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Review

Complex Environmental Monitoring in Russia and India

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Abstract: Relevance. Complex environmental monitoring is one of the main aspects of risk management concept. Natural hazards are potentially damaging physical events and phenomena, which may cause the loss of life, injury or human life disruption, property damage, social, economic, and political disruption, or environmental degradation. The study object is hazardous geological processes. **Aim.** To define the relationship between geological hazards and risks. **Methods.** Systematic approach to the natural hazards research on the base of risk concept is a very fruitful and progressive method. Areas of possible disaster events could be the places of the highest risk at the natural risk maps of the territories. **Results.** It is necessary to use big data bases and data banks and GIS technologies for such maps constructions. It is necessary for people leaving under natural risk to understand and estimate this risk and to know how to overcome it and how to act in case of crises events. Earthquakes, volcano eruptions, tsunamis, curst, suffusion, coast erosion, and landslides belong to geological hazards. The development of modern socio-economic system provides for the establishment and operation of such grand and environmentally hazardous facilities like pipelines, nuclear power plants, chemical industry, etc. Most ecologically dangerous objects or grandiose constructions are in seismic areas and tectonically active zone, in which there may be strong earthquakes, as well as landslides and mudflows. During operation it is necessary to ensure the safety of both the expensive facilities and safety of the environment.Under these conditions, the timely detection of dangerous earthquakes and giving alarms and automatic shutdown of environmentally hazardous facilities is a paramount task.Risk management concept is a good instrument for systematic approach to the problems of the rational land use. Monitoring systems elaboration and construction is designed to provide natural and man-made risk management and reduction for providing of sustainable development of environment and society.

Keywords: monitoring, risk, risk management, risk analysis, risk assessment, mapping, land use planning.

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ГЕОТЕКТОНИКА И ГЕОДИНАМИКА

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Обзорная статья

Комплексный экологический мониторинг в России и Индии

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Аннотация: Актуальность работы. Комплексный экологический мониторинг является одним из основных аспектов концепции управления рисками. Природные опасности - это разрушительные физические события и явления, которые могут привести к травмам или человеческим жертвам, материальному ущербу, социальным, экономическим и политическим потрясениям или ухудшению состояния окружающей среды. Объект исследования – опасные геологические процессы. **Цель работы** – найти взаимосвязи между геологическими опасностями и рисками. **Методы исследования.** Системный подход к исследованию природных опасностей на основе концепции риска является прогрессивным методом. Местами возможных стихийных бедствий могут быть районы наибольшего риска на картах природных рисков территорий. **Результаты работы.** Для построения таких карт необходимо использовать большие базы данных, банки данных и ГИС-технологии. Для населения, постоянно находящегося в условиях природных рисков, необходимо понимать и оценивать этот риск и знать, как его преодолеть и как действовать в случае кризисных явлений. Землетрясения, извержения вулканов, цунами, карст, суффозия, береговая эрозия и оползни относятся к геологическим опасностям. Развитие современной социально-экономической системы предусматривает создание и эксплуатацию таких крупных и экологически опасных объектов, как трубопроводы, атомные электростанции, химическая промышленность и т. д. Большинство экологически опасных объектов или грандиозных сооружений находятся в сейсмических районах и тектонически активных зонах, в которых могут происходить сильные землетрясения, а также сходить оползни и сели. Во время эксплуатации необходимо обеспечить безопасность, как дорогостоящих объектов, так и безопасность окружающей среды. В этих условиях своевременная регистрация опасных землетрясений и оповещение сигналом тревоги, а также автоматическое отключение экологически опасных объектов является первостепенной задачей. Концепция управления рисками является хорошим инструментом для системного подхода к проблемам рационального землепользования. Разработка и построение систем мониторинга призваны обеспечить управление и снижение естественных и техногенных рисков для обеспечения устойчивого развития окружающей среды и общества.

Ключевые слова: мониторинг, риск, управление рисками, анализ рисков, оценка рисков, картирование, планирование землепользования.

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1. Introduction

Natural hazards are potentially damaging physical events and phenomena, which may cause the loss of life, injury or human life disruption, property damage, social, economic, and political disruption, or environmental degradation.

Earthquakes, volcano eruptions, tsunamis, curst, suffusion, coast erosion, and landslides belong to geological hazards [Kutepov et al., 2002; Osipov et al., 2002; Wirtz et al., 2014].

The development of modern socio-economic system provides for the establishment and operation of such grand and environmentally hazardous facilities like pipelines, nuclear power plants, chemical industry, etc.

Most ecologically dangerous objects or grandiose constructions are in seismic areas and tectonically active zone, in which there may be strong earthquakes, as well as landslides and mudflows. During operation it is necessary to ensure the safety of both the expensive facilities and safety of the environment.

Under these conditions, the timely detection of dangerous earthquakes and giving alarms and automatic shutdown of environmentally hazardous facilities is a paramount task [Corominas et al., 2014; Ragozin, 2003; Svalova, 2014, 2015, 2016a-c, 2017a, b, 2018a-d, 2019; Svalova et al., 2019].

2. Monitoring Systems for Natural Hazards

2.1. Topsides Induced Acceleration Monitoring System for Oil and Gas Offshore Platforms – TIAMS

Analysis of seismological phone changes will give possibility to elaborate early warning system. Sergeev Institute of Environmental Geoscience RAS (IEG RAS) has developed and delivered the “System monitoring acceleration induced on the upper part of the offshore oil and gas platforms” for deposits Lunskoe- A (LUN-A) and Piltun – Astokhshkoye (PA-B) for Sakhalin-2 project. The System is intended to ensure the safety of the operation of these facilities. [Svalova, 2011, 2018b; Ginzburg et al., 2018a, b].

IEG RAS for many years carries out all the work necessary to create the monitoring of environmental and seismic safety,

In 2005-2006. IEG RAS has developed and delivered the “System monitoring acceleration induced on the upper part of the offshore oil and gas platforms” for deposits Lunskoe-A (LUN-A) and Piltun – Astokhskoye (PA-B), located near about Sakhalin for Sakhalin-2 project. “System ....” is intended to ensure the safety of the operation of these facilities.

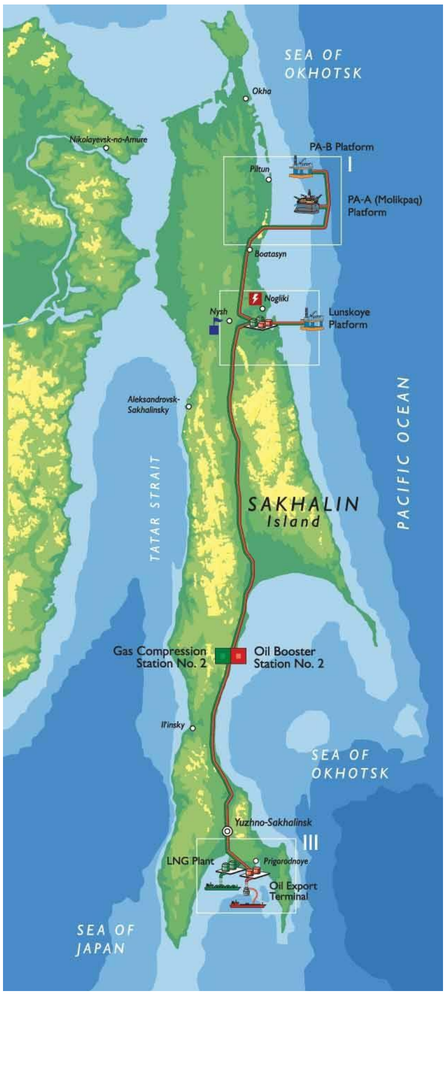

Fig. 1a. Sakhalin Island and oil-gas platforms.

According to the Sakhalin II Project Sakhalin Energy Investment Company is building offshore oil and gas platforms PA-B and LUN-A at the Sakhalin Island shelf.

The platforms are situated within the seismically dangerous area where destructive earthquakes are likely to occur.

Oil and gas platforms for deposits Lunskoe-A (LUN-A) and Piltun – Astokhskoye (PA-B) for Sakhalin-2 project are represented at Figures 1.

To reduce the risk of environmental accidents that can appear during oil and gas production the as a result of destructive earthquake Client took a decision to provide platforms with Topsides Induced Acceleration Monitoring System (further referred as TIAMS).

Fig. 1b. Platform for PA-B deposit

Fig. 1c. Commissioning works in South Korea.

Fig. 1d, e. Platform for Lunskoe-A (LUN-A) deposit.

Institute of Environmental Geoscience RAS has won the Tender for design, development and manufacturing of the TIAMS arranged by Sakhalin Energy Investment Company (SEIC). Basing on the technical assignment Information and Measuring Systems Department, IEG RAS has designed and manufactured in 2005-2006 TIAMS packages for two offshore oil and gas platforms near Piltun – Astokhskoe (PA_B) and Lunskoe (LUN-A) fields.

LUN-A and PA-B platforms are very complicated constructions. Each platform has three decks of the football ground size. The platforms are supported by four legs. Their diameters are from 16 to 24 meters, height is approximately 60 m; depth of the sea at the site is 30-35 m. The lower decks are placed at the height of ~ 27 m, the upper decks are at the height of 50-60 m above the sea surface.

Friction pendulum bearings are placed at the tops of the legs to damp horizontal oscillations under seismic and load impacts to the platform supports.

The main function of the TIAMS is to determine dangerous earthquakes from other impacts induced to the platform (ice impacts, ship impacts, wave impacts, drill snatch, etc.) that can cause accelerations same to the dangerous earthquakes accelerations at the topsides of the platforms. In case the destructive earthquake has been detected and its acceleration level exceed the threshold of 0,5 g in any key point of the platform the TIAMS shall initiate the Emergency Shutdown signal (ESD).

In such away TIAMS shall provide safety of the oil and gas offshore platforms.

It is necessary to mention that there were no such systems in the world practice between earthquake detection systems that can detect earthquakes from other impacts that can cause the same accelerations as dangerous earthquakes.

During the first stage IEG RAS has done the following:

− Theoretical justification of the external non-seismic impacts to the platform, detection of their features: value and direction of the affecting forces and time dependences.

− Modelled of 17 variant of impacts using ABAQUS platform model developed by AMEC.

− Qualitative physical analyses of the topsides responses to the earthquakes and other impacts, detection of the main directions and methods of the mathematical processing of the modeling results.

− Developed the software program to process modeling results.

− Analyses of modeling results from seismic and non-seismic impacts.

− Determined the key point for the sensors and their numbers as 6.

− Developed requirements for sensors installation.

− Developed earthquake detection algorithm and algorithm of signal initiation

An experience in development of such systems and its operation in the severe environment are very important for solving the same problems at other hazardous ecological objects, such as atomic power plants, chemical plants, high dams and barrages. Such systems can also be used to provide safety of the mega polices.

2.2. Landslide Monitoring System for Coastal Slope of the River Yenissei

Experience of the System creation was used for real time early-warning landslide monitoring system construction. This system was successfully used for landslides monitoring of coastal slope of the river Yenissei.

A second example of environmental safety monitoring system is a system of monitoring of dangerous geological processes. The system is designed for monitoring of landslides coastal slope of the river Yenissei in real time. The system provides rapid collection of measurement data on the state of the observed landslides, processing and analysis of the distribution of monitoring results between users and controls the security of shopping and entertainment complex, located on the coastal slope.

Geohazards monitoring system designed to monitor landslides coastal slope of the river Yenissei in real time. The system provides rapid collection of measurement data on the state of the observed landslides, processing and analysis of the distribution of monitoring results between users and controls the security of "June" shopping and entertainment center, located on the coastal slope (Fig. 2a).

The monitoring system includes eight mass displacements of ground points, two points of monitoring changes in the level of groundwater and automatic workplace of geologist, provides organizations with the process of collecting, processing and distributing data and carrying out management of all its elements (Fig. 2b-d).

In order to collect and exchange information using cellular communications channels, which included two GSM-modems (primary and backup), and each control point it is a part of a GSM-modem.

Fig. 2a. Trade and amusement complex "JUNE", located on the monitored coastal slope of the river Yenissei.

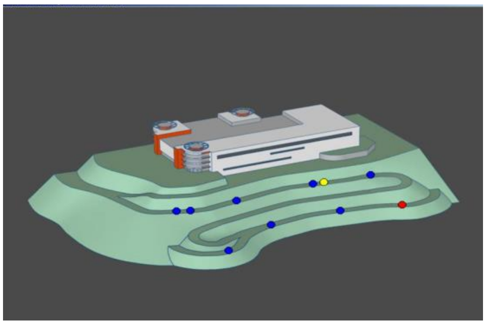

Fig. 2b. The main window of the work program.

The system has two modes of user access to information. Access to each of the modes of operation is carried out by a password. The first mode of access – "Operator," which is only possible to view all parameters of the control points and the region, measurement data and alarms, and change the system configuration or structure of any device in this mode cannot be. The second access mode – "Administrator", in which it is possible to make a change of settings and system structure. To transmit alarm signals provided connectivity with unified duty-dispatch service of Krasnoyarsk by the Internet.

Equipment set deep frame is designed to measure linear displacement of soil that occurs when the landslide processes caused by natural and man-made causes, by its (linear movement) transformation into a digital code (Fig. 5b). The kit has controls equipment malfunctions and unauthorized access to and allows you to quickly transfer the alarm information. Complete registration of groundwater level is designed for continuous automated measurement level, water temperature and atmospheric pressure well and transfer the measurement results in digital form (Fig. 5b-d). The kit has fault controls equipment and unauthorized access to it.

Fig. 2c. Equipment set deep frame. Fig. 2d. Complete registration of groundwater levels.

Fig. 2e. Installation and commissioning of geohazards monitoring system (Ginzburg A.A.).

Fig. 2f. After installation and commissioning of geohazards monitoring system (Ginzburg A.A.).

The monitoring system has two operating modes: normal and abnormal. In any mode of functioning of the data from the hardware coastal slope control points are processed in real time. If the ground speed displacement mass or velocity of groundwater level changes less than a predetermined threshold, the information is recorded and subsequently subjected to analysis and comparison with data obtained previously. In another case, when the speed of the displacement of soil mass or rate of change of groundwater level with some – any control point exceeds a predetermined threshold, the equipment together with the data sends an alarm. Alarm is the basis for the transition to a freelance mode, in which decisions are made on a more detailed examination of the coastal slope and, if necessary, the evacuation of people from the building trade and entertainment complex “June” and further strengthening of the coastal slope (Fig. 2e,f).

2.3. Landslide Monitoring System for Objects of the 2014 Olympics in Sochi

It is necessary to elaborate specific monitoring system for every type of landslide. One of the case studies was mountain area of the 2014 Winter Olympics in Sochi, Caucuses. The landslide hazard is the main geologic hazard along the combined road from Adler to Krasnaya Polyana. The largest part of the area along the road is landslide-prone area and numerous landslides historically occurred on the bank slopes. At present, monitoring systems are installed at a number of Olympic structures (Fig. 3).

Fig. 3a. Ski slope.

Fig. 3b. Bobsleigh track.

Fig. 3c. Bobsleigh track.

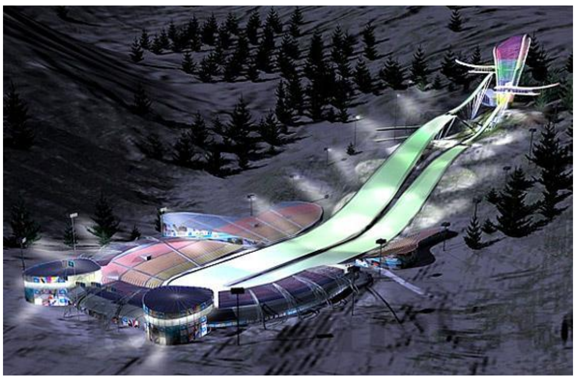

Fig. 3d. Ski jump.

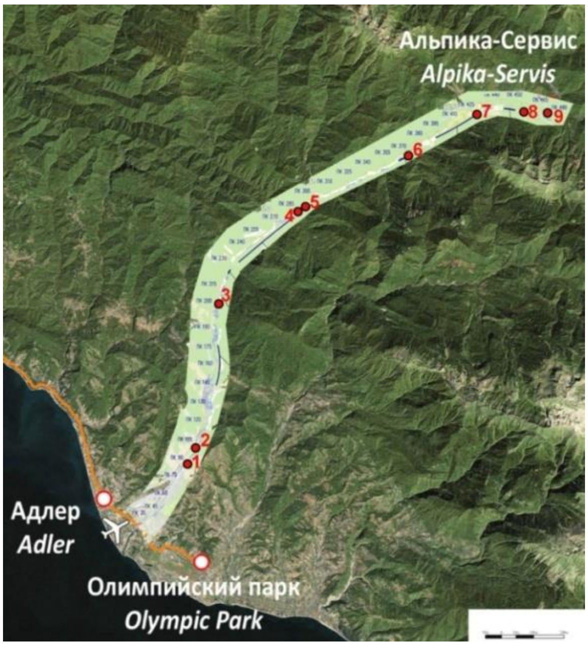

Fig. 3e. The location of landslide sites along the combined road from Adler to Alpika-Service (Krasnaya Polyana).

Also monitoring systems were used during constructing the roads. They include an automatic monitoring of main parameters which characterize the state of the landslide area at each moment.Numerous factors contribute to such an active development of landslides in the region, such as a high degree of bedrock weathering on slopes. Abundant rainfalls and saturation of cover sediments also lead to the formation of numerous cracks and sliding.Nine landslide sites have been detected along the route of the combined road during geological investigations.

It was determined that the most widespread type of landslides within the study area is a debris slide. Several sites, especially ones at the beginning of the route, exhibited block-type landslides of compression-extrusion.The investigations have shown that on landslide slopes with relatively long-time displacements and with periodic changes in displacement conditions, the acceleration of a displacement velocity up to hazardous levels may lead to the initiation of the sliding in new areas near upper and side borders of an active landslide. This increase of the size of a landslide can result in a catastrophic destruction.

Two general methods of observations were accepted in the automatic monitoring system, set along the combined highway and railway: 1) extensometric arrays (providing automatic measurements of displacements over the surface of a landslide prone slopes), and 2) inclinometric measurement in drills (supplying measurements of sliding parameters vs depth, some in manual and automatic modes).The results of research have shown that the most useful parameters related to the characterization of an active landslide state and sliding dynamics, including the progressing development of a landslide during activation, are: landslide displacement velocity, depths of slip surfaces and propagation of active displacements within the territory.

Landslide hazard criteria were proposed for the constructions of the road based on the monitoring data of an active landslide at one of the study sites along the railway from Adler to Krasnaya Polyana. These criteria are based on measurements of displacement velocities and distribution of landslide deformations (including new volumes of ground masses involved along the margins of active landslides) with area and dept.As a result, several monitoring methods as related to the landslide hazard were recommended along the Adler-Krasnaya Polyana railway: automatic observations of displacements over the slope surface using extensometers;inclinometers (during site visits and in partly automatic mode).

2.4. Russia-Turkey Gas Pipeline “Blue Stream” Monitoring System

The construction of the Russia-Turkey gas pipeline “Blue Stream” was accomplished in 2002 (Fig. 4). The pipeline route of a total length of 1226 km crosses the Black Sea. The pipeline consists of two pipes each 610 m in diameter. The project volume of transported gas is equal to 16 billion cubic m per year. When approaching the Black Sea, the pipeline crosses the northwestern slopes of the Big Caucasus Ridge, where landslides are widespread. Thirty-five landslides are registered at this section of the pipeline route, 7 of them being the most hazardous. The on-line operating automatic control system of landslide processes was projected for these sites. The following registering devices were installed at each of the 7 sites:the seismic acoustic control unit; the inclinometric control unit; the groundwater level control unit.

Fig. 4a. "Blue Stream" scheme.

Fig. 4b. "Blue Stream" during construction.

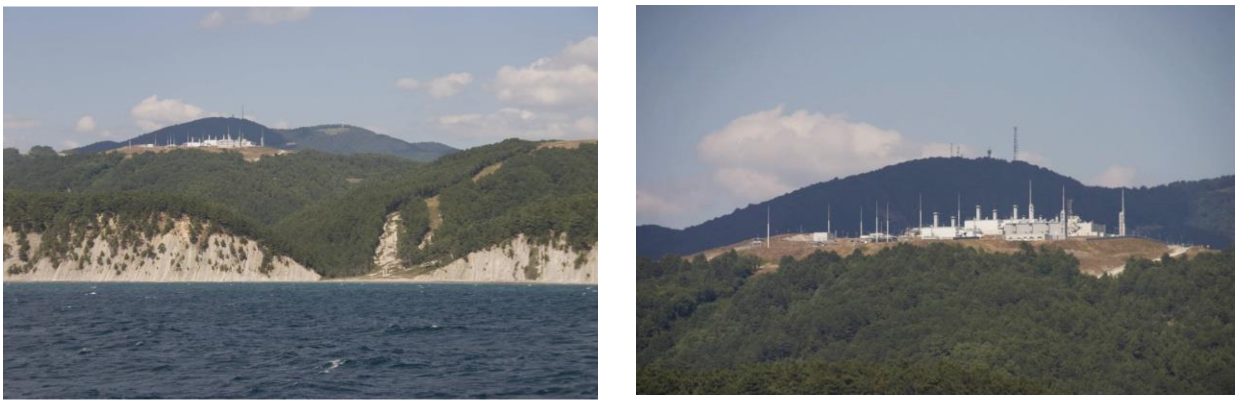

Fig. 4c, d. The compressor station "Beregovaya," view from the sea. Visible glade in which the buried pipeline.

Each unit was disposed in a separate borehole drilled in the landslide-prone slope. The equipment of each borehole provides the control of only one parameter.The measurement complex included the gauge of seismic acoustic emission and two units of data registration and collection. A special hydrogeodynamic gauge was used for measuring the groundwater level, and the tree-point extensometer was applied for rock mass displacement measurement.The measured data are communicated to the monitoring center, where they are processed using the special software.

In addition to the surface automatic control, the remote sensing control based on the high-resolution space and aerial survey is used. The remote survey data are also processed using the special software. The developed monitoring system permits to control the conditions of the landslide-prone slopes and thus ensure the safety of pipeline operation at the site of high geological risk.

1.5. Eastern Siberia–Pacific Ocean Oil Pipeline

Similar monitoring system was elaborated and constructed for ESPOOP. The Eastern Siberia–Pacific Ocean oil pipeline (ESPO pipeline or ESPOOP) is a pipeline system for exporting Russian crude oil to the Asia-Pacific markets (Japan, China and Korea). The pipeline is built and operated by Russian pipeline company Transneft. The 4,857-kilometer pipeline is being laid by the route of Taishet-Kazachinskoye-Skovorodino-Kozmino. Because of protests of environmental organizations, the initial pipeline route was moved 40 kilometers north of Lake Baikal (Figures 5).

The pipeline consist of 32 pumping stations, including 13 with tank farms with a total capacity of 2.67 million cubic meters. For feeding pumping stations with electricity, a 35 MW power station was built near the town of Olyokminsk in the Sakha Republic. It is fired by the crude oil from the ESPO pipeline. The power station is designed for independent operation in demanding Arctic temperature conditions.

During the construction of pipelines it arises the necessity of laying tracks on sloping areas or near them (at the intersection of rivers, construction along the coast, etc.) (Fig.5).

IEG RAS provided geological research before and during ESPOOP construction and elaborated ESPOOP monitoring system.

Fig. 5a, b. Eastern Siberia–Pacific Ocean oil pipeline.

Fig. 5c, d, e, f. ESPOOP construction.

3. Monitoring in India.

According to the United Nations Environment Program (UNEP), most of disasters happen in developing nations like in India and it is always the poorest who are most at risk like the hilly region habitants of Uttarakhand. These are getting both frequent and more serious. Since 1990, their number increased threefold and their cost, in real terms, rose ninefold culminating into economic losses from weather-related disasters exceeding those for the previous decade. As the population and poverty is increasing in the hilly regions of Uttarakhand, more and more people are having to live on vulnerable land of hill slopes. The earth's natural defenses against disaster are becoming even more eroded due to deforestation. Even, the global warming is playing an important role in controlling the weather conditions of this area.

3.1. Geological Setting of the Uttarakhand Area

The focus is on the Sub-Himalaya and Lesser Himalayan terrain. From south to north, the following sub-divisions of the Himalaya are generally recognized:

1. Sub-Himalaya – refers to southern most part of Himalaya and is demarcated to the south by the alluvial piedmont. To the north, the Sub-Himalaya is delineated by a tectonic Main Boundary Thrust (MBT). The Sub- Himalayan belt consists predominantly of fluvial sequences which have been deposited in the Neogene.

2 .Lesser – Himalaya – refers to the litho-tectonic province which is demarcated to the south by the MBT and is separated to the north by the Main Central Thrust (MCT). It predominantly consists of Proterozoic – Cambrian shelf to shallow marine sequences deposited in two main belts viz; the inner carbonate belt and the outer Krol belt.

3. Higher Himalaya

4. Tibetan Tethys Himalaya

5. Indus Suture Zone.

Of these, the first two are of relevance to present investigations. The following Fig.6 shows five seismic zones divisions (I to V) and the area of Sub and Lesser – Himalaya in Uttarakhand lying in the northern part of India which is falling under Zone IV indicated by the green color).

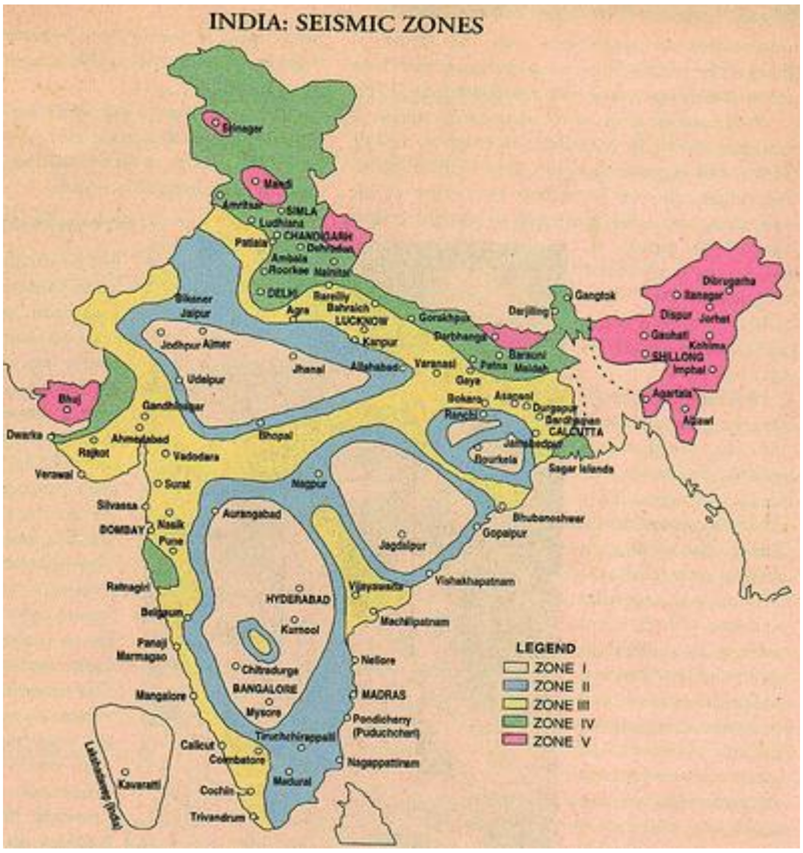

Fig. 6. Seismic Zones of India
(Green color shows the highest seismic activity zone – Utaarakhand lies in this zone)

3.2. Monitoring the Damage by Space-Based Satellite

In a bid to quantify the extensive damage due to deforestation and incessant rain, the Uttarakhand state government is now forced to seek help of state-of-the-art space based satellite technology [Sharma, Singh, 2013]. Such a sophisticated technology is being used in the Central Himalayan region to assess the natural as well as the human induced damages. The monitoring and assessing the damage of Central Himalayan region through satellite imagery is more relevant than physical land verification because most of the areas are inaccessible due to poor communication. The state government has acquired a Canadian Satellite Radar Sat-II, which is a high resolution satellite fitted with the highly sensitive cameras, that can easily take high resolution physical pictures of the damages caused to the roads, properties, agricultural lands etc. by landslides and flash floods etc. The satellite is being used to provide data pertaining to the rising water levels in all the big dams dotting the Uttarakhand Himalaya including the Tehri dam (260 m high Large Tehri Dam on one of the tributaries of the river Ganges in Central Himalayan Region, is the highest in this part of world) as well as the damages the landslides triggered by these overflowing reservoirs have caused in villages in their vicinity. Besides, there is one more major advantage of carrying out this type of scientific assessment that relates to getting a correct picture of the extent of the damage that would be done by the construction of medium and big dams to the region's fragile hills. Once that is known, it would be easy to take necessary measures required to build such hydropower projects without causing damage to the environment. One of the major monitoring strategies could be through micro zonation approach. Satellite imagery can help both the monitoring and measuring of soil erosion.

Number of eco-task force have been created by the Government of India by enacting "The Forest Conservation Act, 1980" to conserve the forests for protecting the valuable soil cover, acquiring fresh water and air, shelter, and a clean and healthy environment.

Conclusions

Risk management concept is a good instrument for systematic approach to the problems of the rational land use. Measures for risk reduction could belegislative; organizational and administrative; economic, including insurance; engineering and technical; modeling; monitoring; information. Monitoring system organization and construction is one of the most important method for natural hazards forecasting, prognosis and early warning.

The "System monitoring acceleration induced on the upper part of the offshore oil and gas platforms" for deposits Lunskoe- A (LUN-A) and Piltun – Astokhskoye (PA-B) for Sakhalin- 2 project have been developed and constructed by Sergeev Institute of Environmental Geoscience RAS (IEG RAS). The system was successfully modified for landslides alarm monitoring and used for coastal slope of the river Yenissei and for a number of large industrial objects and urban areas.

It is impossible to stop natural disasters to occur but it is possible to mitigate the damage caused by them. Landslides and debris floweffects can be mitigated by effectively controlling deforestation. Balance is required between development and protection of natural resources in the Himalayan region.

Monitoring through Canadian Satellite Radar Sat-II which is being used in the Central Himalayan region has helped in taking appropriate steps, as some of the human activities had an impact on increasingly instability of slopes, making them susceptible to potential degradation by run off through flash floods, sheet erosion and massive landslides.

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