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Note : *Part A and B of this report contain the technical details on the basis of which the major recommendations and Technology Action Plan have been prepared. It will be necessary for local administrators and technical personnel to examine these sections in detail.*

EXECUTIVE SUMMARY

This report, presents a rapid assessment of the impact, damage and possible technological strategies for house reconstruction in areas of Garhwal affected by the earthquake of 20th October, 1991. It identifies, specific measures for the demolition, reconstruction and strengthening of each of the major house types in the area. It also outlines technological options for the provision of emergency shelter to protect victims over the severe winter and monsoon. This report has been prepared on the basis of a rapid appraisal of the earthquake affected regions, observations made on 850 buildings, 9 village level studies and detailed discussions with the villagers, the District Administration and other agencies working in the area.

The earthquake impact has been strongest in Uttarkashi, Tehri Garhwal and parts of Chamoli district. Over 1,000 lives were reported lost and other casualties are being reported due to exposure and breakdown of life-support services. The estimated number of houses damaged in the region is over 30,000.

As observed by various experts, this region will continue to be highly prone to earthquake and induced landslide risks in the foreseeable future. Hence, there is a need for investment in providing earthquake resistant housing in the area.

The broad issues to be addressed during reconstruction are :

1. Relocation of houses or communities
2. Site improvement
3. Regulation of future land use
4. **Reduction of vulnerability of buildings**
5. Restoration of infrastructure and services

This report, focusses on the options and mechanisms to reduce the earthquake vulnerability of buildings. The additional issues must be addressed expeditiously, to initiate the process of building reconstruction.

The report establishes the need for detailed re-assessment of damage to focus the reconstruction programme. A detailed Guide to Damage Assessment and Reconstruction has been prepared (*Table 4.5, pp.52-58*) on the basis of this study.

The major house types that have to be addressed are Slate roofed houses on Stone random rubble masonry (over 70% of the housing stock); CGI sheet roofed houses on Stone walls (upto 13%) and RCC roofed houses on Stone (upto 12%) or Brick (upto 9%). The strategies for each vary.

Random Stone rubble in mud mortar has been the most disastrous walling system in the area largely due to the lack of through, corner stones and tensile reinforcement. This will have to be corrected by cast-concrete corner blocks, timber framing (possibly recycled) or a RCC lintel band and vertical steel or timber reinforcement (See *Manual of Reconstruction in Earthquake Affected Garhwal Region, BMTPC/TARU, 1992*).

A composite roof of CGI sheets on timber planking and trusses on reinforced stone masonry walls has emerged as the most pragmatic reconstruction option. CGI sheets have already been distributed as part of the first phase of relief. A number of the poorer families will not even be able to afford this without considerable financial assistance. Tools, metal truss connectors, simple erection equipment and skilled carpenters will have to be brought into the area to help execute this work.

Available house designs will have to be modified according to local constraints and lifestyles of people. The current type-design based approach will not be able to effectively address these constraints. Variations on existing house plans should be low, except to meet earthquake, thermal comfort and cost considerations.

Following the earthquake, most households have very low asset holdings and incomes and will not be able to afford to repay loans for houses with "conventional" technology, for some time to come. It will therefore be necessary to draw largely upon building material (Slate; Timber and Stone) from collapsed or demolished houses. Besides, financial institutions will be required to come forth and disburse loans for demolition and

reconstruction (partially in the form of materials), apart from under existing rural employment programmes and relief grants already distributed.

The estimate of investment required per unit, depending on intensity of damage ranges from Rs 500 to 55,000 in four slabs as presented in the table on page 8 of this section. The total investment of the reconstruction programmes is likely to be in the range of Rs. 40 to 60 crores, depending on the extent of improvement and mode of implementation.

The primary agency of construction should be the local people, with artisans. The supply of materials (especially timber and cement) must be provided through the State Govt. Technical support and training of artisans would have to be provided on a large scale to artisans and contractors through agencies e.g. District Building Centres, CBRI, and BMTPC along with qualified NGO groups.

The process of reconstruction and disaster mitigation will need to be managed in six sub-programmes :

1. Damage Assessment and Identification of risk-prone settlements
2. Demolition of severely damaged buildings
3. Relocation of hazard prone settlements and buildings
4. Repair and Reconstruction of buildings
5. Provision of building services
6. Strengthening of damaged buildings

Areas of short-term and medium-term action to be taken at the village, district and State \ Centre level, have been listed in the Recommendations section. The institutional arrangements and the details of the projects will have to be worked out with the respective governmental and non-governmental agencies, entrepreneurs and, last but not the least, the villagers themselves.

MAJOR OBSERVATIONS AND RECOMMENDATIONS

ESTIMATED DAMAGE INTENSITY IN THE REGION

The respective District Administration(s) have prepared an assessment of the total damage in two classes as presented in *Tables 1.5, page 6 and 1.9, page 10*. The classification of damage intensity was determined by administrative expediency rather than scientific analysis. This report presents a somewhat different picture based on the rapid appraisal of sample villages and buildings studied. This partially because of the use of the international MSK classification in this study and an appreciation of the process of repair and reconstruction as recorded in *Table 4.5, page 52 to 58*. An estimate of the damage has been prepared based on field data on intensity of damage to different types of building and cross-checked with both secondary data and damage reports from the local administration. This is only indicative of the scale and relative proportion of damage in the region and is not a substitute for data provided by the local administration. It may however, be considered necessary to reappraise the extent of damage (as is being done in some areas) based on the guidelines presented in this document.

ESTIMATED NUMBER OF HOUSES BY DAMAGE INTENSITY & DISTRICT IN GARHWAL				
DAMAGE INTENSITY	UTTARKASHI	TEHRI GARHWAL	CHAMOLI	TOTAL
Slight or Moderate	5,700	4,900	400	11,000
Heavy	5,900	5,300	350	11,200
Severe or collapsed	4,000	3,600	250	7,850
TOTAL	15,600	13,800	1,000	30,050
Source: TARU field data, Census of India (projections) and district administration damage assessment				

EXISTING NORMS FOR RELIEF

The existing norms for relief and reconstruction assistance are presented in the table below. The quantum of assistance that has been extended will be inadequate to meet the needs of the affected households as the intensity of damage, scale of demolition and reconstruction activity were underestimated in the earlier appraisal.

EXISTING NORMS FOR RELIEF AND RECONSTRUCTION IN GARHWAL		
DAMAGE TYPE	CENTRAL NORMS	U P GOVT. NORMS FOR GARHWAL EARTHQUAKE
Fully	Relocation/construction: Rs. 1,000/- Construction: Rs. 500/-	Rs. 20,000/- (including 10,000 in form of building material) + 15,000 loan assistance
Partial	Repairs: Rs. 200/-	Rs. 5,000/-
Central norms for assistance to Bihar and Sikkim (following 1988 earthquake)		
Category	Unit cost of repair/reconstruction	Enhanced subsidy
EWS (rural)	Rs. 6,000/-	15% of cost subject to a maximum of Rs. 1,500/-
EWS (urban)	Rs. 15,000/-	15% of cost subject to a maximum of Rs. 1,500/-
LIG (rural)	Rs. 20,000/-	10% of cost subject to a maximum of Rs. 1,500/-
LIG (urban)	Rs. 30,000/-	10% of cost subject to a maximum of Rs. 1,500/-
Source: Norms adopted by Govt. of Uttar Pradesh in wake of earthquake		

INDICATIVE SPECIFICATIONS FOR RECONSTRUCTION OF NEW HOUSES

The norms for investment in the construction of new buildings are complex to derive given the range of house types, intensity of damage, investment capacity and aspirations of the people. In addition, the core house concept has severe limitations because of the requirement of a minimum area of 60 to 120 sq.m. to shelter both the people and their cattle from the cold (*Table 3.1, page 20*). However, the following table presents an rough estimate of the cost of constructing a new building on a prepared site, using recycled material and a roof of Slate or CGI. The limitations of this approach must be recognised, in that it averages a wide range of variables that on the ground are critical factors in the reconstruction process.

INDICATIVE SPECIFICATIONS FOR RECONSTRUCTION OF NEW HOUSES	
Building system	Indicative specifications
Foundation	Random rubble stone masonry in mud mortar (or cement) with width of 45 cm. and minimum depth of 30 cm. and appropriate base concrete and reinforced plinth beam based on site conditions.
Walls (ground and first floor)	Random rubble stone masonry in mud mortar (or cement) with a maximum width of 45 cm. with adequate through and corner stones (or cast concrete blocks) and vertical reinforcement (of timber or steel) at all corners. Timber bond beams along the length of the building and an RCC ring beam at roof level are indicated.
Intermediate floor	Timber planks on timber or steel sub-structure with adequate cross-bracing and rigid connections to walls.
Roof	CGI sheet or Slate cladding on timber planks and trusses tied down by a wall plate.
Openings	Timber framed and shuttered centrally placed openings with adequate reinforcement.
Source: TARU field data and BMTPC/TARU Manual for reconstruction in Garhwal	

ESTIMATED INVESTMENT PER UNIT BY DAMAGE INTENSITY

The estimate of investment per unit required to repair, reconstruct, demolish and rebuild damaged buildings is presented in the table below. This has been compiled taking into account the average prevailing costs of materials and labour. The costs of cartage to remote locations will have to be estimated locally. This estimate assumes that the bulk of the local stone used for walling and Slate for roofing can be recycled. It also assumes the recycling of up to 50% of the timber in existing buildings and re-use in a more efficient manner (e.g trusses). The cost ranges emerge from the range of house types in the region and the differential intensity of damage to them. This expenditure estimate is independent of the interim relief of 22 CGI sheets that have been provided by the State government to meet the need of emergency shelter.

ESTIMATE OF INVESTMENT REQUIRED PER UNIT TO REPAIR, RECONSTRUCT, DEMOLISH & REBUILD DAMAGED BUILDINGS IN GARHWAL		
DAMAGE INTENSITY	ACTIVITY	ESTIMATED INVESTMENT PER UNIT (Rs.)
Slight or Moderate	Repair	500 to 2,000
Heavy	Reconstruction	8,000 to 12,000
Severe	Reconstruction	12,000 to 16,000
Collapse	Demolition and new construction	40,000 to 55,000 (plus 6,000 for demolition and site clearance)
Source: TARU field data and damage assessment		

The quantum of actual investment would depend on the level of technological support that can be provided. The rough breakup of expenditure of various sub-components are as follows: Slight or Moderate damage (10 %); Heavy damage (30 %) and Severe damage and collapse (60 %). The cost of relocation would be an additional expenditure. Relocation would include the cost of site development, physical and social infrastructure. settlements to be relocated.

TECHNOLOGY ACTION PLAN FOR RECONSTRUCTION IN GARHWAL

The technological options for building reconstruction in Garhwal will have to be drawn from both earthquake engineering experience and what is acceptable to the local people. Else, the reconstruction programme may risk a failure similar to the early years of the Indira Awaas Yojana (IAY) programme or even the lack of use of the emergency community shelters provided by the government. The availability of these inputs has not only to be appropriate but also timely.

The local population was found, during the study, to be fairly clear about the materials that they would like to use for reconstruction. Slate and RCC (in most areas) have been rejected as roofing options, in many areas, because they are heavy and have caused considerable casualties. Random rubble walls in mud-mortar have also been perceived as the major cause of failure. However, the lower floor of buildings will be built in Stone. Two solutions to the masonry failure problem have emerged locally: timber framing or RCC tie-beams. CGI sheets are currently perceived as the only roof cladding option, for which the people require support.

The dominant view is to retain the traditional form of house, especially in the higher altitudes where pastoral communities are dependant on cattle. The broad specification would therefore be: a ground floor in stone masonry with adequate reinforcement, timber intermediate floor, upper floor with timber framing and planks and roof of CGI sheet on timber planking.

The scale of reconstruction work given the high altitudes, remoteness and poverty of the people is large, both in terms of logistics and investment, is very large. Therefore, the judicious use of technical input to augment and redirect local effort would enable cost reduction, faster execution and medium-term disaster mitigation. An indicative set of technology related interventions would therefore be:

- o providing access of low-income households to Timber, Stone and CGI sheet
- o upgradation and reinforcement of traditional walling
- o construction with light-weight materials
- o upgrading masonry and carpentry skills on a mass-scale
- o setting up a materials production and technical support system through permanent Building Centres/sub-centres
- o demonstration of earthquake resistant house designs
- o resiting of buildings and settlements on risk free sites
- o demolition and propping of hazardous buildings

PROVIDING ACCESS OF LOW-INCOME HOUSEHOLDS TO TIMBER, STONE & CGI SHEET

The primary requirement for low-income households is enhanced access to quality building material i.e. Timber and Stone (of adequate length and size) and CGI sheet roofing. A major change in roof cladding is expected from Slate and RCC to CGI sheet roofing. However, some of the poor households will remain unable to shift to a new cladding material because of lack of finances. The dominant roof support and framing material will continue to be timber, especially because of the transportation, cost and fabrication problems with steel. A major shift out of Stone masonry for the ground floor of houses is not anticipated.

Issue: The major constraint to the supply of timber is the lack of release from the Forest Corporation/Department stocks. Unseasoned and treated timber will shrink, warp, crack and be attacked by pests (e.g. borers and termites). The use of timber that is either stolen or recently cut from the forest will reduce the life of buildings.

Action: *The District Administration, in coordination with Voluntary agencies and the Building Centres could supply seasoned, treated and pre-cut timber trusses, rafters, beams, poles, tie-beams and door/window frames from standard sections. The section details can be based on the work of the Timber Engg. Division, FRI. Seasoned timber will have to be released by the Forest Corporation. In addition, a medium size steam-based seasoning plant can be constructed in each district to cater to this demand. Ten Solar seasoning kilns can be set up in various remote location (with subsidy from NEDA/DNES). Mobile trailer mounted ASCU treatment plants are available and can be moved to convenient locations. Timber saw mills can be requisitioned/recommissioned to take care of sawing/planing of large sections. Such mills are located at Budhakedar and Ganeshpur.*

Issue: Lack of access to/use of through and corner stones and resultant failure of Stone masonry walls because of strictures on quarrying and degradation of masonry protection.

Action: *Organised quarrying of long (> 40 cm) through and corner stones for walling should be promoted. Appropriate leases may be granted to villagers for local quarrying support for transport and marketing through the open market and Building sub-centres.*

In the areas where this is not practicable, cast stone concrete blocks of requisite specifications can be produced locally using petrol driven vibrator-gang mould equipment. Supply of cement and clean sand will have to be ensured along with simple quality control measures.

Issue: Lack of affordability to upgrade roof from Slate to CGI in partially/undamaged houses in increasing future risk.

Action: *Provision of CGI sheets on a subsidised basis as the material component of a long term housing loan through District Administration/PDS.*

Alternatively, upgradation of Slate clad roofs by using timber trusses, wall plates, connectors and adequate reinforcement of walls.

Issue: A severe constraint to access to building materials is transportation from the road head to villages. The only effective means of transport is mules. The number of mules to cater to the reconstruction activity is low and need to be increased.

Action: *Local ownership of mule teams could be supported under IRDP.*

UPGRADATION AND REINFORCEMENT OF TRADITIONAL WALLING

Issue: The damage to most buildings has been because of the collapse of Stone masonry walls. This has been because of a number of defects in construction that can be improved and upgraded. This includes: proper through stones; corner bonding and reinforcement in timber or RCC beams; plinth, lintel and gable bands in timber or RCC, proper siting of buildings and separation of rear walls from retaining walls. This can be undertaken by upgrading local construction practice to cut down the quantity of "imported" material like cement and steel which is both difficult to transport and unaffordable by most households.

Action: *Propagation of wall upgradation techniques through manuals, films, training and demonstration buildings. The CBRI Stoneblock technique can be introduced with adequate equipment support under TRYSEM.*

CONSTRUCTION WITH LIGHT-WEIGHT MATERIALS

Issue: Most villagers have decided that the first floor of their houses would have to be constructed of a light-weight frame of timber or steel with cladding of timber or possibly cane ("ringal") panels for insulation. The roof cladding is anticipated to be of CGI sheet on timber planking for insulation.

Action: *Setting up production facilities, training and designs for (timber, steel and cane) for light-weight structures at Tehsil level. Loans for entrepreneurs to be made available through banks.*

UPGRADING MASONRY AND CARPENTRY SKILLS ON A MASS-SCALE

Issue: The failure of buildings with bad workmanship is clearly evident. Traditional techniques to build earthquake resistant buildings have either been forgotten or set aside in the rush to construct buildings rapidly over the last decade. The primary techniques that have to be disseminated, are improved dry-stone and stone walling, stone masonry in cement mortar, stone-block masonry, reinforced bands for walls, trusses, wall plates and use of steel connectors for roofs.

Action: *On-the-job training and extension programmes for local and "imported" masons and carpenters in earthquake resistant construction. Development of training packages could be undertaken by BMTPC in collaboration with the Building Centres and District Administration.*

SETTING UP A BUILDING MATERIALS PRODUCTION AND TECHNICAL SUPPORT SYSTEM THROUGH BUILDING CENTRES/SUB-CENTRES

Issue: Lack of technical support infrastructure to manage reconstruction process. Technical specialists trained in conventional materials (e.g RCC) will be unable to manage a large-scale decentralised reconstruction programme, largely using local materials and skills. A flexible institutional mechanism is required that can link the local administration, voluntary agencies, artisans and householders.

Action: *High priority to commissioning Building Centres/Sub-Centres with specialised consultants on rural construction to train and provide advice. Sub-Centres would function as building material production and stocking yards for timber, steel, concrete products. Information and turnkey design services would be made available from Sub-Centres.*

DEMONSTRATION OF EARTHQUAKE RESISTANT HOUSE DESIGNS

Issue: Even though the basic built form of houses in the area can be divided into single storey and the two-storey type of construction, considerable variation exists in the size and layout of individual houses. The danger of building large numbers of type-designed houses is of not meeting the functional requirements of (e.g. extended) households or being beyond their economic capacity. The most effective demonstration of earthquake resistant technology will be on community buildings (e.g schools and panchayat buildings). Thereafter, demonstration houses can be built in consultation with selected local households.

Action: *Construction of community buildings using upgraded techniques of earthquake resistant construction in affected villages on a priority basis, which will also create local employment. Construction of a number of demonstration earthquake resistant houses based on traditional built form and space use in each affected sector. Funding can be provided by CAPART. BMTPC could coordinate the preparation of a document laying out various design options.*

RESITING OF BUILDINGS AND SETTLEMENTS ON RISK FREE SITES

Issue: A significant proportion of settlements (upto 25%) are exposed to landslide and snow-load risk. Identification of damaged/undamaged villages/portion of villages at grave risk because of landslide, rockslide or snow-load and arrange for evacuation/ re-siting and providing information of the above to villagers is essential

Action: *Coordination with Geological Survey of India, Wadia Institute of Himalayan Geology and Univ. of Roorkee on scientific assessment of risk due to landslide and snow load. BMTPC could coordinate the preparation of settlement planning guidelines for risk prone villages.*

DEMOLITION AND PROPPING OF HAZARDOUS BUILDINGS

Issue: Immediate identification of hazardous buildings that are in danger of imminent collapse by a multi-disciplinary task force of experts. Demolition of the above buildings with the aid of technical experts and para-military agencies. Breaking down of dislodged rocks and short term containment of rock-slides and small landslides that threaten settlements. Propping and shoring of severely damaged buildings to avoid collapse under snow load/melt conditions. The local administration has expressed the need for technical support for both rural and urban buildings in this area.

Action: *The BMTPC could commission the preparation of a set of guidelines prepared for the above in consultation with the Univ. of Roorkee and CBRI. BMTPC could identify consultants/firms to undertake technical support and repair activities in the affected area. State Govt. could arrange the deputation of departmental personnel to provide technical support and can arrange for the provision of simple tools: e.g. chain block pulleys, jacks, sledgehammers to aid demolition.*

DISASTER MITIGATION & ECONOMIC REHABILITATION PLAN

Issue: Most relief and emergency shelter activity is being taken up as a fire-fighting exercise, with almost no technical support and medium term perspective. Resiting and evacuation of villages because of landslide risk has for example only become an operational issue at this juncture, when many effected areas are about to be cut off due to snowfall. This points very clearly towards the need for more effective inter-agency coordination and the need for professional support in the reconstruction work.

The reconstruction of buildings in the area will in the long term depend on the economic rehabilitation of the region. In many agricultural villages both terraces and field irrigation channels have been completely destroyed. Repair is estimated to take over 2 years and will be essential. In pastoralist areas, cattle mortality has been and is expected to be high over the next six months. This would mean that a large number of the poor families would not be able to feed themselves. The question of paying back loans for housing with no effective asset holdings will not arise for sometime. It will therefore be crucial to dovetail reconstruction with government employment programmes in the area. Some of the norms may have to relaxed in this case.

Action: *Preparation of a comprehensive rehabilitation, Disaster Mitigation and economic rehabilitation plan for the affected region. The Plan could be commissioned by the State Government and executed through a consultancy arrangement.*

SHORT AND MEDIUM TERM RECOMMENDATIONS

Recommendations have been made at three levels: village, District and State/Central Government in two time-frames: short and medium as presented below:

Village level

Short-term

Immediate evacuation/ re-siting if recommended by the District Administration

Immediate identification of hazardous buildings that are in danger of imminent collapse.

Demolition of the above buildings with/ without aid of the technical support from the Army and other para-military agencies.

Propping and shoring of severely damaged buildings to avoid collapse under snow load/ melt conditions

Breaking down of dislodged rocks and short term containment of rock-slides and small landslides that threaten settlements

Rapid construction of local emergency shelters (especially in high altitude areas)

Arrangement for treatment of drinking water using chemicals provided by the District Administration.

Medium term

Recycling, grading and storage of timber, slate and stone for reconstruction after March. This should not be done at the expense of cattle, that will die if left exposed in the snow.

Collection of long stone pieces that will serve as through stones/ corner stones during reconstruction

Selection, cutting, planing, seasoning and treatment of timber for reconstruction

Village level extension programmes on earthquake and landslide hazard, patterns of failure of construction and technical options on repair and reconstruction.

District level

Short-term

- Identify villages/portion of villages at grave risk because of landslide, rockslide or flash-flood and arrange for evacuation/ re-siting and provide information of the above to villagers immediately
- Identify high altitude villages/buildings with high risk of building collapse and arrange emergency shelter/evacuation on a priority basis and provide information of the above to villagers immediately
- Arrange for the immediate demolition of hazardous buildings with technical support from the Army and other para-military agencies.
- Arrange for the provision of simple tools: e.g. chain block pulleys, jacks, sledgehammers to aid demolition
- Arrange for the provision of atleast 22 additional CGI sheets to each household (over and above the 8 supplied) to construct emergency shelter in the absence of any other arrangement by the government.
- Arrange for the release of timber planking for the insulation and space heating arrangements for government provided emergency community shelter.
- Arrange for emergency water supply in areas where freezing does not take place and make water treatment chemicals available to avoid the outbreak of water borne diseases.
- Re-examine the classification of damage to houses on the basis of the effort required to repair, demolish or reconstruct.

Medium term

- Set-up an geographic database on damage to buildings to enable better coordination of relief and reconstruction activities
- Arrange for extension and training facilities for households, artisans and technical personnel with a focus on reconstruction using local materials, techniques and house forms with a minimum of imported components and technology

State/Central level

Short-term

Expedite the provision of materials for emergency shelter at village level

Expedite the setting up of Building Centres and sub-centres and the immediate functioning of staff in them

Expedite the provision of information on landslide and flash-flood risk to the District Administration based on the best available information with GSI, RRSA using photo-interpretation.

Relax the conditions of employment programmes to enable the local population to undertake reconstruction activity

Commission the preparation of a printed manual and film training aids for relocation, demolition, repair, recycling and reconstruction

Expedite the setting up of an expert technical support group that will be stationed in the region to provide technical support

Reexamination of terms of credit/loan for reconstruction based on a realistic estimate of household capacity to repay

Medium-term

Expedite the preparation of an Action Plan for reconstruction.

Arrange for the movement of masons and carpenters with skill in hill construction from areas in Kumaon and Himachal to aid reconstruction.