E. Specialists for natural hazard assessment

Depending on the sectoral scope, objectives and priority fields of activities the specialists needed for an evaluation of potential natural hazards (e.g. desertification) will vary a lot by discipline (meteorology, geology/soil science, hydrology, agronomy, livestock management, wildlife management, rural sociology, economics).

2.2.2. Contents of the EIA Report

In general, EIA Report should consist of a comprehensive review of potentially hazardous natural (and man-made) phenomena in the project area, risk assessments, alternatives for activities that specifically increase the risk (e.g. siting, land use, construction, or productional activities), and a description of practical project level systems of monitoring and early warning, and at last recommendations for mitigation measures. It should clearly spell out potential conflicts that might rise from differing interests in project implementation and that could further increase the risk for a hazard. It should also describe current problems of early warning systems. It should also clearly state the needs of further information, and this is at best done by giving a TOR for supplementary studies.

<u>Aspects to be included into the EIA Report</u>

1) Existing or expected hazardous phenomena, including a short historical description of potentially hazardous (natural) phenomena.

2) Information of existing monitoring and early warning systems and practices and their efficiency (e.g. natural services controlling wildfires, monitoring of food security).

3) Review of important legislation and national strategies and other important institutional factors.

4) Analysis of special socio-economic trends (population growth, migration, nutrition, health, education, etc..) that might increase vulnerability/resilience of people in the project area and in the region.

5) Analysis of existing cultural buffering mechanisms, coping strategies and special tactics in avoiding hazards, in coping with risks and in survival.

6) Potential impacts with special attention to irreversible vs. controllable impacts; short-term vs. long-term impacts; direct vs. indirect impacts and positive and negative impacts.

7) Consideration of alternatives with special attention to siting, construction operations, altering land use and changes in productional practices and strategies.

8) Description of structural and non-structural mitigation measures (e.g. sound land use, zoning, cultivation practices, reforestation, terracing, etc.).

9) Recommendations for awareness-building.

10) Monitoring and recommendations for practical early warning systems.

2.3. Recommendations for Activities at the Project Level

Disaster prevention and preparedness aspects should be incorporated in the planning and implementation of any development project. Necessary baseline information including historical data of potential hazards, and vulnerability analysis, risk assessment (e.g. hazard mapping), project-specific mitigation measures (e.g. flood barriers, practical early-warning systems), monitoring systems, use of appropriate technology and awareness-building should be considered in each project.

If the project is sited in high risk area it could develop a specific hazard strategy giving emphasis on risk reduction measures. Awareness-building and participation of people at risk should be focused on by selecting appropriate methods. Awareness-building should have a special role in high-risk areas.

Effective early warning systems improve the possibilities to adjust and modify potential hazard impacts. Each project should develop practical early warning systems of its own that cooperate with the existing institutionalized/central early warning systems. Such practical early warning systems can be effective if they are based on local people's wide participation and on their own traditional buffering mechanisms and coping strategies. For instance, food storages for buffering local level food insecurities can be more effective and better maintained and more widely accepted by local people if they are based on existing cultural practices and structures.

As the traditional buffering mechanisms no longer are satisfactory because of the recent socio-economic trends in many regions, people at risk should be able to use more advanced technologies in risk reduction. Also authorities or experts, and local, regional and national decision-makers and need to know how local people perceive risks and what are their needs. Government officers and professionals should be able to interpret risks correctly and to react timely to early warnings. They should be aware how to apply appropriate measures of risk reduction. Hazard-specific information could be channelled through existing extension systems, through in-service training of e.g. farmers and decision makers, through mass media or formal school system. Awareness-raising promotes the overall preparedness of people and infrastructure at risk and therefore it should be part and parcel of any project.

2.3.1. Land use and siting

DHA has recommended that each disaster prone country should prepare hazard and risk maps for local, national, sub-regional and regional disaster preparedness and risk reduction plans. These recommendations include the following maps and reports that should be available and in use:

* national hazard maps for various hazard types: fast impact hazards, slow onset hazards and technological hazards
* national risk maps indicating all major existing developments, infrastructures and populations at risk
* national maps indicating all planned developments within the next 5 - 10 years (= areas at risk)
* national maps indicating all potentially affected key facilities, lifelines, and population concentrations (= elements at risk over hazard)
* disaster management policy/strategy documents indicating priorities for risk reduction programmes;
* special land use zonation and building codes for disaster-prone areas, integrated in the national landuse zonation and building codes

Based on these priorities regional and local hazard and risk maps should be prepared to guide local, national, sub-regional and regional preparedness and risk reduction plans. DHA recommends further that these plans should be incorporated into the development plans at different administrative levels. However, the reality in many regions is just the opposite: people migrate spontaneously where they will, and they build their squatters around major urban centres.

On project level, when deciding over land use and siting of built structures the possibility of various geological catastrophes or flood or storm-induced damages the existing data and information sources (standards, codes of practice, regulations, interviews of local people) should be studied. The high-risk areas should be identified and, as far as possible, avoided in the siting of the structures.

If there exist zoning regulations for local land use in disaster-prone regions, these regulations are to be followed in planning of new projects. Cooperation with local or national level authorities should be ensured. Potential new settlements in the vicinity shall be accounted. The planned project should try to develop strategies to attract people living in high-risk areas to migrate to safer surroundings. The planned project can also have adverse impacts. Improved infrastructure and services may attract people to migrate in risk-prone areas. Zoning can particularly help prevention of flood and geologic/seismic hazards, if it is properly controlled. At best, zoning regulations also safeguard the essential ecological functions of specific ecosystems (e.g. coral reefs, mangroves, watersheds, river deltas or estuaries).

If there are no zoning regulations, the probability of a disaster shall be carefully studied, and at least a rough local zoning system shall be established with prohibitive, restrictive and warning zones.

The following guidelines can be followed when developing zoning for project area/site:

1. In active volcanic regions those areas known to be previously affected by lava flows or mudflows are to be charted, and not used as building sites. In predicting potential new routes of lavaflows or mudflows the topography of the area ought to be carefully examined.

2. In earthquake regions the intensity of the known earthquakes and the damage are to be studied. In case, there are no local earthquake zoning standards, the probability of earthquake and their intensity have to be assessed by using all obtainable seismological records.

3. In areas where the probability of earthquakes is high, siting of buildings on thick, soft soil layers having high water content is to be avoided. Instead, these areas or sites can be used for e.g. conservation or forestry purposes. Special attention should be paid on sites on top of or near potentially active faults. Important structures, like water supply installations should not be located in such a site.

4. Previous landslides near the construction site have to be verified by observing the shape of the surrounding terrain, by checking alterations in the vegetation caused by moving soil, and by using other available information. The stability of soil layers is to be defined including potential variations of water content.Landslide risk shall be carefully examined in active seismic areas where horizontal accelerations and loads can be prominent. If roads or pipelines are to constructed in landslide-prone areas, the possible damage shall be estimated and limited to minimum by proper location of these structures. Intensive ground vibrations caused by blasting or pile driving can induce a landslide in a sensitive site. Hence, gradually controlled loading of the foundation may be needed. In some cases, the water content of the ground material has to be reduced, or the ground water table has to be lowered before starting other construction works.

5. Particularly in hillsides and in mountainous areas the risk for landslides (or avalanches) above the construction site has to be studied. The potential effects of forest felling or other potential changes in the terrain have to be considered, since landslides and mudflows may advance in directions different from previous hazards. The planned structures shall not trigger landslides by improper changes in the ground level, by high loads or by increased water content and lowered strength of soil.

6. In regions of potential wind deposition the advance directions and velocities of sand dunes have to be recorded. Potential passages of dune migration shall not be used for buildings unless it is guaranteed that the motion of the dunes can be prevented by e.g. vegetation (life fences).

7. In flood plains the maximum height of the water table and the duration of the flood have to be studied, and avoided as building sites. Flowing water may create high dynamic pressure and erosion of the foundation. Potential changes in discharge directions of river systems and related floods are to be estimated in advance. When designing new structures it should be ensures that the structures per se will not root into changes of discharge. Potential changes in water level have to be monitored carefully.

8. When designing and placing even smaller dams (e.g. for irrigation) the potential structural failures have to prevented. The planned dam should be sited so that the risk for a flood hazard in down-stream areas is at minimum. Dams should not be sited in the nearhood of active faults.

2.3.2. Construction

In building design and construction the highest estimated values of storm wind loads, earthquake loads and static or dynamic water pressures, due to flooding shall be considered. The maximum loads of permanent buildings should be estimated according to a service time of at least 50 years. in case there are no local regulations nor standards of maximum loads, the loads can be defined on a basis of long-term meteorological, hydrological and seismic records.

In active earthquake regions the horizontal loads and the vibration of buildings shall be studied. By proper design a considerably higher resilience can be achieved. Cast in place reinforced concrete is to be preferred due to its high load bearing capacity. Brittle material like bricks should be avoided. In case timber is used as building material structural joints should be used to increase ductility and deformation capacity.

In flood plains the pressure and the erosivity of the flowing water shall be estimated. Protective layers or vegetative cover against surface erosion may be used. In cases of partially submerged closed structures the uplift force of the flowing water needs to estimated.

In areas of potential landslides intensive ground vibrations caused by blasting or pile driving may trigger a slide. Gradual controlled loading of the foundation soil may be needed, and in some cases the water content of the soil has to be reduced or the ground water level has to be lowered before starting other construction works.

2.4. Sectoral Considerations

There are certain sector specific issues that are to be considered when planning and implementing sector activities. When selecting priorities, sub-projects, and sectoral activities special emphasis should be laid on such activities that support community-based disaster prevention, decrease the risk of natural hazards and give local people various alternatives to fulfill their basic needs and guarantee their livelihood in future.

2.4.1. Agriculture

Potential hazards

Agriculture will be/is most probably affected by drought, desertification process, tropical storms and related heavy rains, winds and floods, and locust infestations. In a world-scale the largest impacts are those of droughts and slowly progressing desertification and related famine and migration. Agricultural activities will most probably be affected by changes and variations of local climate because of the climate change.

Activities that increase hazard-proneness

A: Drought and desertification

Projects having their activities in the semi-arid or sub-humid areas where drought is a recurrent phenomena should make a strategic choice of reducing the known risks of a coming hazard. Project activities/factors that most probably can increase the risk and deepen the impacts of drought and accelerate desertification process include the following:

* new land clearance,
* absence of erosion control methods and large areas of open cultivated fields/grazing lands,
* land forms and soils that are naturally saline or erosive or situate in steep slopes,
* irrigation,
* heavy mechanization,
* intensive use of chemical fertilizers and pesticides,
* cropping patterns based on monocultures,
* non-drought-resistant and non-pest-resistant crop varieties,
* absence of good quality food storage systems at household and at community level,
* ineffective food marketing and delivery systems at local and regional level,
* local economic patterns based on single product or solely based on agriculture.

For instance, in dry regions salinization can locally become a real threat to productional activities or result in slow-progressing desertification, if irrigation systems are not well-designed or do not function properly. Inexpensive water can result in over-use of water. The use of salt-bearing ground water can result in waterlogging and accumulation of salts.

Salts accumulate also because of flooding of low-lying lands, evaporation from depressions having no outlets, and the rise of ground water table close to soil surface.

B: Tropical storms and related hazards

Floodplains are in many regions, particularly in arid regions, the only and seasonally productive environments because flooding recharges soil moisture and renews the alluvial soils with silt. Flood reduction measures, thus, can end up with impoverishment of local agricultural practices, natural vegetation, wildlife and livestock, and riverine fisheries. Structural measures, like flood channels or barriers reduce the frequency of flooding, and as a result the sediments entering the river system from the upstream watershed will be driven to mouth of the river, if there are no outflow possibilities downstream. Increased sediment loads in the river itself can change physically the flow with sedimentation, altering the strength and height of the flow in the estuary, delta or shoreline of the coast, and affect fishery populations. Coral reefs which are very sensitive to increased sediment outflow from rivers, can be totally damaged.

C: Pest infestations

The occurrence of migratory forms of locusts and grasshoppers seems to be in relation to periodic droughts and following rains and favourable winds. The growing number of harmless domestic grasshopper forms results from land clearance and intensive agricultural practices and increases the risk for migratory forms of locusts in future.

D: Climate change

Agricultural activities also produce significant amounts of greenhouse gases (NOx/fertilizers, CO2/land clearance/energy, CH4/rice production/ruminants) that will affect on the production capacity in the longer-term through the process of climate change. Recent research shows that the probability of extreme weather events such as storms and heavy rainfalls can increase on a consequence of climate change.

Climate change will most probably weaken the possibilities for agricultural production in already drought-prone semi-arid and arid regions. The predicted changes, even smaller ones, in crop-water availability, whether in form of decreased rainfall or decreased soil moisture, are likely to be the most important factors for agriculture. The existing research from Kenya suggests rather drastical food insecurities through drop-downs in maize and milk yields. The diversification of production patterns is thus vital and specific attention should be given to the proper selection of crop varieties and development of more drought-resistant local varieties.

Measures for prevention and mitigation

Project activities that most probably increase hazard-resistance (e.g. drought-resistance) effective local level early warning systems, locally developed production technologies that are adapted to the local environment, diversified production patterns combining food production and income-generating activities, and secure access to resources and human resources development.

On project level, the regular flow of agro-meteorological information and related prospects for crop harvests, livestock yields and overall food security situation should be guaranteed. Thus, project should have links with local (or national) weather forecasting body and with food security institutions. Project should also closely cooperate with the existing agricultural research stations and programmes that study e.g. the quality of soil or existing genetic diversity of wild plants, cultivars, and their potential uses for nutritional purposes. One project component or sub-project can be part of national or regional research programmes which aim at breeding drought- and pest-resistant local varieties, or project can promote local level seed production. Thus, project should be able to prevent or adapt in acute food deficits. Project should always monitor the condition of the local environment(management and monitoring plan), if major technological changes are being introduced.

Project should guarantee the development of local and ecologically sound technologies for production(i.e. LEISA, low-external-input-agriculture). These can be e.g. traditional inter-cropping methods, alley cropping with multipurpose trees, enriched fallows/green manuring, crop rotation, live fences or terracing and contouring or improved fodder for the livestock. Such local production technologies promote also the aim of the diversification of production patterns (e.g. farm forestry, artesany, rural services etc.). In high-risk areas (e.g. arid and semi-arid regions) special attention should be paid to the selection of locally adapted, drought- and pest-resistant varieties of crops and trees.

Ecologically sound production technologies are in most cases also the best options for the farmer by being relatively economic, by creating independence of external inputs (e.g. fertilizers, pesticides, machinery) and by strengthening the risk-resilience (e.g. decreasing potential health risks caused by agro-chemicals). Potential health impacts of the planned technologies should always be studied in advance, and aspects of occupational health and safety should be monitored during the project.

Project should guarantee secure rights to resources, especially to land and water for vulnerable people. Participatory working and planning methods, skills development and training can be used when e.g. political, and legal means fall outside the framework of the project.

Prevention of climate change could mean, for instance, the following mitigation measures: avoidance of new land clearance, reforestation, agro-forestry, fuelwood plantations, minimization of herd sizes, improvement of the effectiveness of energy usage among others, or in general, low-external-inputs-agriculture (i.e. LEISA). In pest hazard reduction the following alternatives can be considered: land use regulations, avoidance of land clearance, inter-cropping, crop rotation, avoidance of agro-chemicals, timing of the tillage, usage of natural enemies of the pests and other biological methods. Project should have links to local or regional pest research institutes (e.g. ICIPE). Protection against floods includes guaranteeing the existence of sufficient vegetation cover whether trees, scrubs or other perennial or annual crops. Special attention should be given to revegetation of watersheds particularly in hillsides. Crop risk reduction could mean for example selection of such varieties that have longer maturing times, or changing the planting cycles.

2.4.2. Forestry

Potential hazards

Forestry is most probably affected by the same hazards as agriculture: drought and desertification, tropical storms and related heavy winds, rains and floods. A special question concerning forestry is wildfire that can destroy vast areas of vegetation.

Activities that can increase hazard-proneness

Project activities drastically alter the following natural factors or factors in relation to these can increase the risk:
* existing vegetative cover (e.g. maximum area of forest cut),
* site-specific geologic factors (land formation, soil structure),
* site-specific geo-morphologic factors (e.g. slope stability, slope orientation, slope gradient),
* site-specific meteorologic factors (e.g. temperature variations, wind, rainfall).

For instance, the size of a single forest plot is important with regard to resistance to wind and hydraulic regulation, or e.g. slope stability when constructing new roads for harvesting. Uncontrolled deforestation should also be halted because of its global level negative impacts as increasing concentrations of carbon dioxide significantly affects the climate.

A: Drought

The clearance of vegetative cover may change the micro-climate to a more extreme one, and accelerate desertification process. Trees and scrubs protect soil against erosive winds balancing temperature variations and moisture conditions.The more diverse the vegetative cover with varying root and canopy systems, the better protection from erosion and recurrent drought.For instance, simple strip planting along main or feeder roads or other open land sites can locally halt drought impacts.

B: Floods

A key driving force in the increase in flood disasters is the rapid rate of the deforestation in the tropics. Accelerating deforestation of watersheds, particularly around smaller rivers and streams, can increase the severity of flooding, reduce streamflows and dry up springs during dry periods, and increase the total load of sediment entering waterways. In general terms, the more arid the region, the smaller the infiltration capacity and thus the more dangerous the run-off potential. Vegetation cover is especially important in soils containing clays where the risk for flood (/and landslides) is high because of the lower infiltration capacity of clay material. Also shallow soils laying over impermeable materials are very sensitive to floods and need a protective vegetative cover.

C: Wildfires

Most wildfires are drought-induced. Thunderstorms and lightnings are the principal causes of wildfires. Once the fire starts, its spread and severity depends on wind and humidity. On-site observations and local forecasts greatly increase the effectiveness of fire-fighting activities. Drought risk reduction measures are compatible with wildfires, too.

Measures for prevention and mitigation

A particular focus should be laid on reduced demand of wood through e.g. efficient use of fuelwood, development of alternative energy sources and conservation of fuelwood and forests. As forestry related activities are often important means of food security, and a source of income-generation, more emphasis should be given to the multiple and traditional uses of forests: e.g. bee-keeping, nut and seed gathering, mushrooms, medical plants, forage, fuelwood plots, carpentry, and agro-forestry. When selecting sub-projects or components of the project farm forestry, social/community forestry activities, watershed management/protection, inter-cropping/agro-forestry, erosion control, reforestation of ecologically fragile sites (e.g. hilltops and steep slopes), and controlled livestock management practices among others should be studied carefully as potential alternatives.

2.4.3. Water Supply and Sewerage

Potential hazards

The following hazards can affect water supply and sewerage projects:

* droughts
* heavy rains
* floods
* earthquakes, tropical storms

Activities that increase hazard-proneness

A: Droughts

Reliability of water supply is heavily dependent on the quality and quantity of water in raw water sources. For adequate impact considerations, long-term climatologic data must be analysed while planning water projects in drought-sensitive areas.

Severe drought may empty the surface water sources and reservoirs, and should always be taken into account in the dimensioning of the reservoirs in potentially drought-stricken areas. Drought may also endanger the use of groundwater as the groundwater levels may drop drastically during long dry periods.

Droughts may have an impact on sewerage as the functioning of sewerage systems require certain minimum flows in the sewers.

B: Tropical storms and related rains and floods

Tropical storms, heavy rains and related floods caused by them on the spot or downstream, all affect greatly both the quality of water as well as the security of physical structure of the water supply and sewerage systems.

During floods and heavy rains there is a risk for source contamination, for example of wells and water storages, is acute. In practice, when surface water infiltrates directly to wells or water storages, there is always high risk of pollution.

C: Earthquakes and Landslides

Earthquakes and landslides may cause severe breakages of water supply and sanitation systems. For example, earth movements may break the pipelines as well as damage the structures of treatment plants.

D: Other Hazards

Deforestation may have long-term effects on water supply through increasing the high flows as well as sedimentation in the water reservoirs. While on the other hand increasing the surface runoff, deforestation usually at the same time decreases the groundwater formation as well as the dry-period flows. Deforestation and intensive agriculture affect also the quality of water through increasing the contents of suspended solids and nutrients (e.g. nitrogen, phosphorus) in water.

Measures for prevention and mitigation

The potential impact of droughts must be studied in the selection of sanitation and sewerage methods as well as in their dimensioning.

In the design of wells and water storages potential preventive measures against tropical storms and related hazards have to be considered. For example, in flood-sensitive areas, the wells may have to be e.g. elevated with additional rings.

Tropical storms and related floods threaten also the various physical structures of water supply. For example, the dams of reservoirs as well as the pumping stations, etc. must be designed according to the risk potential. Especially the design of various dam structures require sound knowledge of the flow extremes and floods, as the hazard of a collapsing dam may be disastrous for even wide populations.

In sewerage project the impact of heavy rains should carefully be taken into account in selection of the sanitation and sewerage method as well as in its dimensioning. For example, common, or "Finnish" guidelines for dimensioning should never be used in places where heavy storms and exceptionally heavy rains are common. Always, when dam structures are planned, special attention should be paid on dam safety. Local design standards should usually be applied, if such exist. In case local standards are unsuitable in high-risk areas, international standards used in the country concerned should be applied.

The risk for earthquakes and related hazards should be taken into account in the design of the systems as well as in selection of the pipe materials, etc. For buildings and other related structures, same prevention methods should be applied as for any buildings.

The risk for deforestation should be analysed during studies regarding the water sources, as they in the long run may endanger the entire basis of the selection of water sources. If there is a risk of increased amounts of solid waste and nutrient as a result of deforestation, it should affect the process design of water treatment plants.

2.4.4. Infrastructure

Potential hazards

The sudden onset hazards pose most harmful effects on densely populated areas/sites. Roads, bridges, power plants and lines, telecommunication centres and lines, schools and hospitals are among most vulnerable public facilities, and besides very important for human functions. A natural disaster can turn to a chemical catastrophe if industrial plants producing or using in their processes hazardous substances are damaged.

Activities that increase hazard-proneness

A: Flooding

Spontaneous and unplanned settlements in floodplains or coastal areas rise the risk for damages caused by river flooding or storm surges. Deforestation on hilltops and hillsides in the upstream, or more intensive agricultural practices in the upstream because of population pressure increase the risk for floods in the downstream, and increase the risk for damages to infrastructure.

Specific structures aimed at flood protection can also increase the flood risk. Any measure that increases the velocity of the flow, increases also the erosivity of the flow. Erosion of river banks and sedimentation are obvious risks. Channel improvement tend to transfer the problem of flooding downstream.

The built structures per se can increase the risk of flood damages e.g. in downstream communities. Buildings, flood barriers, for example increase the height and the velocity of water flow, and reduce floodplain storage capacity, and increase the total runoff. The installed storm drainage systems can have similar kind of negative impacts.

B: Geologic hazards

The principal structural factors of buildings that are at risk during seismic activity are: building configuration, size of openings, vertical rigidity, ductility, foundations and the quality of construction works. Although ground failure and deformation are major risks to build structures, also the phenomenon of resonance is important. Loose or unconsolidated soils can amplify low frequencies, and thus become a real risk to tall buildings. Specific building forms may increase the risk of an earthquake hazard (L-, U-shaped, split-level, a towe). Depending on the ground material (i.e. rock and land formation) the natural vibration of a building can be increased with catastrophic results. Certain building materials are known to be highly vulnerable: stone masonry and brick masonry. On a contrary, wood and concrete are relatively resistant materials.

The most vulnerable components of road facilities are underpasses and overpasses, bridges, viaducts and tunnels and roads on mountains. The determining factor for a certain road structure to survive is the capacity to resist ground shaking. The vulnerability of bridges is dependant on the ability to resist lateral forces (i.e. slides). In fact, bridges are not usually designed to resist lateral forces. Railway networks have high vulnerability in earthquakes, and damages are similar to those of the road system.

The vulnerability of centralized water supply systems is dependant on the element. The vulnerability of pipelines depends on the general flexibility of the line and on the flexibility of the joints. Flexible joints help to resist longitudinal ground displacement. Installations for water treatment and transport are known to have high vulnerabilities.

The weakest points of electrical systems are generators and transformers. Damages to the power supply systems is often caused by collapse of buildings and failure of foundations, similar effects as on water supply systems. Electrical constructions in the open air, like wires are known to be less vulnerable. The secondary risk of fire should not be forgotten.

Volcanic eruptions can light fires. They may contain toxic chemicals, e.g fluorine, which can contaminate water.

Measures for prevention and mitigation

Any infrastructure development or urban development project should analyze all the potential hazards carefully including also the potential risk for technological hazards caused by e.g. industries and power plants. This analysis should be formulated into a specific strategy or an action plan for mitigation.

Most common structural measures used in flood prevention and risk reduction are embankments around public facilities, construction of drains, culverts, bridges, construction of roads and buildings above normal flood level, construction of control dams and ponds. Structural flood control methods such as levees or channel improvements increase the discharging capacity of a stream. Modification of the channel (e.g. wider/deeper, clearing of vegetation, smoothing the bed and walls) helps to increase the speed of the flow, hence preventing flooding along that river section.

Sound and effective land use offers means to reduce the risk of flooding/geologic hazards. Land use regulations should have the mandate to direct different human functions to different risk zones: e.g. health facilities are needed in high-risk areas, but schools should not be located in high-risk areas. In case of flooding, reforestation of river banks, terracing of hillsides/hilltops and floodplains, and awareness-building campaigns should be considered as appropriate means of prevention and mitigation.

Zoning can be an effective means of controlling floodplain development or unplanned settlement in the earthquake-prone areas. Zoning the land for e.g. agriculture, reforestation and conservation is an available possibility, but needs full support and participation of local people. As wetlands have an important role in flood control, zoning to prohibit activities in wetlands that will reduce their water storage capacity is vital. Regulations in zoning ordinances could then prohibit or specify the types and operations of construction or any other development activity. Sewage disposal system or disposal of toxic and other hazardous substances, or constructed structures (e.g. buildings or roads) should be prohibited if they are most likely to amplify the effects of floods.