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Geo-Disaster and Its Mitigation in Nepal

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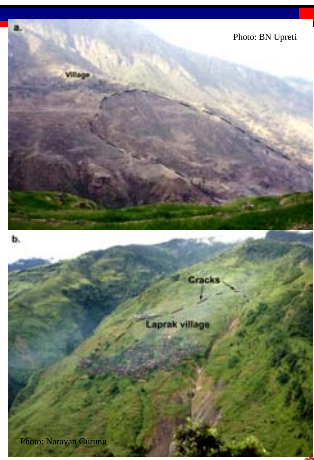
Presentation structure

- Brief overview of Geology and Climate of Nepal
- Rainfall as triggering agent
- Stability analysis
- Rainfall threshold of Landslide for the Nepal Himalaya
- Landslide hazard mapping in Nepal
- Mitigation measures
- Conclusions



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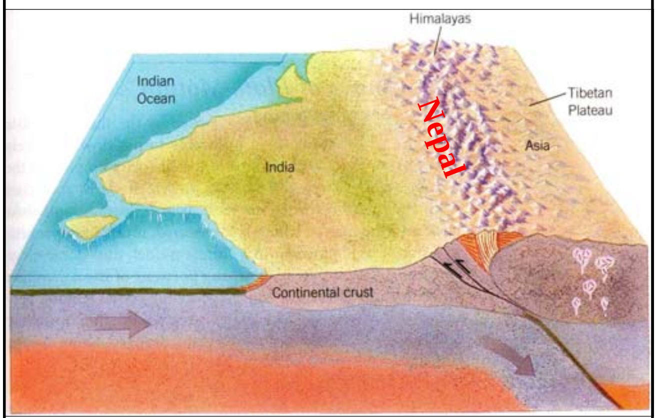
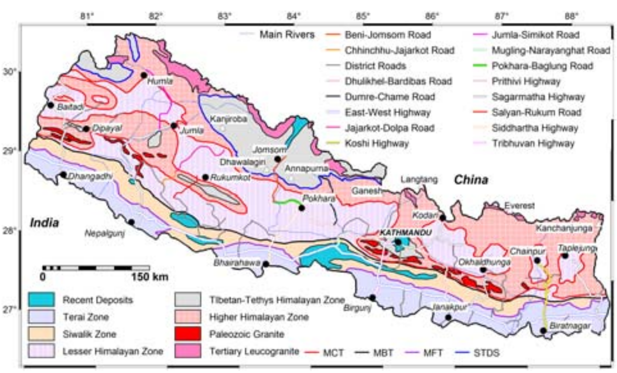


4

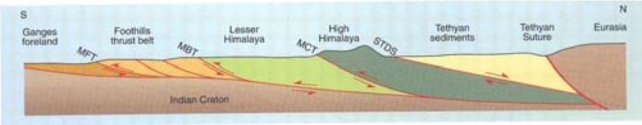
The Nepal Himalaya

- The longest division of the Himalaya
- Extended about 800 Km
- Starts from west at the Mahakali River
- Ends at the east by the Tista River (India)



Geological Map of Nepal

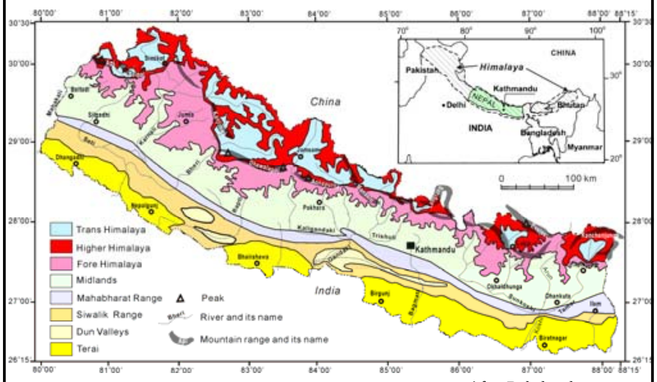
6



Simplified North-South Cross Section of Nepal Himalaya

7

Regional geomorphological map of Nepal

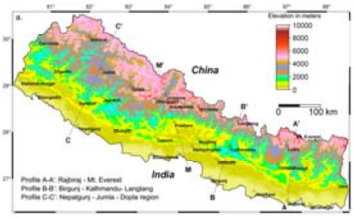


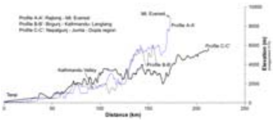
After Dahal and Hasegawa (2008)

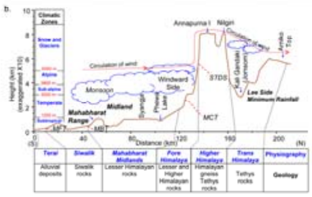
8

Huge difference of elevation in short distance

South is less elevated
North is highly elevated







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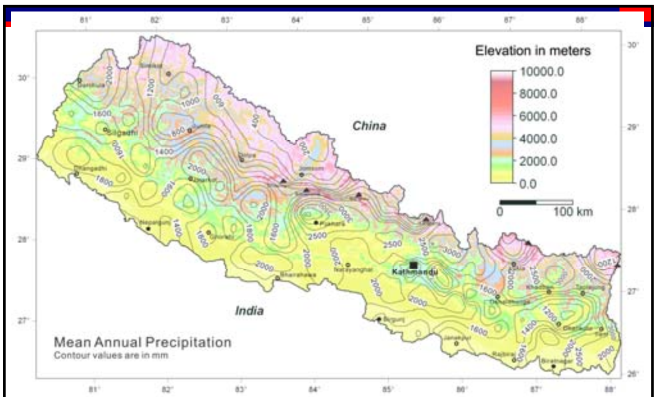
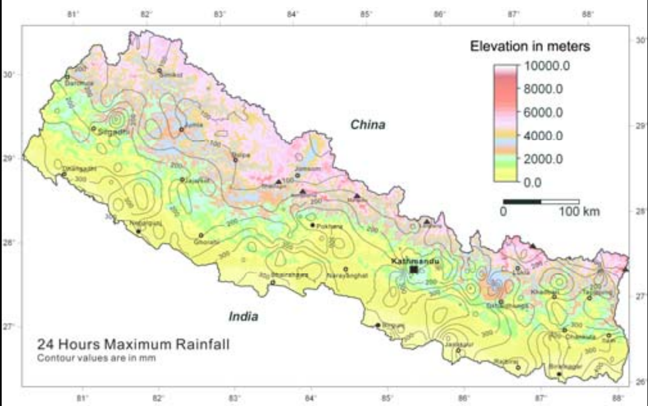


Strong South Asian Monsoon , 90% annual rainfall occurs within three months



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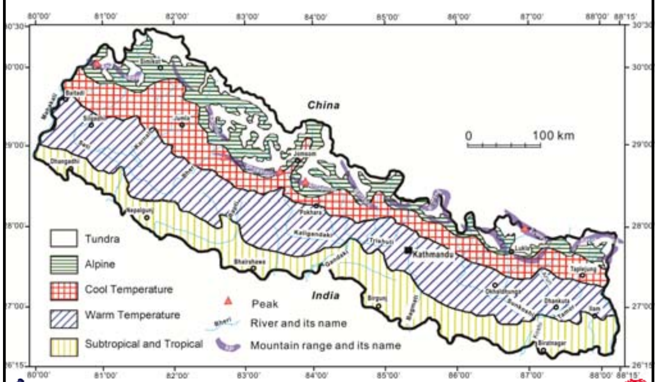
Climates of Nepal



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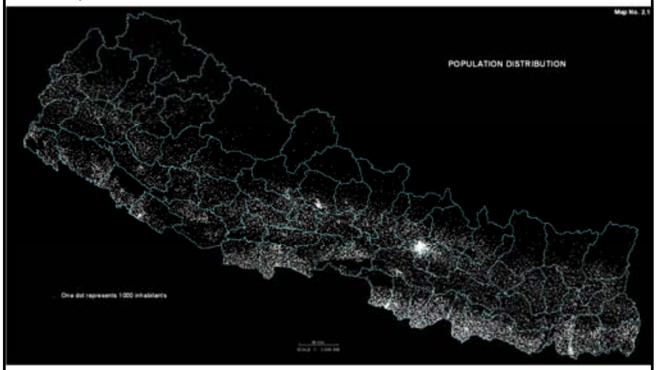
Source: DoS, Nepal



More Concentration of people in Lesser Himalayan Region

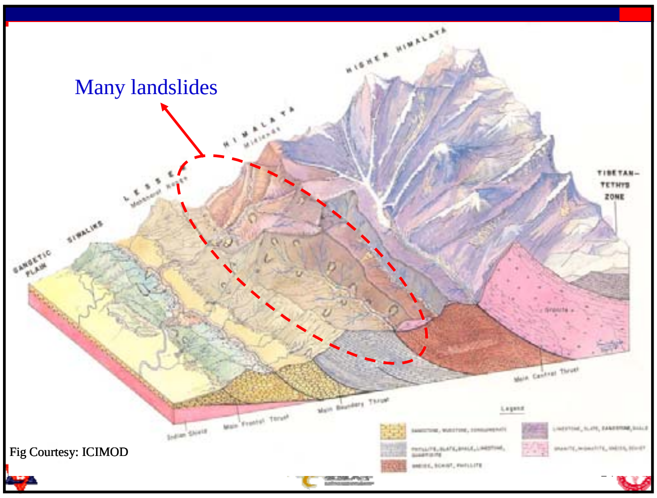
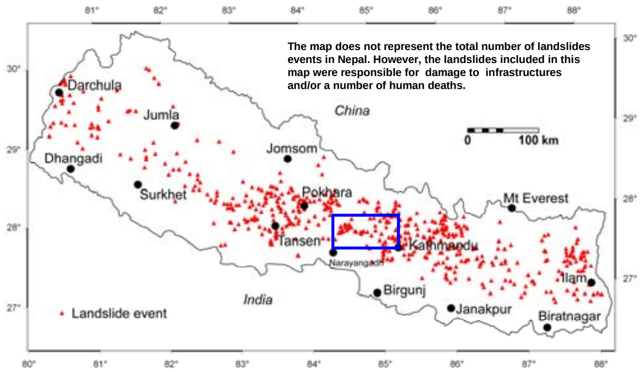


Fig Courtesy: ICIMOD

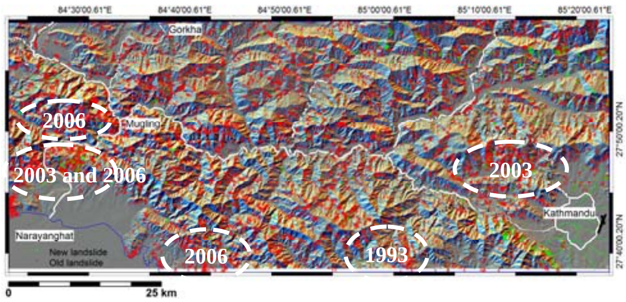
Distribution of Landslides in Nepal



After Dahal and Hasegawa (2008)

Slope failure inventory – In central Nepal

1993 to 2010 , in total 9884 events were identified



New landslides: 655
Old landslides: 9229

4043 Sq km. area of central Nepal

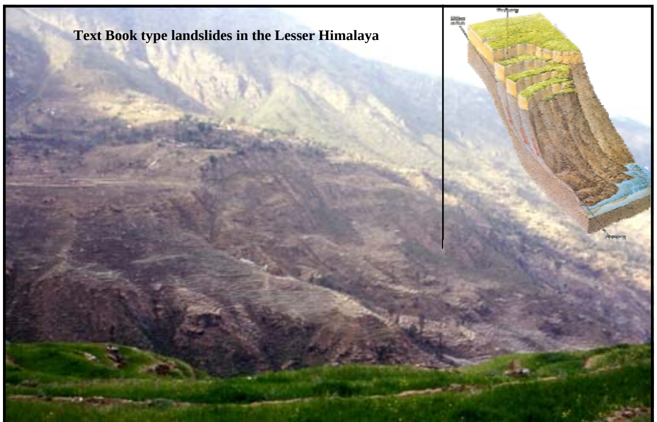


Photo : BN Upreti

Landslide on the right bank of the Bhotekoshi River.
Location: north east of Kathmandu

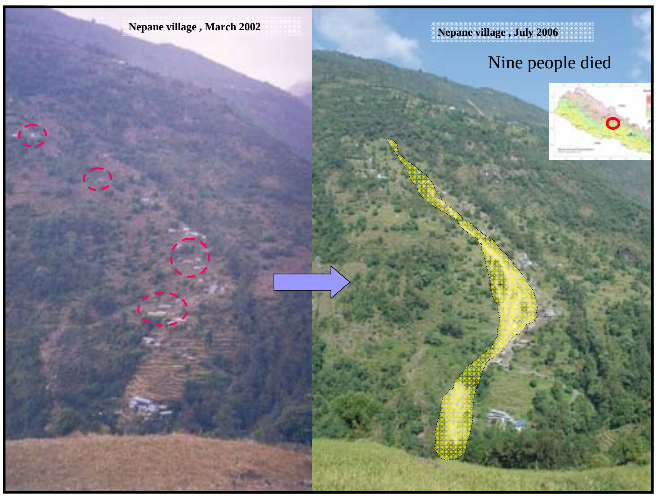

A landslide view in Ghatte Khola, Achham, Western Nepal, 2006

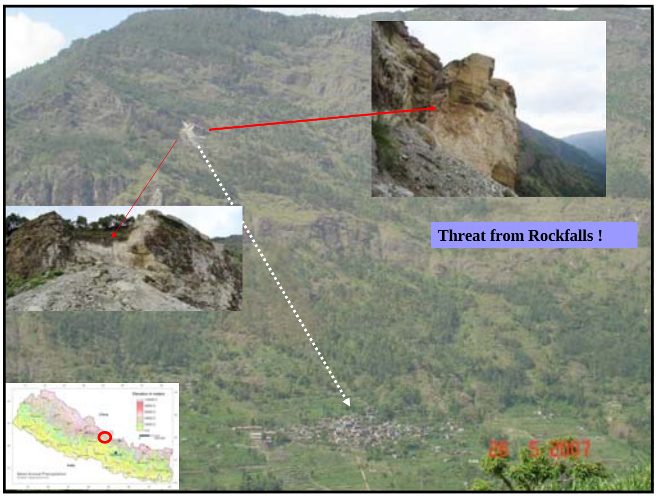

Landslide in the upper part of the Argheli Khola, Achham district

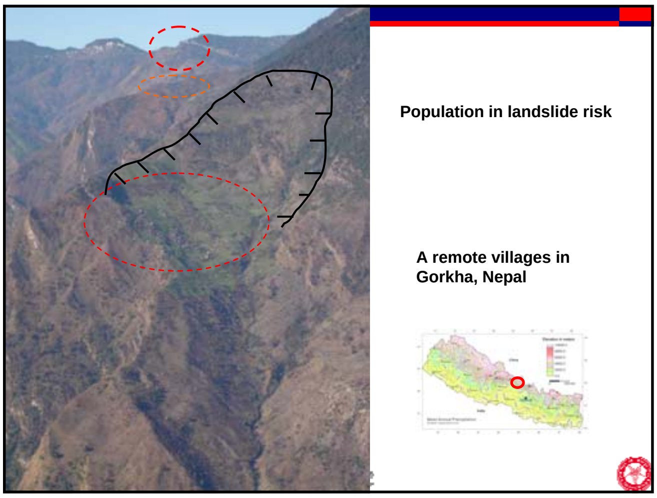

Photo © Kantipur
Debris flow channeled in steep gully is now found to be very prominent on Roadside Slopes of Nepal
Ramche Debris flow, killed 15 army personnel
21

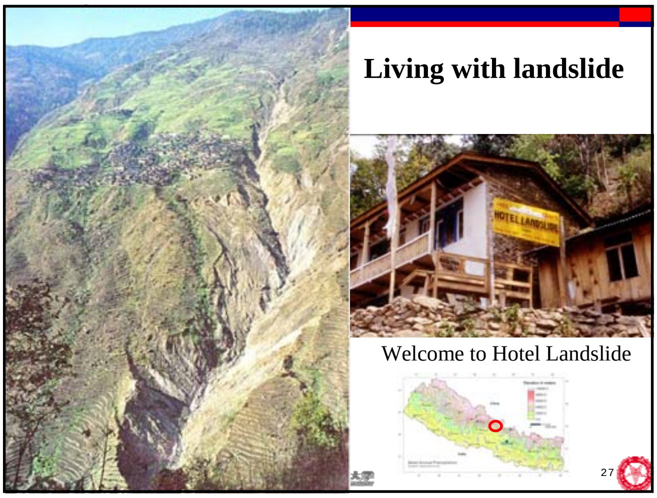

Nepal Army searching the Victims
Liquefied debris
Nepal Police searching the Victims
Seti Devi Khola
The matatirtha landslides at Kathmandu
22

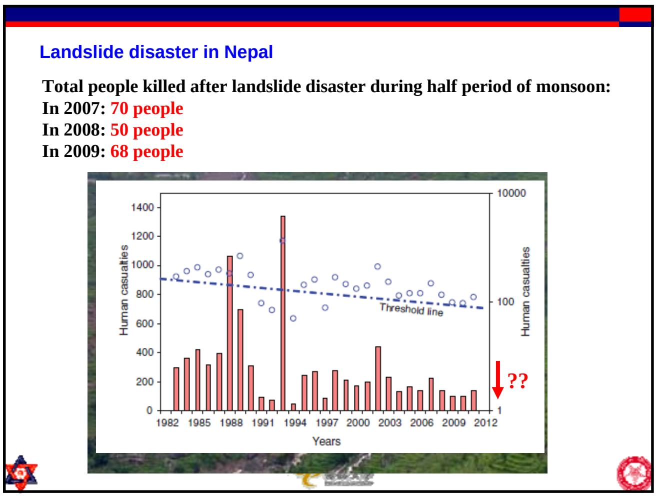

Recovered Death Bodies
Total 16 people killed
Death body recovered
1
2
3

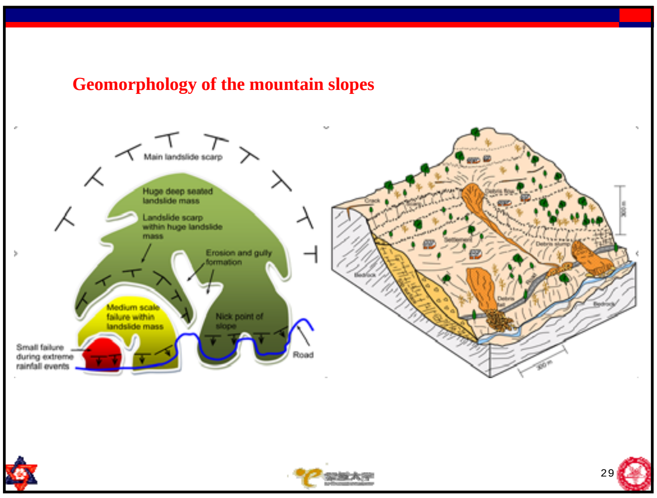

Nepane village , March 2002
Nepane village , July 2006
Nine people died


Threat from Rockfalls !

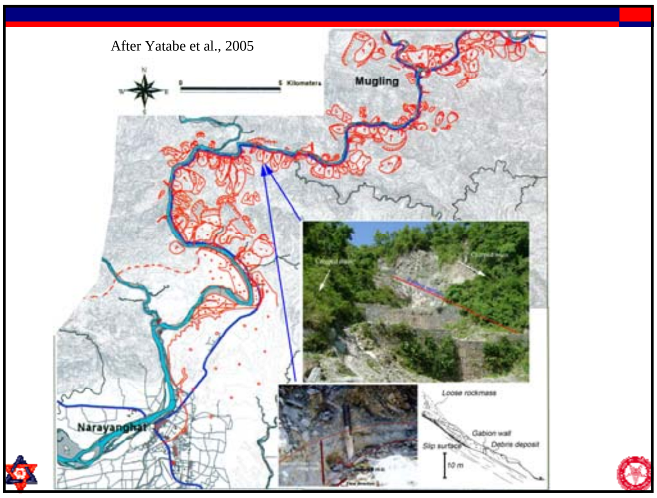

Population in landslide risk
A remote villages in Gorkha, Nepal

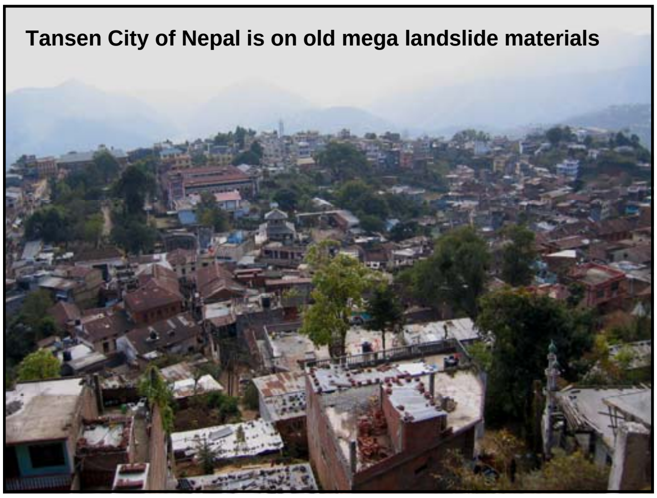

Living with landslide
Welcome to Hotel Landslide
27

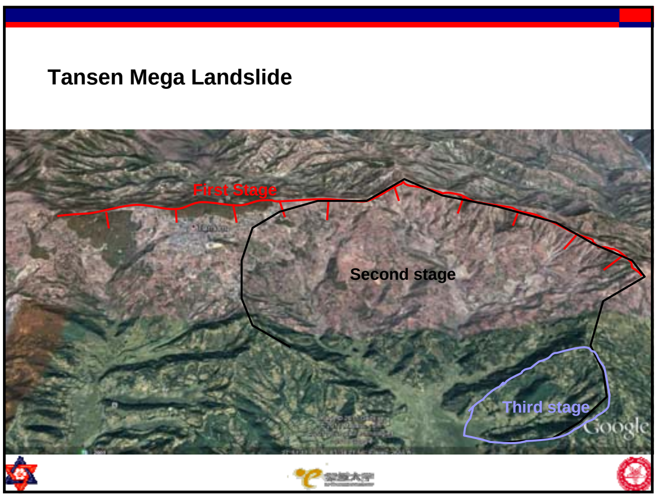

Landslide disaster in Nepal
Total people killed after landslide disaster during half period of monsoon:
In 2007: 70 people
In 2008: 50 people
In 2009: 68 people
Human casualties
Threshold line
Years
??

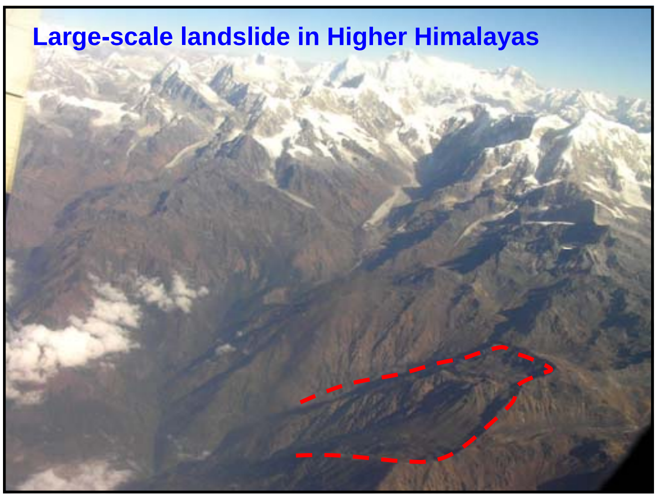

Geomorphology of the mountain slopes
Main landslide scarp
Huge deep seated landslide mass
Landslide scarp within huge landslide mass
Erosion and gully formation
Medium scale failure within landslide mass
Nick point of slope
Small failure during extreme rainfall events
Road
29

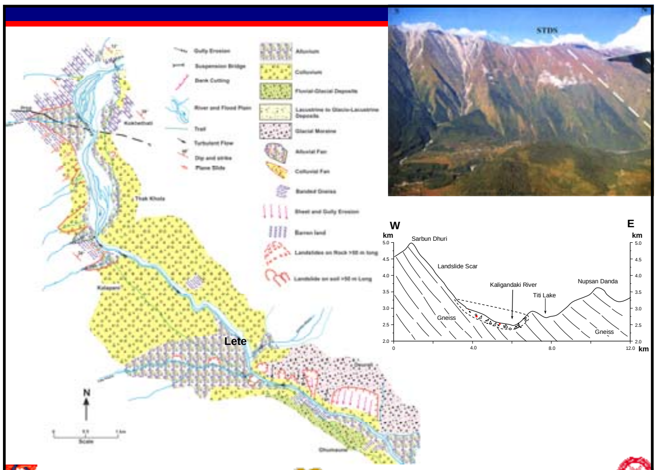

Narayanghat City
Kaligandaki
Landslide materials
Trishuli
Scar
Mugling-Narayanghat Road
Creeping

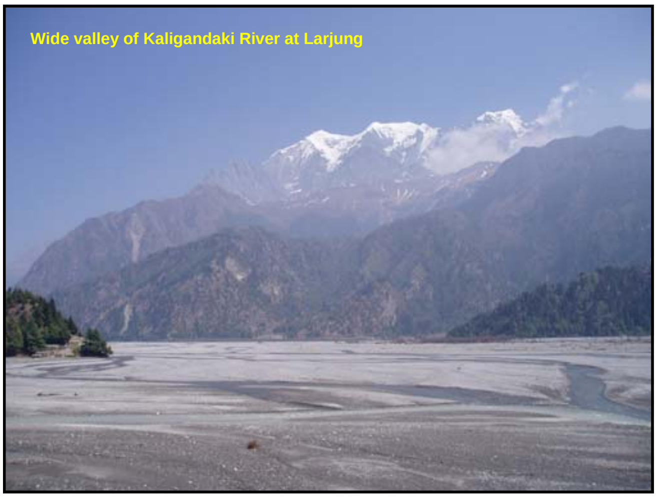

After Yatabe et al., 2005
Mugling
Narayanghat
Loose rockmass
Gabion wall
Slip surface
Debris deposit
10 m

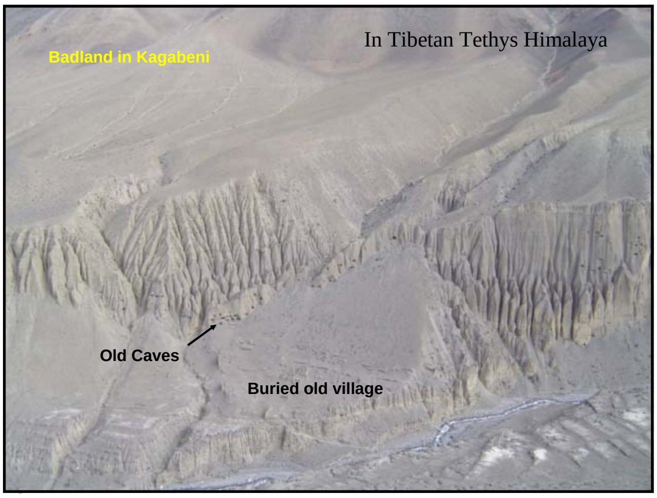

Tansen City of Nepal is on old mega landslide materials


Tansen Mega Landslide
First Stage
Second stage
Third stage

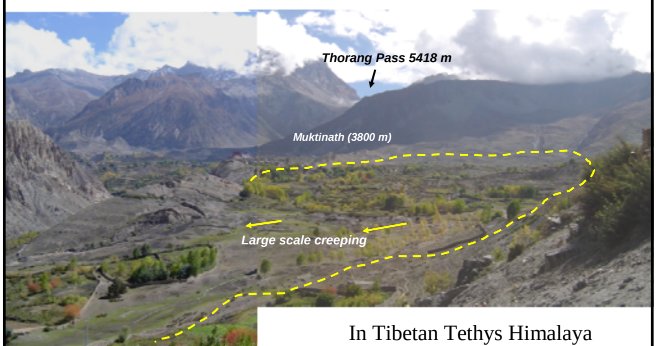

Large-scale landslide in Higher Himalayas







Large scale creeping in Jharkot area



In Tibetan Tethys Himalaya

1. Labor intensive method

Applied for construction of early roads in Nepal
Labor groups employed as labor contract, no work contracts
No heavy equipment used except work tools
Mostly full cut roads, Structures and embankments minimized
Side casting of surplus material permitted, Blasting for rock breaking

2. Conventional Mechanized Road Construction Practice

Applied in highways, feeder roads and urban roads
Earthwork equipment used for cut, slope trimming and embankment construction
Mechanized compaction of backfill and embankments
Laborers used for minor works – drainage, slope finishing
Blasting for rock breaking permitted

3. Labor-Based Road Construction Method

Mostly used for district roads and feeder roads
Only light equipment used, no heavy equipment used
Maximum use of local laborers for works
Limited blasting permitted for rock breaking

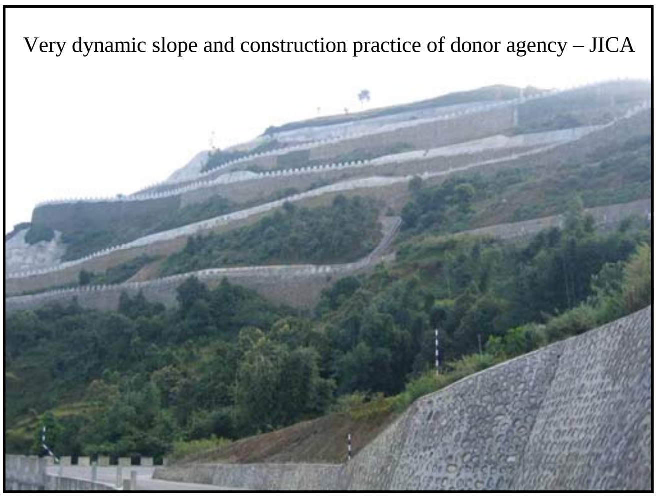
4. Low-cost Environment-friendly or Green Road Method

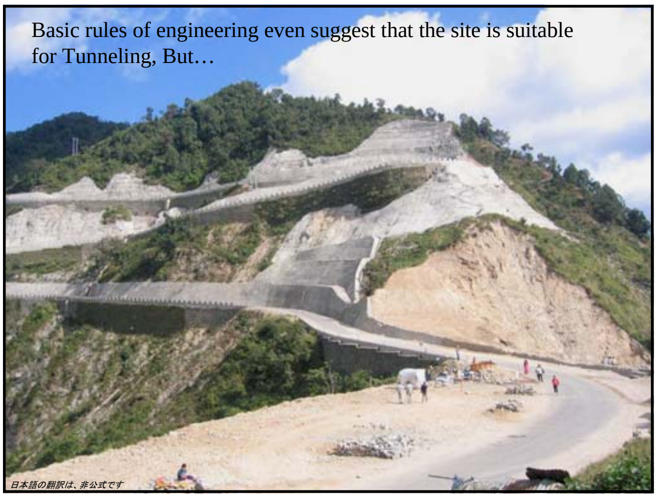
Stage construction of road (1 m, 2 m, 3 m and 4m) in combination with bioengineering
Only local laborers used through community based organizations
Balanced cut and fill principle – no haulage of surplus material
Bioengineering measures as an integral part in each stage
Natural compaction principle – no artificial compaction
Only local material used except some gabion wires
Use of cement discouraged
Blasting for rock breaking not permitted
Road formation out cambered for sheet flow – no side drains
Equipment may be used only for gravelling and pavement
Prevailing method for rural and agricultural roads
Also applicable for construction of highways and feeder roads
Method is inherently poverty focused and uses poorest people

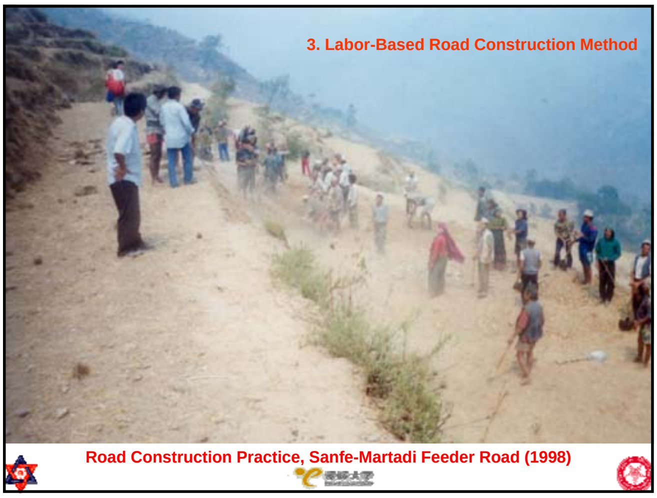
Road Construction Practice in Nepal

(Modified after Adhikari 2004)

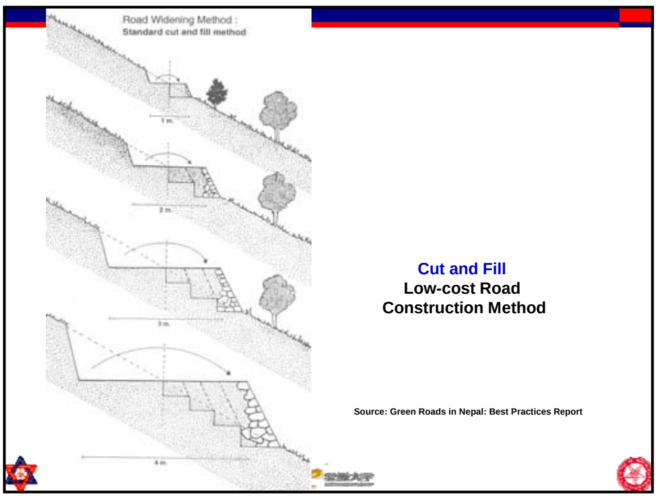

Very dynamic setting and construction practice of donor agency – JICA
2. Conventional Mechanized Road Construction Practice
We even capture course of River, Dhulikhel-Nepalthok Road


Very dynamic slope and construction practice of donor agency – JICA


Basic rules of engineering even suggest that the site is suitable for Tunneling, But…
日本語の翻訳は、非公式です


3. Labor-Based Road Construction Method
Road Construction Practice, Sanfe-Martadi Feeder Road (1998)

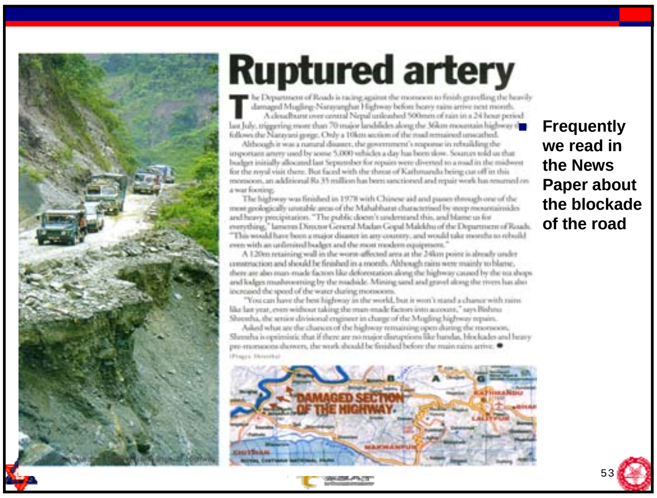

4. Low-cost Environment-friendly or Green Road Method


Road Widening Method :
Standard cut and fill method
Cut and Fill
Low-cost Road
Construction Method
Source: Green Roads in Nepal: Best Practices Report

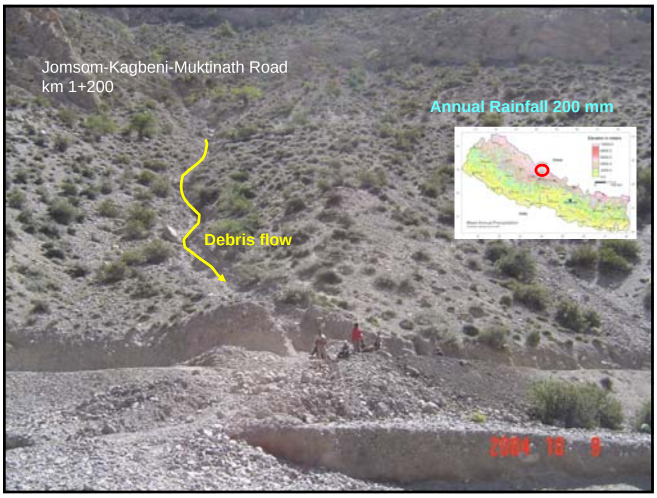

Butchering of Himalayan Slopes – An example of cruelty on Himalayan environment in the name of "Lost Cost"

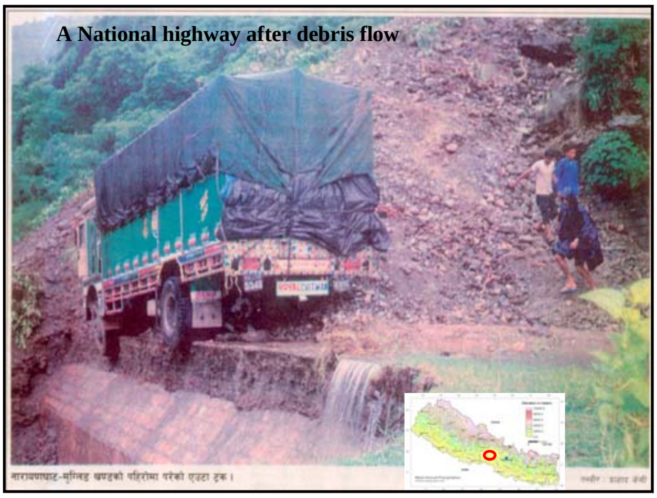

Roads after construction and one set of monsoon
50


Failure at contact between rock and soil
Rock
Soil cover


Ruptured artery
DAMAGED SECTION OF THE HIGHWAY
Frequently we read in the News Paper about the blockade of the road
53


Problems in Road


Jomsom-Kagbeni-Muktinath Road
km 1+200
Annual Rainfall 200 mm
Debris flow


A National highway after debris flow


Jan 4, 2003


Butwal-Tansen Road, near Siddhababa
2003 January

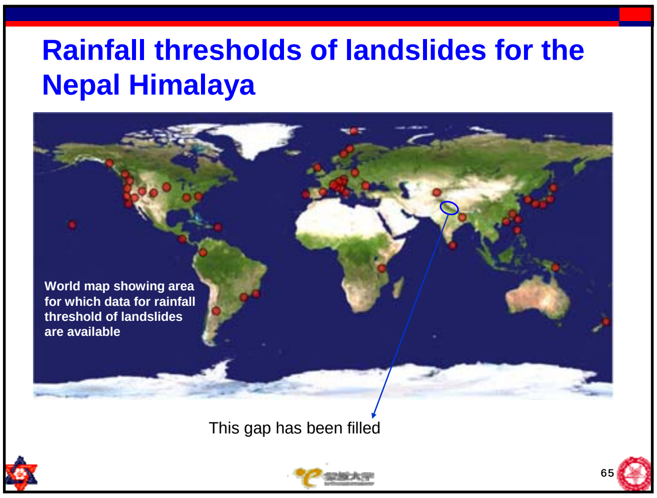

News of national newspaper, October 9, 2004
पहिरोमा पुरिएर नौ यात्रुको मृ
Rockslide buried nine passengers

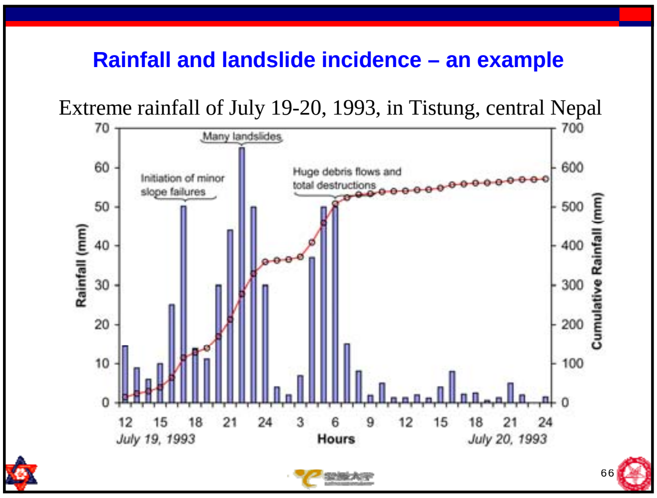

2004 October 8


2004 October 8

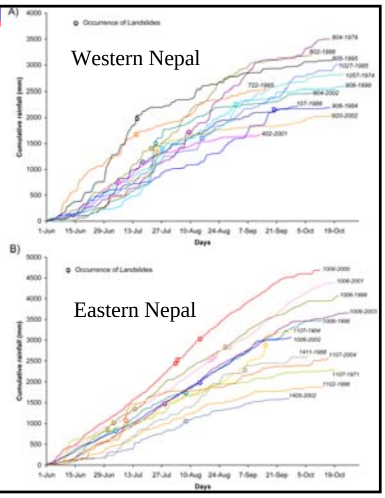

Same site in 2009
What will happen if there is another failure?

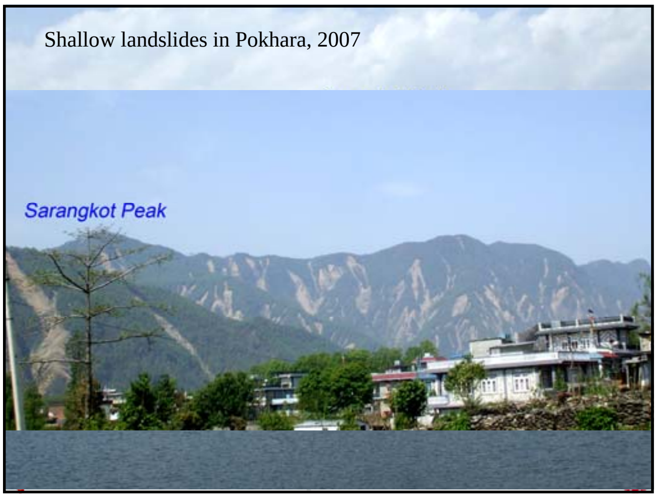

Trail on Steep slope
4 9 2004


Rainfall thresholds of landslides for the Nepal Himalaya
World map showing area for which data for rainfall threshold of landslides are available
This gap has been filled
65

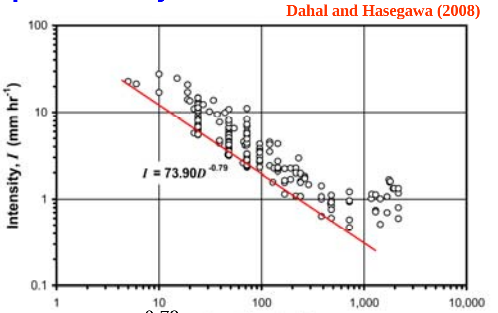

Rainfall and landslide incidence – an example
Extreme rainfall of July 19-20, 1993, in Tistung, central Nepal
Many landslides
Initiation of minor slope failures
Huge debris flows and total destructions
Rainfall (mm)
Cumulative Rainfall (mm)
Hours
July 19, 1993
July 20, 1993
66

Rainfall and landslide occurrence





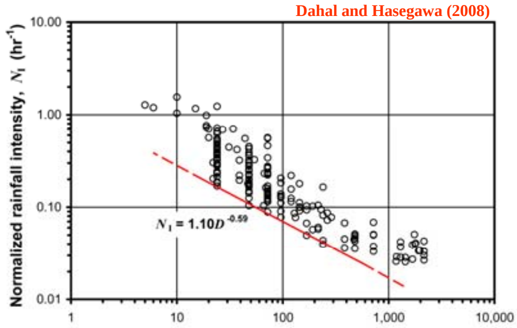
Rainfall Threshold of Landslides for the Nepal Himalaya



$$I = 73.90D^{-0.79}$$

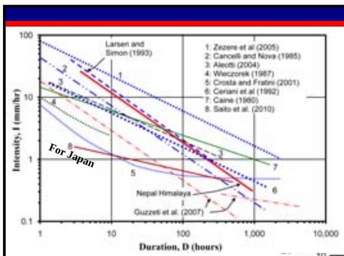
193 landslide data

Normalize rainfall intensity-Duration threshold

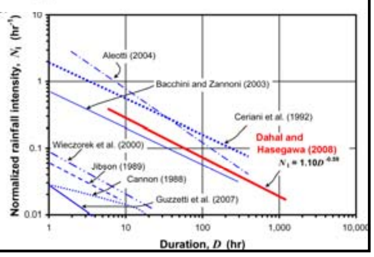


$$NI = 1.10D^{-0.59}$$

193 landslide data



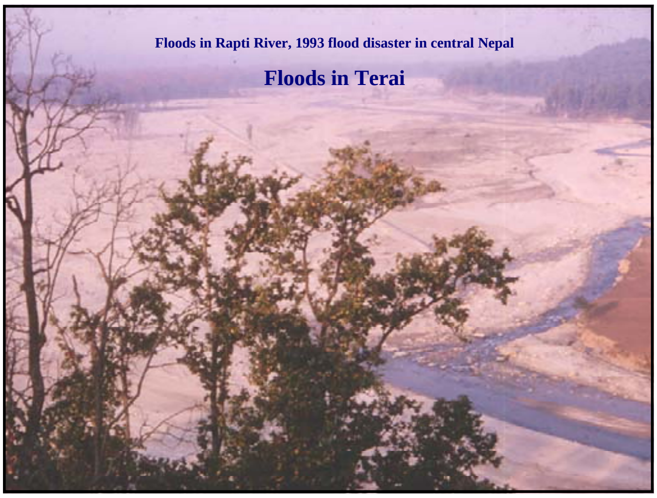
Researchers	Area	Equation
Caine (1980)	World	$I=14.82D^{-0.39}$
Cancelli and Nova (1985)	Valtellina, northern Italy	$I=44.67D^{-0.78}$
Ceriani et al. (1992)	North Italy	$I=20.1D^{-0.55}$
Larsen and Simon (1993)	Porte Rico, Caribbean Sea	$I=91.46D^{-.82}$
Deganutti et al. (2000)	Italian Alps, a torrent	$I=15D^{-0.70}$
Wieczorek (1987)	California	$I=1.7+9D^{-1}$
Crosta and Frattini (2001)	World	$I=0.48+7.2D^{-1}$
Aleotti (2004)	Piedmont region, Italy	$I=19D^{-0.50}$
Giannecchini (2006)	Tuscany, Italy	$I=76.199D^{-0.692}$
Guzzetti et al. (2007)	CADSES mid-latitude climate for $D<300$ h	$I=18.6D^{-0.81}$
Guzzetti et al. (2007)	CADSES mid-latitude climate for $D>300$ h	$I=0.82D^{-0.79}$

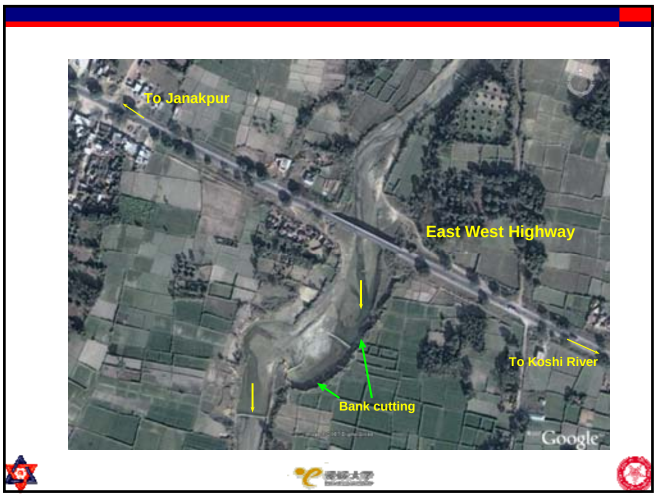


Comparison of the landslide triggering; a) rainfall intensity–duration and b) normalized rainfall intensity–duration thresholds from various studies with Dahal and Hasegawa (2008) for the Nepal Himalaya


Plain Area of South, Terai


Floods are common issues in Terai


Floods in Rapti River, 1993 flood disaster in central Nepal
Floods in Terai

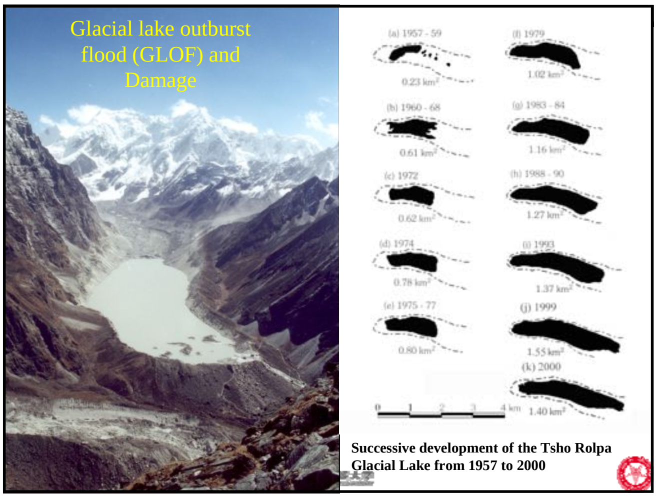

To Janakpur
East West Highway
To Koshi River
Bank cutting

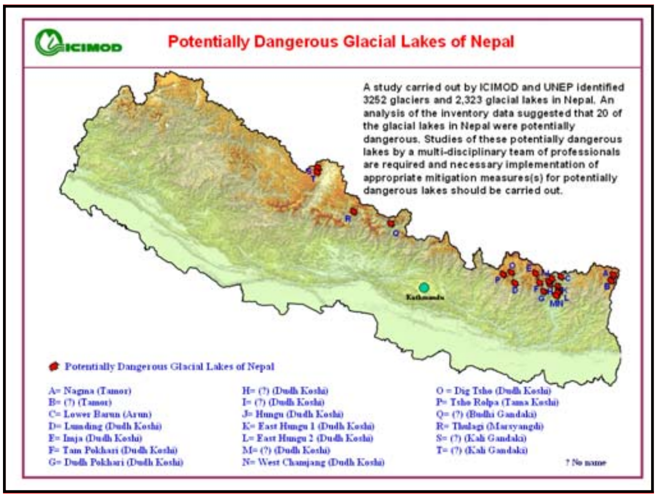

Koshi flood in 2008
Inundation
Flood
East-West Highway

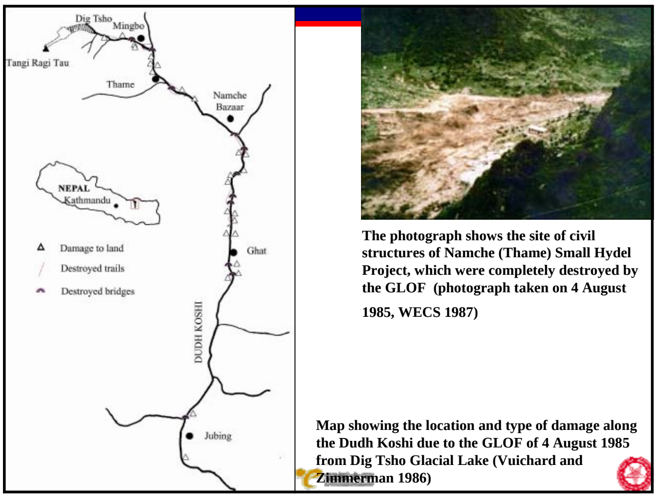

Tatopani
Rock Slide
1998
River damming Seven hour
Landslide Damming and flooding


Level of Dam
Debris


Debris flow and damage of bridge
To Pokhara
To Kathmandu


Glacial lake outburst flood (GLOF) and Damage
(a) 1957 - 59
0.23 km²
(b) 1960 - 68
0.61 km²
(c) 1972
0.62 km²
(d) 1974
0.78 km²
(e) 1975 - 77
0.80 km²
(f) 1979
1.02 km²
(g) 1983 - 84
1.16 km²
(h) 1988 - 90
1.27 km²
(i) 1993
1.37 km²
(j) 1999
1.55 km²
(k) 2000
1.40 km²
0 1 2 3 4 km
Successive development of the Tsho Rolpa Glacial Lake from 1957 to 2000


ICIMOD
Potentially Dangerous Glacial Lakes of Nepal
A study carried out by ICIMOD and UNEP identified 3252 glaciers and 2,323 glacial lakes in Nepal. An analysis of the inventory data suggested that 20 of the glacial lakes in Nepal were potentially dangerous. Studies of these potentially dangerous lakes by a multi-disciplinary team of professionals are required and necessary implementation of appropriate mitigation measures(s) for potentially dangerous lakes should be carried out.
Kathmandu
Potentially Dangerous Glacial Lakes of Nepal
A= Nagma (Tamor)
B= (?) (Tamor)
C= Lower Barun (Arun)
D= Lumding (Dudh Koshi)
E= Imja (Dudh Koshi)
F= Tam Pokhari (Dudh Koshi)
G= Dudh Pokhari (Dudh Koshi)
H= (?) (Dudh Koshi)
I= (?) (Dudh Koshi)
J= Hungu (Dudh Koshi)
K= East Hungu 1 (Dudh Koshi)
L= East Hungu 2 (Dudh Koshi)
M= (?) (Dudh Koshi)
N= West Chamjang (Dudh Koshi)
O = Dig Tsho (Dudh Koshi)
P= Tsho Rolpa (Tama Koshi)
Q= (?) (Budhi Gandaki)
R= Thulagi (Marsyangdi)
S= (?) (Kali Gandaki)
T= (?) (Kali Gandaki)
? No name


Dig Tsho
Mingbo
Tangi Ragi Tau
Thame
Namche Bazaar
NEPAL
Kathmandu
Damage to land
Destroyed trails
Destroyed bridges
Ghat
DUDH KOSHI
Jubing
The photograph shows the site of civil structures of Namche (Thame) Small Hydel Project, which were completely destroyed by the GLOF (photograph taken on 4 August 1985, WECS 1987)
Map showing the location and type of damage along the Dudh Koshi due to the GLOF of 4 August 1985 from Dig Tsho Glacial Lake (Vuichard and Zimmerman 1986)


Before and after the 10 June 2000 Flood

Glacial lake outburst flood (GLOF) and Damage

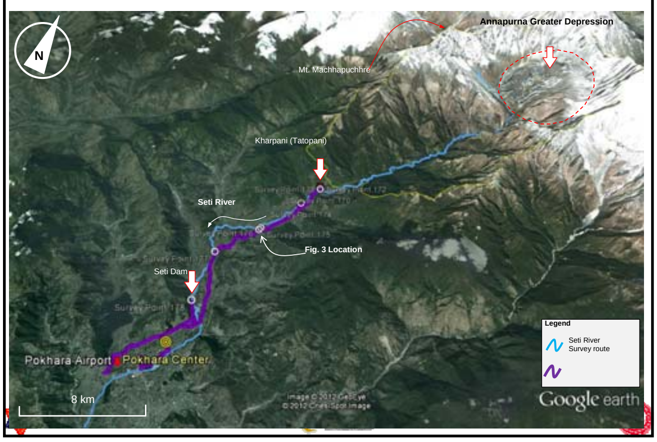
Glacial lake and burst

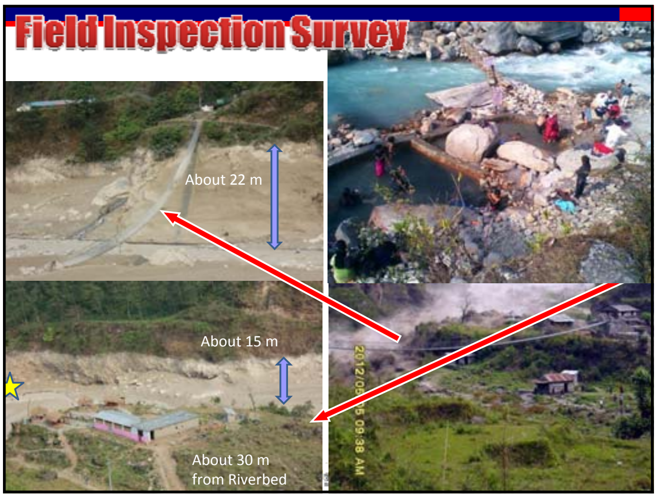
Destruction along the path of a Glacial lake Outburst Flood in Nepal

Destruction along the path of a Diksho Glacial lake Outburst Flood in Nepal

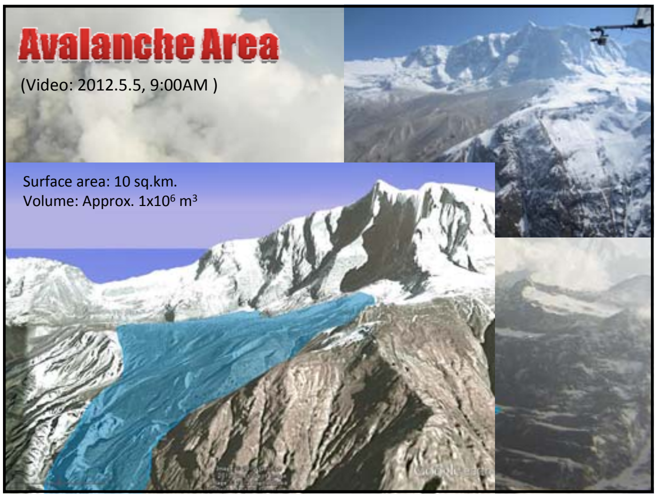
1255-Flash flood in Seti River, Pokhara – May 5, 2012

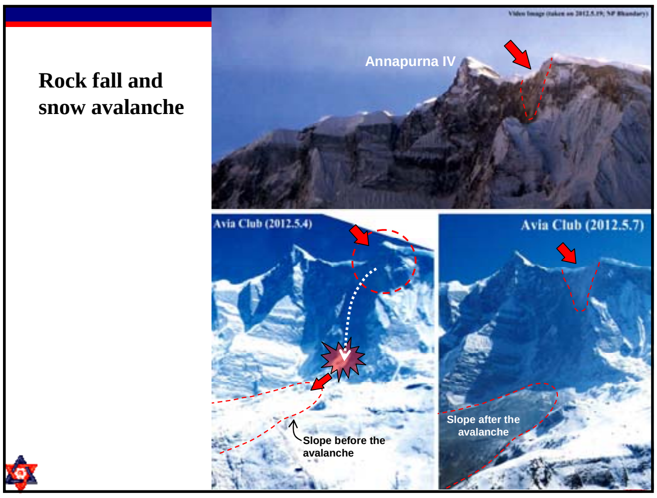
Field Inspection Survey




Field Inspection Survey
About 22 m
About 15 m
About 30 m
from Riverbed
2012/05/05 09:38 AM


1
Traces of debris on the bridge
2
Highest flow line
Flow direction
Approx. 18 m
Approx. 30 m
① Damaged suspended trail bridge with traces of debris
② Present situation of the damaged trail bridge
③ Devastated Kharpani (Tatopani) area
3
Main settlement area with a bus stand and shops
Completely washed out road section
Seti Dam
Flow direction

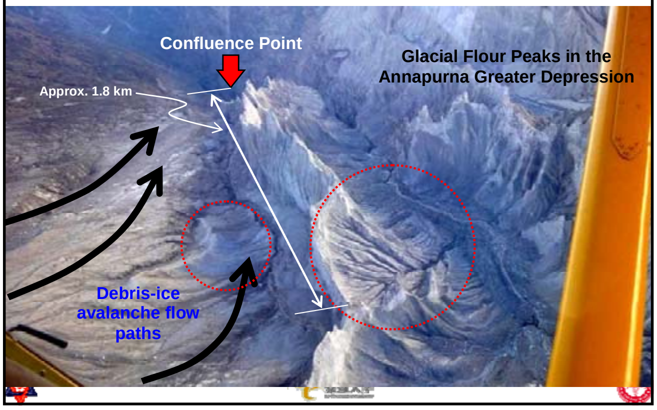

Avalanche Area
(Video: 2012.5.5, 9:00AM)
Surface area: 10 sq.km.
Volume: Approx. 1x10⁶ m³


Rock fall and
snow avalanche
Annapurna IV
Avia Club (2012.5.4)
Avia Club (2012.5.7)
Slope before the avalanche
Slope after the avalanche

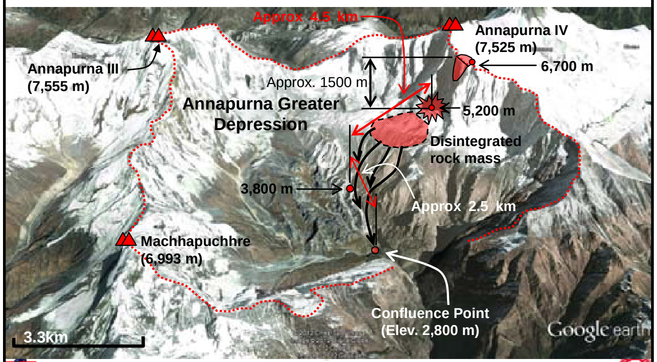

Possible zone of small rock fall
which triggered snow avalanche
Source area of
Avalanche
Transportation Zone of
snow avalanche and flow direction
Peaks of Glacial flour (rock flour)


Seti gorge
Flow path of snow and debris
Ice capped peak
of glacial flour

Avalanche Travel Path



Illustrated Derbis-Flood Mechanism



Earthquakes in Nepal

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Earthquakes in Nepal and seismic gap

- Indian plate moving toward north at a rate of 2 to 5 cm per year and the occurrence of frequent seismic activities along the Himalaya and its surroundings
- During past 120 years, five great earthquakes occurred along the Himalayan front

Earthquakes in Nepal

a. Magnitude-Frequency Data on Earthquakes in Nepal and the Surrounding Region in the period of 1911-1991 (modified after BCDP, 1994)

Earthquakes of Magnitudes in Richter Scale	5 to 6	6 to 7	7 to 7.5	7.5 to 8	>8
No. of Events	41	17	10	2	1
Approximate Recurrence Interval, yr.	2	5	8	40	81

b. Past earthquakes and damage records

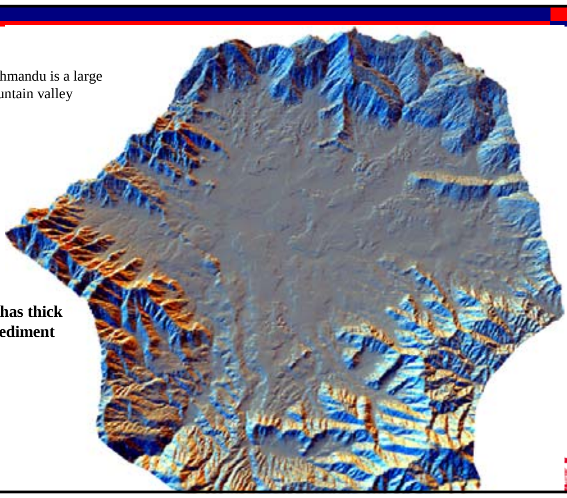
Year	Epicenter	Magnitude	Deaths	Houses Destroyed
1934	East Nepal	8.1 (M_W)	8,519 people died out of which 4,296 died in Kathmandu Valley alone	Over 200,000 buildings and temples etc. damaged, about 55,000 buildings affected in Kathmandu Valley (12,397 completely destroyed).
1936	Annapurna	7.0 (M_L)	Record not available	Record not available
1954	Kaski	6.4 (M_L)	Record not available	Record not available
1965	Taplejung	6.1 (M_L)	Record not available	Record not available
1966	Bajhang	6.0 (M_L)	24	6,544 houses damaged (1,300 collapsed)
1980	Chainpur	6.5 (M_L)	103	25,086 buildings damaged (12,817 completely destroyed)
1988	Udayapur	6.5(M_L)	721	66,382 buildings damaged
2011	Sikkim/ Nepal border	6.9(M_L)	6 died and 30 injury (2 died in Kathmandu valley alone)	14, 544 house damaged (6, 435 completely destroyed)

M_L - Richter Magnitude, M_W - Moment Magnitude

Kathmandu City Earthquake Risk

In every 100 years, Kathmandu face great earthquake of more than 7 Richter scale

Kathmandu is a large mountain valley



Valley has thick lake sediment

Kathmandu Valley consists of Lake sediment

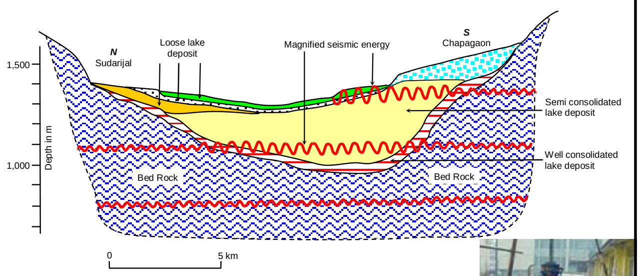
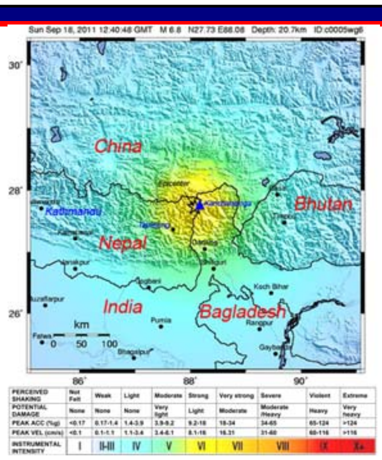


Illustration of earthquake energy advancement in soft sediment

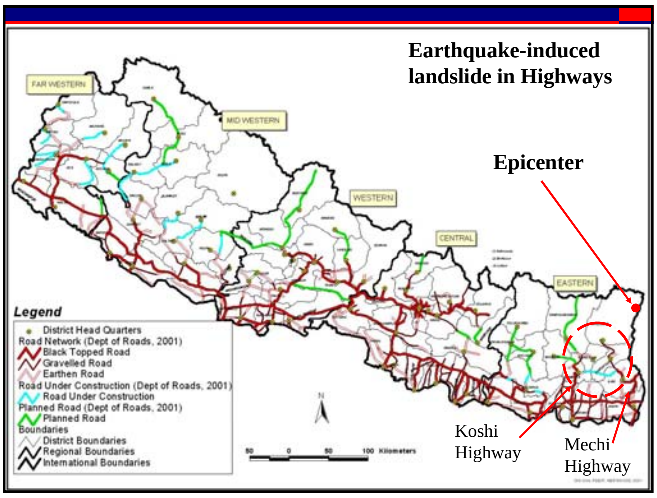
Very few geotechnical study

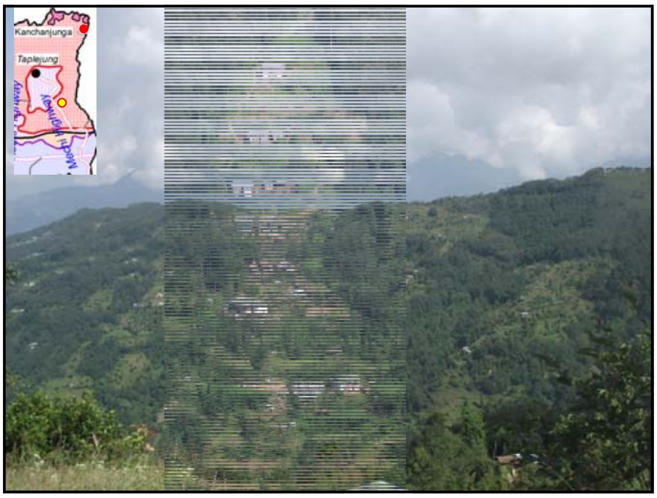
Living with Risk

Please think what will happen if great earthquake hit Kathmandu !!



Shake map of the Sikkim-Nepal Border Earthquake of September 18, 2011 (modified after USGS)





Mitigation and Management practice

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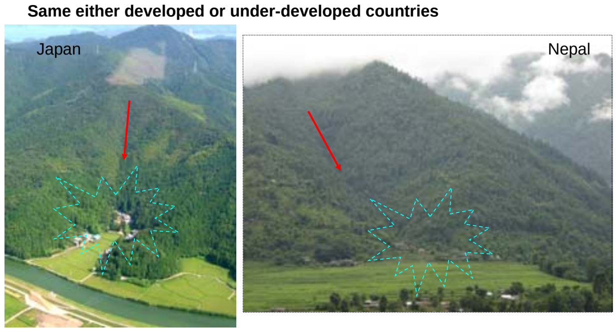
People's perceptions towards debris flow risk…

Same either developed or under-developed countries



Hazard and susceptibility mapping practice for landslides and flood hazard mitigation

The predictive modeling approach for landslide hazard study

White box model vs Black box model

- **Heuristic qualitative approach:**
- **Statistical quantitative approach:** **Black box model**
  - **Data driven multivariate statistical analysis and**
  - **Experience driven bivariate statistical analysis.**
- **Deterministic approach:** **hazard analysis in true sense, highly white box model**

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Management of landslide hazard zones

Community participation

- Till date no definite initiation from government, only few works
- The hazard maps should be brought into the knowledge of local people in order to aware and motivate them in proper land use and disaster management practices.

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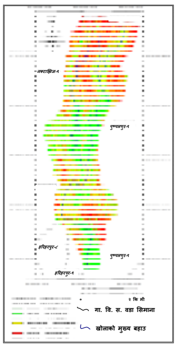
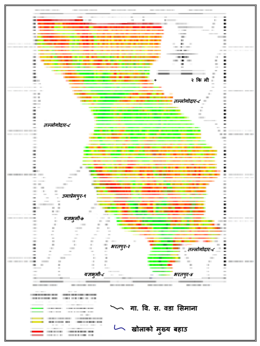
Landslide hazard map prepared in Nepali language to use in community level



3 colour map



The three colours presented in maps could energize people's feeling towards Siwaliks degradation and aware them to manage.

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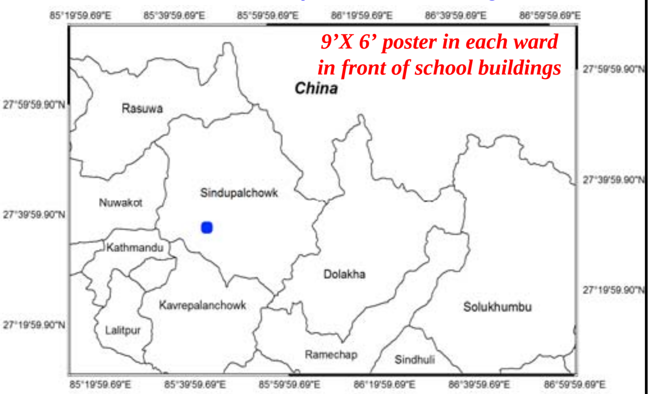
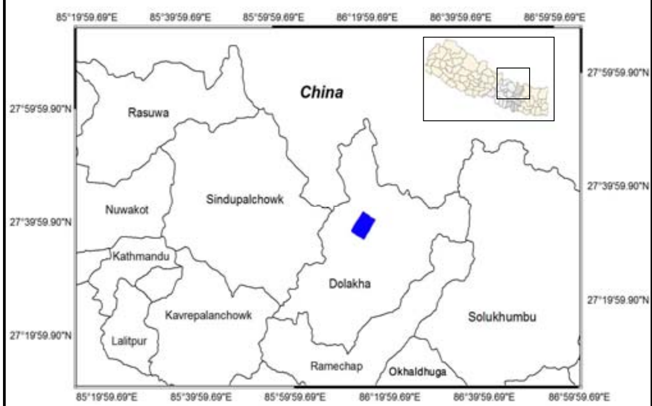
Landslide hazard map of Basbari-Badegau VDC

9'X 6' poster in each ward in front of school buildings



123



Flood hazard map- Koshi River

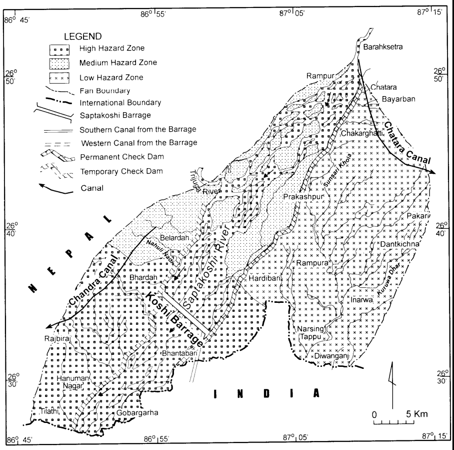
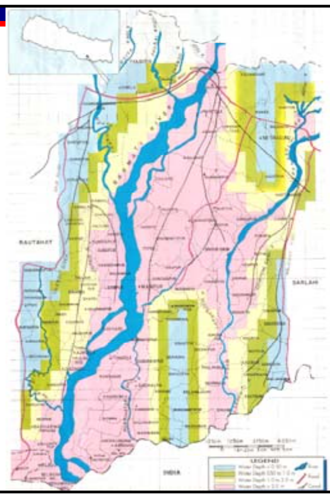


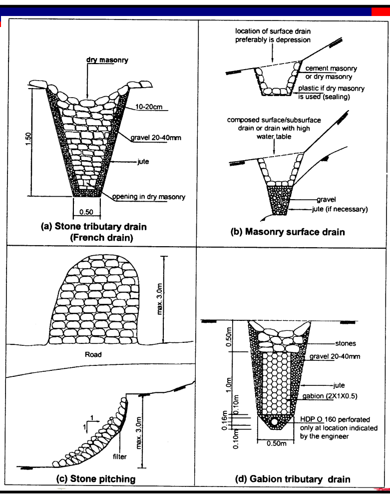
Fig. 18: Flood hazard map of the Sapta Koshi alluvial fan.

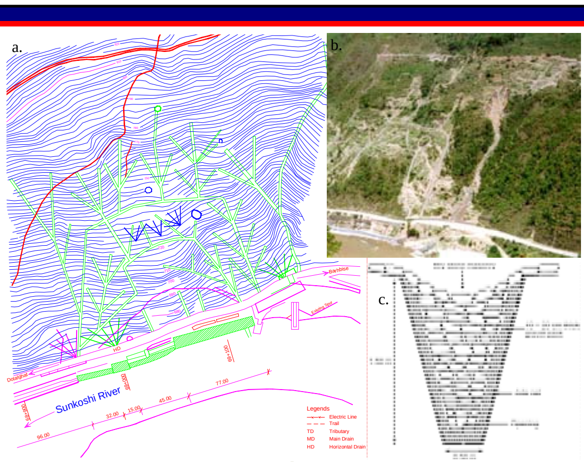
Flood hazard map- Bagamati River



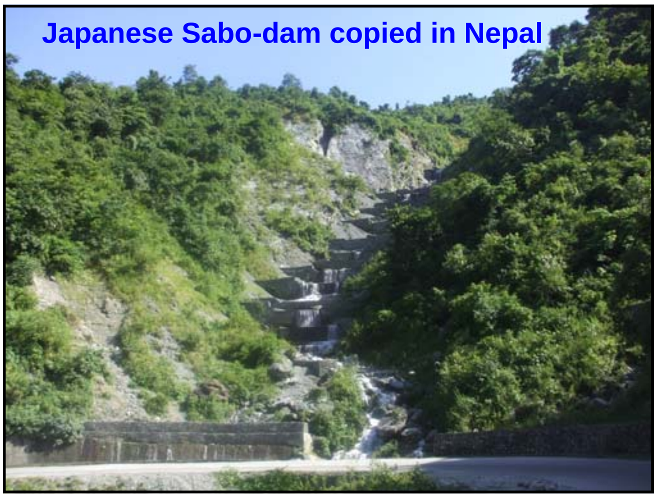
Engineering approach of geo-disaster mitigation

Low cost technology in roadside slope protection





km 69+000 of Arniko Highway French Drain is draining well



IIUSTRATION OF STRUCTURAL MEASURES

Bioengineering on Problematic slope

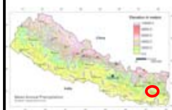


Photo source J Howell

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Famous Baglung loop before and after bioengineering, western Nepal

Photo source J Howell

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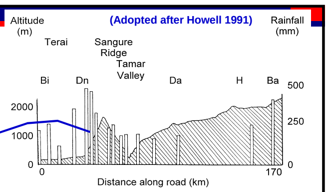
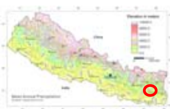
Rainfall pattern of the Koshi Highway Eastern Nepal





Stable slope in the area of maximum rainfall because of bioengineering structures

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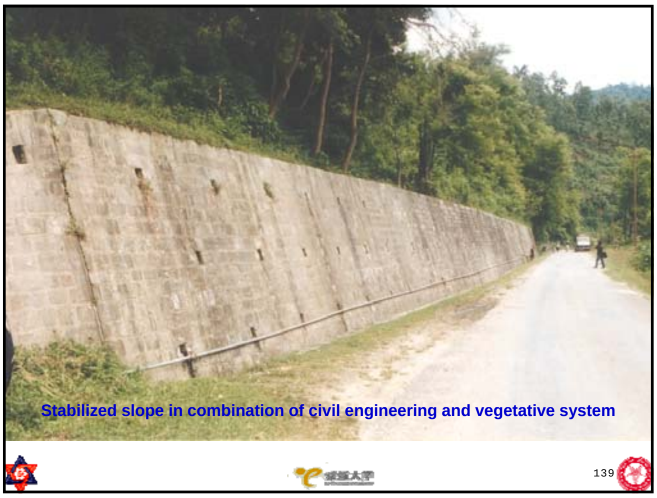
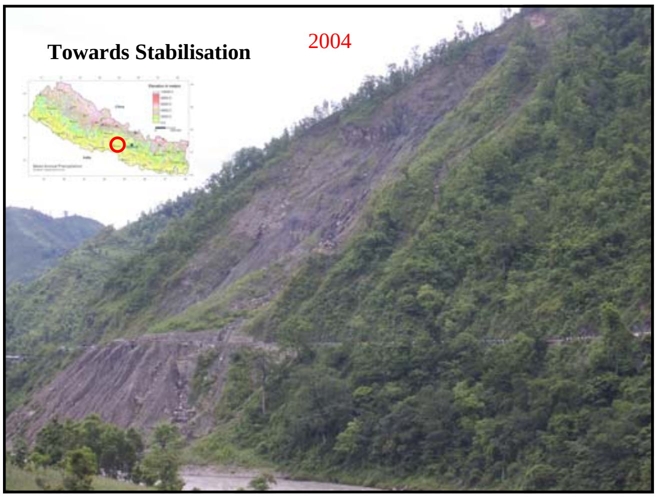

Stabilized slope in combination of civil engineering and vegetative system
139


Effectiveness of Bioengineering to in
our roadside slopes
Coir netting in roadside slope at Balephi-Jalbire Road (0+500 km),
Sindhupalchowk


Balephi-Jalbire Road, km 0+500
After Drainage and Bioengineering Measures
17 8 2004

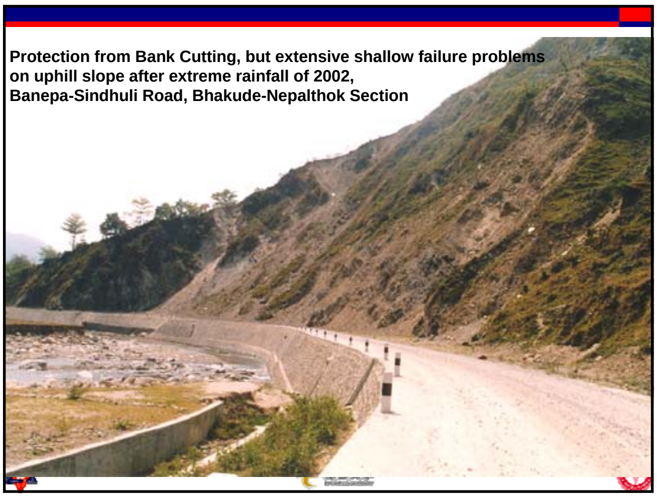

Tree Plantation
Chainage 9+200, Structural Measures with and Bioengineering Measures


Krishnabhir landsides
2003
'03 4 26
143


Towards Stabilisation
2004


Krishnabhir is also now continue process of stabilization by the help of bioengineering and structural measures
2007
www.ranjan.net.np

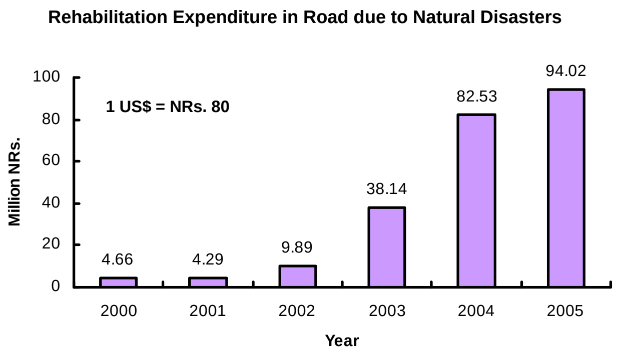

Cantilever Structure through Rock bolting km 31+950, Arniko Highway


Protection from Bank Cutting, but extensive shallow failure problems on uphill slope after extreme rainfall of 2002,
Banepa-Sindhuli Road, Bhakude-Nepalthok Section


Concrete masonry
Stone masonry
Bhakunde-Nepalthok Road, (Banepa-Sindhuli Road) Near Katunje, 2003


Community participation in river training work – use of locally available materials


After six years
Thanks to nature !!



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Concluding remarks

- Highly dynamic physical processes dominate the mountainous terrain of Nepal, and therefore, mitigating geo-disaster is a challenge.
- Monsoon rainfall is the main trigger of landslides and floods in Nepal
- Construction, maintenance and rehabilitation of infrastructure under the unique Himalayan condition require innovative and more pragmatic approach compared to less critical terrains in other parts of the world.
- Land management code should be implemented in coordination with landslide and flood hazard zonation map of the area
- “Low cost” infrastructure is not always right for low income countries like Nepal

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Concluding remarks contd.

- Over the years, Nepal has gained both good and bad experiences in geo-disaster mitigation:
  - in design and survey of geo-disaster mitigation programs,
  - in the fields of hazard and risk assessment,
  - in low cost rural road engineering – how much bad and how much good
  - in community based river training work, and
  - in slope maintenance incorporating indigenous techniques.
- The governmental agencies involved in geo-disaster management must change their status from implementer to facilitator.
- Government should enhance institutional capacity building at local level to enable local bodies to undertake the immense responsibility of geo-disaster mitigation.
- Positive people perception for geo-disaster mitigation and community participations in mitigation program are very important for geo-disaster management in Nepal