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Analysis of the Present and Past Environmental Conditions of Uttarakhand

1. Summary

This report provides a comprehensive analysis of the environmental conditions in Uttarakhand, examining both the present state and historical changes across eight key parameters: Geological and Topographical Factors, Climatic Conditions, Forest and Biodiversity, Water Resources, Land Use and Urbanization, Disaster Risk and Management, Pollution and Environmental Degradation, and Socio-Economic & Policy Aspects. The analysis, based on provided research material, reveals a region of significant ecological importance and fragility, facing increasing environmental pressures from climate change, urbanization, and developmental activities. Key findings include a warming climate with altered precipitation patterns, accelerated glacial retreat impacting water resources, significant forest cover but ongoing deforestation in certain areas, increasing urbanization leading to land use changes and environmental degradation, a high vulnerability to natural disasters, rising levels of air, water, and soil pollution, and the complex interplay of socio-economic factors and evolving environmental policies. The report concludes with an overview of these outcomes and offers recommendations for future environmental management and policy in Uttarakhand.

2. Introduction

- **2.1 Background on Uttarakhand's Environmental Significance:**
Uttarakhand, nestled in the heart of the Himalayas, holds immense environmental significance. Its location within this global biodiversity hotspot underscores its crucial role in maintaining ecological balance 1. The Himalayas, a young and dynamic mountain range, are characterized by their geological youthfulness 4 and ongoing tectonic activity 1, which have shaped the region's unique and fragile ecosystems. Uttarakhand is also the origin of major rivers such as the Ganges and Yamuna, vital lifelines for a vast population in the Indian subcontinent 2. The state's diverse topography, ranging from snow-covered peaks and glaciers to lush valleys and plains, contributes to a wide array of microclimates and habitats, fostering a remarkable richness in biodiversity 2. The altitudinal variation, spanning from subtropical foothills to alpine meadows, creates a spectrum of

ecological niches that support a high species richness. Given the ecological fragility of the Himalayan region, Uttarakhand is particularly susceptible to environmental changes and natural disasters, highlighting the interconnectedness of its geological, climatic, and biological factors.

- **2.2 Purpose and Scope of the Report:**

This report aims to fulfill the user's request for a detailed analysis of the present and past environmental conditions of Uttarakhand. The scope of this analysis encompasses the eight key parameters explicitly stated in the user's query. Utilizing the provided research snippets as the primary data source, this report will delve into each parameter, examining historical trends and the current situation. Furthermore, it will integrate insights derived from the research material to provide a comprehensive understanding of the environmental challenges and changes in the Uttarakhand region. In line with the user's requirements, this report will also outline the project's work process, estimate the time required for its completion, provide a project overview, and conclude with the outcomes of the analysis, including potential recommendations.

- **2.3 Report Structure:**

The subsequent sections of this report are structured to provide a logical and detailed analysis of Uttarakhand's environmental conditions. Section 3 will present a comprehensive analysis of each of the eight parameters: Geological and Topographical Factors, Climatic Conditions, Forest and Biodiversity, Water Resources, Land Use and Urbanization, Disaster Risk and Management, Pollution and Environmental Degradation, and Socio-Economic & Policy Aspects. Section 4 will offer a project overview and detail the methodology employed for this analysis. Section 5 will provide an estimation of the time required for the project. Section 6 will present the overall conclusion drawn from the analysis. Finally, Section 7 will outline the key outcomes of the analysis and discuss their implications.

3. Analysis of the Uttarakhand Environment

- **3.1 Geological and Topographical Factors:**

- 3.1.1 Present State of Geological and Topographical Features:

Uttarakhand exhibits a highly varied topography, characterized by snow-covered peaks, glaciers, deep canyons, roaring streams, beautiful lakes, and a few patches of dusty plains in the south. This diverse terrain significantly influences the microclimates and contributes to the region's high habitat diversity. The state is traversed by major mountain ranges, including segments of the Zaskar and the Great Himalaya (Himadri) in the north, the Lesser Himalaya (Himachal) with ranges like Mussoorie and Nag Tibba, and

the Siwalik Range further south. These ranges, formed by the tectonic collision of the Indian and Eurasian plates, dictate the region's drainage patterns and geological stability. Significant peaks such as Nanda Devi (7,817 meters) and Kamet (7,756 meters) stand as prominent features, particularly in the Himadri zone, which are critical for glacial formation and act as primary sources of water supply. Uttarakhand can be broadly divided into several physiographic zones running parallel from northwest to southeast: the Himadri, the Himachal, the Siwalik, the Bhabar (a narrow bed of gravel and alluvium), the marshy Tarai in the southeast, and flat-floored depressions known as duns, such as Dehra Dun. Each of these zones possesses distinct geological characteristics and associated environmental conditions. The state is drained by the extensive Ganges and Yamuna river systems, along with their principal tributaries like the Tons, Bhagirathi, Alaknanda, Mandakini, Pindar, and Dhauliganga. These river systems, fed by glaciers and rainfall, play a vital role in the region's ecology and socio-economy. The soils of Uttarakhand also vary significantly depending on the region, ranging from gravel and stiff clay in the north to brown forest soil in the south, coarse-textured infertile soils in the Bhabar, and rich clayey loams in the Tarai. This variation in soil composition influences vegetation types, agricultural potential, and the susceptibility of the land to erosion.

- 3.1.2 Changes Observed Over Time and Their Environmental Impacts:

The Himalayas, as a young and dynamic orogenic belt, are in a constant state of flux. This youthfulness contributes to the region's inherent geological instability and its high susceptibility to earthquakes and landslides. The ongoing northward movement of the Indian tectonic plate, converging with the Eurasian plate, continues to exert immense tectonic stress along fault lines. This collision has resulted in the formation of major tectonic features such as the Main Central Thrust (MCT), the Main Boundary Thrust (MBT), and the Main Frontal Thrust (MFT). These thrust zones are areas of significant seismic activity, making Uttarakhand fall under high seismic risk zones IV and V. Geomorphometric analysis indicates that districts like Uttarkashi, Chamoli, and Pithoragarh exhibit higher tectonic activity, evidenced by their highly dissected terrain, higher relief, and frequent earthquake events. This continuous tectonic activity directly influences the risk of earthquakes and landslides, shaping the environmental landscape. Evidence also suggests that the region was once submerged under the Tethys Sea in the geological past, as indicated by the discovery of Ammonite fossils. This marine history has likely contributed to the richness of the faunal diversity in Uttarakhand. Glaciers in Uttarakhand, a critical component of its water resources, exhibit

both surges and retreats. While the majority of glaciers worldwide are retreating due to climate change, the Wadia Institute of Himalayan Geology has studied an unnamed glacier in the Dhauli Ganga basin that has shown an extraordinary growth 19. This rare phenomenon, where the glacier expanded by over 800 meters in a single month, suggests the complex interplay of hydrological pressure melting and geological conditions 19. However, this is an exception, as Uttarakhand is witnessing an increasing frequency of landslides 20. These landslides are potentially linked to the region's geological instability, changing climatic conditions including altered precipitation patterns and extreme rainfall events, and various human activities such as deforestation and unplanned construction 20. The expansion of infrastructure, such as the national highway (NH-58), has also been identified as a factor contributing to increased landslide susceptibility 20. These geological and topographical changes over time have profound environmental impacts, influencing the stability of slopes, the flow of rivers, and the overall ecological balance of the region.

Table 3.1: Major Tectonic Features and Their Significance

Tectonic Feature Name	Age (if available)	Location/Zone	Significance
Main Central Thrust (MCT)	Paleo-Proterozoic	Central Himalayas (Higher)	Delimits Lesser and Central Himalayas, significant seismic activity
Main Boundary Thrust (MBT)	Neogene	Outer/Sub-Himalayas, Lesser	Thrust zone, significant seismic activity
Main Frontal Thrust (MFT)	Miocene-Pleistocene	Outer/Sub-Himalayas	Southernmost and youngest thrust system
North Almora Thrust (NAT)	Proterozoic	Lesser Himalaya	Thrust contact with Lesser Himalayan

			Metasedimentary sequence in the north
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- **3.2 Climatic Conditions:**

- 3.2.1 Historical Temperature and Precipitation Data Analysis:

Uttarakhand experiences a diverse range of climatic conditions, varying from hot and moist subtropical in the southern part to cold alpine in the upper reaches of the Himalayan mountains in the north 4. This zonal variation profoundly influences the distribution of flora and fauna and shapes agricultural practices across the state. Altitude plays a critical role in determining the climate, with higher elevations experiencing colder temperatures and distinct precipitation patterns, including significant snowfall 4. The southwest monsoon season, typically from July to September, is the primary source of annual precipitation for the region, crucial for sustaining water resources and agriculture 2. Analysis of historical temperature and rainfall data over the past century reveals notable long-term trends. The region has recorded a unanimous warming trend, particularly prominent in the mountainous districts 21. Concurrently, there has been a declining rainfall trend, which has become steeper after 1970, although this trend varies across different regions of the state, with some plain areas even receiving more rainfall than normal 27. These historical trends, especially the warming observed in higher altitudes, have implications for the faster melting of glaciers and potentially more active geomorphic processes 27. Specific findings indicate a warming trend in Almora 29 and a significant decline in rainfall in districts like Pithoragarh, Bageshwar, Almora, Champawat, and Nainital 27. These historical climatic changes underscore a clear warming trend and shifting precipitation patterns in Uttarakhand, consistent with broader climate change signals, and highlight the importance of considering the variability across different regions and altitudes.

- 3.2.2 Recent Trends in Climate Change:

Uttarakhand is experiencing an increasing frequency of extreme weather events, including forest fires, landslides, flash floods, and droughts, which are becoming a "new normal" for the state and impacting its economy 21. A recent study published in Springer highlights this rising frequency, attributing it to a significant rise in maximum temperatures over the past 40 years 21. Altered precipitation patterns, with extreme rainfall events, are also causing more frequent flash floods and landslides 21. Notably, the overall annual rainfall in the region has decreased, potentially disrupting natural water cycles

21. A key finding is the phenomenon of elevation-dependent warming (EDW), where higher altitudes in Uttarakhand are experiencing faster temperature increases than lower regions 21. This accelerated warming is destabilizing glaciers and heightening the risk of glacial melt, posing a significant threat to the region's delicate ecosystem 21. Indeed, Uttarakhand's glaciers are melting at an accelerated rate due to global warming, increasing greenhouse gas emissions, and black carbon deposits 21. This rapid melting has severe consequences, including increased floods in the short term and water scarcity in the long term 40. Human activities such as road construction and deforestation further exacerbate glacier melt 40. Climate change projections for Uttarakhand indicate a continued warming trend, with temperatures potentially increasing by 1.4°C to 5.8°C by 2100 37. The state is also expected to experience changes in precipitation patterns, with a mixed pattern of positive and negative changes projected, and a potential increase in the frequency of extreme rainfall events 37. These projected changes suggest a future with intensified climate-related challenges for Uttarakhand.

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Table 3.2: Observed Climate Change Trends in Uttarakhand

Parameter	Time Period	Trend	Specific Findings
Temperature	Last 40 years	Increase	Significant rise in maximum temperatures ²¹
Temperature	Last decade	Increase	More prominent warming trend ²⁷
Temperature	1955-2007 (Almora)	Increase	Average temperature increase by 0.460°C ²⁹
Rainfall	After 1970	Decrease	Steeper declining trend ²⁷
Rainfall	Last two decades	Decrease	Significant decline in most districts ²⁷

Extreme Weather Events	Recent years	Increase	Rising frequency of forest fires, landslides, flash floods, droughts ²¹
Glaciers	Recent decades	Retreat	Accelerated melting rates observed ²¹

- **3.3 Forest and Biodiversity:**

- 3.3.1 Current Status of Forest Cover and Biodiversity:

Uttarakhand boasts significant forest cover, with approximately 45.4% of its geographical area under forests 4. These forests are a major asset for the state, providing diverse habitats that support a wide array of biodiversity. The state exhibits four major forest types based on altitude: alpine meadows found in the extreme north, temperate forests in the Great Himalayas, tropical deciduous forests in the Lesser Himalayas, and thorn forests in the Siwalik Range and parts of the Tarai 2. This variety of forest types contributes to Uttarakhand's status as a biodiversity hotspot, harboring a large number of plant and animal species. The state is home to approximately 7000 species of plants and 500 species of fauna 67, including over 175 rare species of aromatic and medicinal plants 5. Furthermore, Uttarakhand is rich in endemic species, with 119 endemic species of flowering plants and 35 endemic faunal species 67. To protect this rich biodiversity, the state has established several important national parks and wildlife sanctuaries, including Jim Corbett National Park, Valley of Flowers National Park, Nanda Devi National Park, Rajaji National Park, and Gangotri National Park 6. These protected areas play a crucial role in conserving the state's unique flora and fauna.

- 3.3.2 Changes in Forest Area, Species Richness, and Conservation Efforts Over Time:

Historically, Uttarakhand has experienced deforestation due to logging activities and the growing demand for infrastructure 8. Data indicates a significant forest cover loss of approximately 210,571,646 square meters between 2001 and 2020, with districts like Udham Singh Nagar, Nainital, and Champawat contributing the most to this loss 74. However, there has been a net increase of 8.04 sq km in forest cover between the ISFR 2017 and ISFR 2019 assessments, indicating that reforestation and conservation efforts are having a positive impact 61. Forest fires remain a recurring threat, causing substantial damage to the state's forest cover and biodiversity 8. Various reforestation efforts and initiatives, including the Miyawaki Forest method, are

underway, involving government bodies, NGOs, and local communities, to promote ecological restoration and increase green cover 8. Conservation efforts are also in place to protect endangered species such as the Bengal tiger, Asian elephant, Musk deer, Himalayan Tahr, and Western Tragopan 66. Climate change is also expected to impact species distribution, potentially forcing mammal species to migrate to higher elevations 86. While conservation and reforestation efforts are ongoing, deforestation and habitat loss, exacerbated by climate change and human activities, continue to pose significant challenges to the state's forest cover and biodiversity

○ **Table 3.3: Forest Cover Change in Uttarakhand (2001-2020)**

District	Forest Cover Loss (ha)	Forest Cover Gain (ha)	Net Change (ha)
Almora	1681.8	4030.7	2348.9
Bageshwar	630.6	2073.3	1442.7
Chamoli	1136.4	3602.5	2466.1
Champawat	1190.5	520.8	-669.7
Dehradun	1581.2	2818.6	1237.4
Garhwal	1228.6	4960.3	3731.7
Haridwar	600.7	5010.2	4409.5
Nainital	8598.8	3434.5	-5164.3
Pithoragarh	1280.5	3851.9	2571.4
Rudraprayag	548.2	2310.1	1761.9
Tehri Garhwal	1002.3	3114.6	2112.3

Udham Singh Nagar	5272.6	1276.0	-3996.6
Uttarkashi	1228.0	2915.5	1687.5
Total	24071.7	41918.9	17847.2

- **3.4 Water Resources:**

- 3.4.1 Status of Rivers, Glaciers, and Groundwater:

Uttarakhand is blessed with numerous river systems, with the Ganga and Yamuna being the two major rivers originating from the Gangotri and Yamunotri glaciers, respectively 2. These rivers, along with their extensive network of tributaries, are vital for the region's ecology and also serve as crucial sources of water for downstream areas. The state is home to approximately 1439 glaciers 93, which are the primary sources of these perennial rivers and contribute significantly to the water security of the region. However, many of these glaciers are currently experiencing retreat due to climate change. The status of groundwater resources in Uttarakhand varies between the plain and hilly regions 2. The Gangetic alluvial plain in the southern part of the state offers suitable zones for groundwater development, whereas the predominantly hilly terrain has limited potential for large-scale groundwater extraction. Groundwater in the plain districts is primarily used for agriculture. Traditional water management systems, such as naulas (natural aquifer tanks) and dharas (springs), have historically been significant sources of water for domestic use, especially in the hilly regions 100. While these systems continue to be important in many areas, they face challenges related to maintenance and their relevance in the face of changing lifestyles and water infrastructure. Overall, Uttarakhand is rich in water resources, but their distribution and availability are increasingly affected by factors such as climate change, urbanization, and developmental activities.

- 3.4.2 Changes Observed Over Time:

The glaciers in Uttarakhand, the primary sources of its rivers, are undergoing significant changes over time. The Gangotri Glacier, the source of the holy Ganges, has retreated by over 3 kilometers since 1817, with the rate of retreat accelerating sharply since 1971 and now estimated at around 22 meters per year 40. A recent study indicates that Uttarakhand's total glacier area shrank by over 21 sq km in just 23 years, with an average annual deglaciation rate of 0.095% 49. This accelerated melting poses a significant threat to the long-term water security of the region and downstream areas. Groundwater levels in Uttarakhand are also experiencing depletion due to over-extraction

for agriculture, industrial use, and domestic purposes, coupled with changing rainfall patterns 27. This depletion is particularly pronounced in agricultural areas like Udham Singh Nagar 107 and is exacerbated by erratic rainfall and infrastructure development 106. The devastating 2013 floods in Uttarakhand had a significant impact on the state's water resources and infrastructure 109. The floods caused immense damage to hydropower projects, bridges, and roads, highlighting the vulnerability of water infrastructure to extreme weather events and altering river flow patterns.

○ 3.4.3 Water Pollution Levels and Sources:

Water pollution levels in Uttarakhand's rivers are a growing concern. The water of the Ganga River in Haridwar has been classified under the 'B' category by the Uttarakhand Pollution Control Board, indicating it is unsuitable for drinking 116. Other rivers, like the Rishikesh in Dehradun, are reported to be highly contaminated due to anthropogenic activities 117. Major sources of this pollution include the discharge of untreated sewage from urban centers and habitations, industrial effluents from various industries, agricultural runoff containing pesticides and fertilizers, and the dumping of solid waste into water bodies 97. Tourism and related infrastructure development also contribute to water contamination through construction activities and inadequate sanitation facilities 106. While spring water is traditionally considered pristine, some regions in Uttarakhand face issues with high mineral content, particularly calcium hardness, and microbiological contamination due to proximity to human settlements and wildlife 97. The deteriorating water quality in Uttarakhand's rivers and other water sources poses a significant threat to both human health and the ecological integrity of its aquatic ecosystems.

Table 3.4: Major Rivers of Uttarakhand - Source and Current Status

River Name	Source (Glacier/Region)	Current Status
Ganga	Gangotri Glacier (Gaumukh)	Polluted in stretches, flow reduced in summer ¹¹⁶
Yamuna	Yamunotri Glacier	Polluted ¹²¹
Bhagirathi	Gaumukh Glacier	Source stream of Ganga, joined by tributaries ¹¹

Alaknanda	Confluence of Satopanth and Bhagirathi Kharak glaciers	One of the two headstreams of Ganga ¹¹
Kali (Sharda)	Himalayas near Kalapani	Forms border between India and Nepal ¹¹
Ramganga	Namik Glacier	Tributary of Ganga, flows through Corbett National Park ¹¹
Kosi	Himalayas near Dharpani Dhar	Joins Ramganga in Uttar Pradesh ¹¹
Mandakini	Chorabari Glacier	Joins Alaknanda at Rudraprayag, prone to destructive monsoon flows ¹¹
Pindar	Pindari Glacier	Joins Alaknanda at Karnaprayag ¹¹
Tons	Supin and Rupin rivers (Bandarpunch Parvat)	Largest tributary of Yamuna ¹¹

- **3.5 Land Use and Urbanization:**

- 3.5.1 Analysis of Present Land Use Patterns and Urbanization Trends:
The dominant land use patterns in Uttarakhand are characterized by a significant proportion of forest cover, followed by agricultural land and urban areas ². Notably, approximately 61.4% of the state's land was covered by forests in 2011-12 ¹²⁴. However, Uttarakhand is experiencing an increasing trend of urbanization, particularly in the plain areas of the state ²⁰. Between 2001 and 2011, the urban population in Uttarakhand increased by 40% ¹²⁸, and the number of census towns rose significantly ¹²⁸. This shift from rural to urban population indicates changing livelihoods and increasing pressure on urban infrastructure. Dehradun district has the highest proportion of urban population (55.5%), while Bageshwar district has the lowest (3.5%) according to the 2011 Census ¹³⁰. The rate of urban expansion has been particularly rapid in the Asan watershed, quadrupling over the past four decades ¹²⁹. Overall, Uttarakhand, while predominantly rural, is undergoing rapid urbanization, which is significantly altering land use patterns and placing increasing demands on natural resources and infrastructure.

- 3.5.2 Effects of Land Use Change and Urbanization on the Environment:
The increasing urbanization and associated land use changes in Uttarakhand are having significant effects on the environment. The conversion of agricultural land and forests to built-up areas is leading to habitat loss and fragmentation, impacting the state's rich biodiversity 20. Rapid urbanization is also contributing to a rise in land surface temperature, resulting in the urban heat island effect, particularly in areas like Dehradun 127. Deforestation and construction activities on fragile mountainous slopes are exacerbating the risk of landslides and soil erosion, making the hilly terrain more vulnerable to natural hazards 20. Furthermore, urbanization is impacting both air and water quality. Increased vehicular emissions, dust from construction, and industrial activities are contributing to rising air pollution levels 127. Similarly, the increased urban population puts a strain on water resources and can lead to the contamination of water bodies through sewage discharge and construction runoff, affecting both the availability and quality of water from traditional sources 106. Overall, the urbanization and associated land use changes in Uttarakhand are posing serious environmental challenges, including habitat degradation, increased disaster risk, and various forms of pollution.
- 3.5.3 Relevant Land Use Policies and Their Impact:
Uttarakhand has been actively developing land use policies to address the environmental and social impacts of urbanization and development. The Uttarakhand Bhu Kanoon (land laws), particularly the revised law approved in February 2025, aims to regulate land purchases by outsiders and manage land use across the state 137. A key objective of this law is to prevent the unchecked purchase of agricultural and horticultural land by non-residents in 11 out of the 13 districts, excluding Haridwar and Udham Singh Nagar 138. The law also imposes regulations on land use within municipal limits, restricting it to designated zones and mandating that purchased land be used only for the specified purpose, with violations potentially leading to government repossession 137. These policies reflect an ongoing effort to balance economic development with the need to protect the state's land resources, cultural heritage, and the interests of local residents in the face of increasing urbanization and developmental pressures. By regulating land transactions and land use, the government aims to ensure sustainable development and prevent the misuse of land, particularly agricultural and forest areas.

Table 3.5: Urban Population Change in Uttarakhand (2001-2011)

District	% Increase in Urban Population (2001-2011)
Almora	33.7
Bageshwar	60.1
Chamoli	25.5
Champawat	38.1
Dehradun	46.9
Haridwar	39.8
Nainital	33.2
Pauri Garhwal	28.6
Pithoragarh	26.3
Rudraprayag	37.0
Tehri Garhwal	30.3
Udham Singh Nagar	39.3
Uttarkashi	31.8

- **3.6 Disaster Risk and Management:**

- 3.6.1 History of Natural Disasters in Uttarakhand:

Uttarakhand is situated in a fragile mountainous region of the Himalayas, making it highly vulnerable to a multitude of natural disasters, including severe earthquakes, landslides, floods, avalanches, droughts, and forest fires 4. The state has a long history of experiencing devastating events. Significant earthquakes include the 1803 Garhwal earthquake, the 1991 Uttarkashi earthquake, and the 1999 Chamoli earthquake 142. Major landslides, such as

the 1880 Nainital landslide and the 1998 Malpa landslide, have caused substantial loss of life and property 142. The state has also been severely affected by floods, most notably the 2013 North India floods (Kedarnath tragedy), which claimed thousands of lives and caused widespread destruction 111. More recently, the 2021 Uttarakhand flood in Chamoli district, triggered by an ice and rock avalanche, resulted in significant casualties and damage to infrastructure 142. The frequency and intensity of these natural disasters appear to be increasing in recent times, potentially linked to the impacts of climate change and developmental activities in the region 111. Glacial lake outburst floods (GLOFs) represent another significant hazard in Uttarakhand's mountainous terrain, with the potential for catastrophic downstream impacts 154.

- 3.6.2 Current Disaster Risk Assessment and Management Strategies: Uttarakhand is located in a highly seismic zone, categorized as Zones IV and V, indicating a high risk of earthquakes 17. To mitigate the impact of natural disasters, the state has been actively involved in disaster risk assessment and the development of management strategies. Landslide hazard zonation mapping has been carried out in various regions to identify areas prone to landslides, providing valuable data for post-disaster management and development planning 158. The state has established a comprehensive institutional framework for disaster management, with the Uttarakhand State Disaster Management Authority (USDMA) serving as the apex body 163. The USDMA oversees the State Emergency Operation Centre (SEOC) and works in coordination with the District Disaster Management Authorities (DDMAs). The State Disaster Response Force (SDRF) is a dedicated force responsible for search and rescue operations 168. Uttarakhand has also invested in early warning systems for various hazards, including earthquake early warning systems and weather monitoring infrastructure 16. Furthermore, disaster recovery frameworks and projects, such as the Uttarakhand Disaster Recovery Project supported by the World Bank, have been implemented to restore infrastructure and build the resilience of communities affected by disasters 164. The Disaster Mitigation and Management Center (DMMC) plays a crucial role in generating awareness and strengthening the state's capacity for disaster management 167. These efforts demonstrate a multi-faceted approach to disaster risk management in Uttarakhand, encompassing risk assessment, preparedness, response, and recovery.

Table 3.6: Major Natural Disasters in Uttarakhand (2000-Present)

Disaster Type	Year	Location (if specific)	Key Impacts
Uttarkashi Earthquake	1991	Uttarkashi	768 deaths, widespread damage ¹⁴²
Chamoli Earthquake	1999	Chamoli-Pipalkoti area	115 deaths, felt widely ¹⁴²
Malpa Landslide	1998	Malpa village, Pithoragarh	221 deaths, village wiped out ¹⁴²
North India Floods (Kedarnath)	2013	Kedarnath Valley	Over 6,000 deaths, widespread destruction ¹¹¹
Uttarakhand Flood	2021	Chamoli district (Rishiganga, Dhauliganga rivers)	Over 200 killed or missing, damage to hydropower projects ¹⁴²

- **3.7 Pollution and Environmental Degradation:**

- 3.7.1 Air Pollution:

Air pollution is an increasing environmental concern in Uttarakhand, particularly in its urban centers. Real-time Air Quality Index (AQI) levels in cities like Dehradun, Lansdowne, and Nainital often fall in the moderate to poor categories¹⁷⁹. Major sources contributing to air pollution in the state include vehicular emissions, dust from roads and construction activities, industrial emissions, unregulated garbage burning, and the burning of domestic fuels¹²⁷. Rapid urbanization is also exacerbating the problem, leading to a rise in pollutants such as nitrogen dioxide (NO₂) and formaldehyde (HCHO) in urban areas like Dehradun¹²⁷. Studies have shown that particulate matter (PM₁₀ and PM_{2.5}) levels are often above prescribed national standards in cities like Rishikesh¹⁸⁷. The air quality in Uttarakhand's urban areas is generally worse than the national average¹⁸⁰.

- 3.7.2 Water Pollution:

Water pollution poses a significant environmental challenge to Uttarakhand's rivers and other water bodies. The Ganga River in Haridwar has been classified as 'B' class, indicating that it is unsafe for drinking¹¹⁶. Other rivers,

such as the Rispana in Dehradun and the Chandrabhaga in Rishikesh, also exhibit poor water quality with high levels of pollutants 117. The primary sources of water pollution in Uttarakhand include the discharge of untreated sewage from urban and rural areas, industrial effluents from various industries, agricultural runoff carrying pesticides and fertilizers, the dumping of solid waste, and the impact of tourism and related construction activities 97. This pollution not only affects the quality of drinking water sources but also threatens the health of aquatic ecosystems. Additionally, some regions in Uttarakhand face water quality issues due to naturally occurring high mineral content, particularly calcium hardness 97.

- 3.7.3 Soil Pollution:

Soil pollution is another critical aspect of environmental degradation in Uttarakhand. Various sources contribute to this problem, including the dumping of industrial waste and effluents, the use of pesticides and fertilizers in agriculture, mining activities, deforestation, and unscientific land use practices 2. Industrial areas like the Tarai Bhavan region of Udham Singh Nagar and the vicinity of cement factories in Haridwar district have been identified as hotspots for soil pollution with elevated concentrations of potentially toxic metals and pesticides 189. Soil erosion is also a major concern in Uttarakhand, exacerbated by weak geological formations, active seismicity, deforestation, and unscientific land-use practices like shifting cultivation 2. A significant portion of the state's area is estimated to have soil loss above the tolerance limit 135. This degradation of soil quality has detrimental effects on agricultural productivity and can lead to the loss of biodiversity.

- 3.7.4 Other Forms of Environmental Degradation:

Beyond air, water, and soil pollution, Uttarakhand faces other significant forms of environmental degradation. Deforestation continues to be a major issue, driven by urbanization, infrastructure development, and agricultural expansion, leading to habitat loss and increased vulnerability to landslides 22. This deforestation, coupled with other factors, contributes to the ongoing loss of biodiversity across the state. Additionally, a concerning trend is the drying up of Himalayan springs, which are vital sources of water for many communities, potentially due to changes in precipitation patterns, deforestation, and groundwater depletion 22. These interconnected issues highlight the multifaceted nature of environmental degradation in Uttarakhand.

Table 3.7: Average AQI Values for Major Cities in Uttarakhand (April &

May 2019)

City	AQI (April 2019)	AQI (May 2019)	AQI Category (April 2019)	AQI Category (May 2019)
Dehradun	202	237	Poor	Poor
Rishikesh	133	144	Moderate	Moderate
Haridwar	121	123	Moderate	Moderate
Kashipur	111	116	Moderate	Moderate
Rudrapur	118	121	Moderate	Moderate
Haldwani	105	105	Moderate	Moderate

- **3.8 Socio-Economic & Policy Aspects:**

- 3.8.1 Socio-Economic Factors Influencing the Environment:

The socio-economic fabric of Uttarakhand is closely linked to its environment. A significant portion of the population depends on agriculture and allied activities for their livelihood, making them directly reliant on the state's natural resources 29. This dependence can lead to unsustainable resource use if not managed with a focus on conservation and long-term sustainability. Tourism plays a pivotal role in Uttarakhand's economy, contributing substantially to its Gross State Domestic Product 5. However, the increasing influx of tourists and the development of tourism infrastructure can also lead to negative environmental impacts such as pollution, deforestation, and increased pressure on local resources. The state is also experiencing rapid urbanization and infrastructure development, driven by population growth and the need for better connectivity and amenities 20. These developmental activities often result in land use changes that can have detrimental effects on the environment. Furthermore, environmental degradation and the impacts of climate change are contributing to migration from the hill districts to the plains in search of better economic opportunities and safer living conditions 21. This complex interplay of socio-economic factors and environmental

conditions necessitates a balanced approach to development that prioritizes sustainability.

- 3.8.2 Review and Analysis of Environmental Policies:

Uttarakhand has implemented various environmental policies to address the challenges arising from its unique socio-economic and ecological context. Land use policies, such as the Uttarakhand Bhu Kanoon enacted in February 2025, aim to regulate land purchase, particularly by non-residents, and ensure land is used according to designated purposes 137. These laws reflect the state's efforts to protect its agricultural land, natural resources, and cultural heritage. Given the state's high vulnerability to natural disasters, Uttarakhand has also established a comprehensive disaster management framework, with the USDMA as the nodal agency responsible for planning, coordination, and monitoring of disaster prevention, mitigation, preparedness, and management 164. Conservation efforts and policies are also in place to protect the state's significant forest cover and rich biodiversity, with various initiatives undertaken by the government and non-governmental organizations 68. While specific policies related to pollution control and water resource management are not explicitly detailed in the provided snippets, the discussions on pollution levels and water status implicitly suggest the existence of such policies. However, the effectiveness of these policies in achieving a sustainable balance between development and environmental protection remains a critical consideration for the state.

5. Time Required

The estimated time required to complete this project, encompassing the detailed analysis and report generation, is as follows:

- **Detailed research and data extraction:** Approximately 12-16 hours
- **In-depth analysis and identification of insights for each parameter:** Around 16-20 hours were dedicated to analyzing the extracted data,.
- **Development of visualizations (graphs, charts, heatmaps):** required approximately 4-6 hours.
- **Writing and structuring the report:** took approximately 4 hours.
- **Review and finalization:** required an additional 2 hours.

6. Conclusion

Uttarakhand's rich, fragile environment faces threats from geological instability, climate change (glacial melt, altered rainfall), deforestation, water pollution, and rapid urbanization. Disaster risks are high, and socio-economic reliance on agriculture and tourism complicates environmental management. Sustainable development is crucial for long-term well-being.

7. Outcomes of the Analysis

Need for Enhanced Environmental Monitoring and Data Collection:

- The analysis highlights the necessity for improved monitoring and data gathering across all environmental parameters.
- This is crucial for accurately understanding ongoing environmental changes and their impacts.

Strengthening Pollution Control Regulations:

- Stricter regulations are required for industrial effluents, sewage discharge, and waste management.
- These measures are essential to safeguard Uttarakhand's water resources and air quality.

Robust Land Use Policies for Sustainable Development:

- Effective land use policies are vital for guiding urbanization and infrastructure development.
- These policies should minimize deforestation and the conversion of agricultural land.

Promoting Sustainable Tourism Practices:

- Tourism practices must prioritize environmental conservation.

- Balancing economic benefits with ecological protection is crucial.

Enhancing Disaster Preparedness and Risk Reduction:

- Given Uttarakhand's vulnerability to natural disasters, improved preparedness is essential.
- This includes early warning systems and resilient infrastructure development.

Investing in Reforestation and Biodiversity Conservation:

- Reforestation efforts, focusing on native species, are necessary.
- Comprehensive biodiversity conservation strategies are vital to protect the state's ecological heritage.

Raising Public Awareness and Community Involvement:

- Public awareness and community participation are crucial for environmental protection.
- Fostering a sense of stewardship is essential for long-term conservation success.