water supply pipeline in Kathmandu Valley by the scenario earthquake. Potential breaks along liquefaction boundaries are assigned to the higher liquefaction susceptibility area.

Table 1: Damage in pipelines due to liquefaction hazard

Liquefaction Potential	**Total**	**Number of breaks in pipes of different diameter(mm)**				
		<200	**200-300**	**300-400**	**400-500**	**>500**
High	1181	917	100	78	32	54
Medium	1698	1306	188	87	58	60
Total	2879	2222	288	165	90	113

Table 2: Damage in pipelines due to ground shaking hazard

Shaking level	**Total**	**Number of breaks in pipes of different diameter(mm)**				
		<200	**200-300**	**300-400**	**400-500**	**>500**
MMI VIII	199	178	6	7	3	6
MMI IX-X	4345	3338	456	260	138	153
Total	4545	3516	462	267	141	158

It was observed that a large number of breakages will be in the pipeline system mainly due to ground shaking hazard. Very old stock of pipeline without maintenance, and a large coverage of high shaking intensity zone in the city are the causes for such result.

5. SUPPLY OF WATER DURING EARTHQUAKE EMERGENCY

5.1 Water demand in emergency evacuation sites

Public spaces (open spaces, institutional areas and industrial areas) and areas covered by Royal Nepal Army are presumed to be available for use as evacuation centers after the scenario earthquake. The evacuation points, supposed to serve the surrounding area at emergency time, were located in GIS maps and the maximum population served by each evacuation site was estimated. Emergency water demand in each evacuation points was then obtained based on well known "Sphere" standards (The Sphere Project, 2000).

5.2 Emergency establishment of pipe system to serve evacuation points

One of the first responses following a disastrous event is to establish a reliable water supply system to the temporary evacuation/shelter centers. In this study, water supply establishment scheme was presented based on the estimated extent of damage from the scenario earthquake. The cost and time required to establish such system is calculated based on the current capacity and strength of the existing system. The possible supply routes from the source point to evacuation site were analyzed and the extents of damage to major pipelines along these routes were estimated. This gave an estimation of the cost of restoration. The total cost for establishing such supplies by way of optimizing the repair along the major link to the identified evacuation sites has been estimated as NRS 57 million (approximately 700,000 US Dollar).

5.3 Institutional capacity assessment

Interviews and questionnaire surveys were taken for the assessment of institutional capacity to cope the disaster. It was found that no mitigation, emergency and recovery plan has been prepared by the organizations responsible for development and operation of the water system. Seismic risk is not considered in operational plans. As a result, no provision of back up of key hardware and system no redundancy is available. The functional vulnerability of the system seems very high even for moderate earthquake which could damage some of the key components.

6. RECOMMENDATIONS

Based on the survey and analysis of the system, it is concluded that the high level of vulnerability of the water system is largely due to non-recognition of earthquake risk in design and construction of the water system. The following measures are recommended to reduce the vulnerability:

1. Conduct Detailed Vulnerability Analysis by undertaking a seismic microzonation of the Kathmandu Valley.
2. Prepare a Mitigation Plan for strengthening the existing physical elements of the water supply system.
3. Develop seismic code for water supply system and implement the agreed standards ensuring seismic-resistant construction of the different elements
4. Strengthen the transmission lines and major distribution veins with incorporation of seismic-resistance.
5. Conduct training program on pipeline repair and maintenance to produce more skilled personnel. The number of such personnel currently is critically small for any emergency.
6. Develop, operationalize and regularly monitor a comprehensive emergency response and recovery plans and ensure that concerned personnel are aware of their responsibilities by conducting periodic drills and training programs.

7. Establish and operationalize a Working Group on Emergency Water Supply and Sanitation (WGEWSS). The working group should draw members from concerned government offices, the local government, NGOs and community. It should monitor and advise the government on the above mentioned points.

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