

風雨同渡五十載

Weathering the Elements Together

回溯過去半世紀香港斜坡安全的發展 居安亦思危

A look back on the development of slope safety in Hong Kong over half a century in preparation for the challenges ahead



↑ 秀茂坪曉光街對下一幅 40 米高的填土坡突然崩塌 (A 40 meter-high fill slope suddenly collapsed below Hiu Kwong Street in Sau Mau Ping)

在上世紀六、七十年代的香港，「山泥傾瀉」這個詞語不時在新聞報道中出現，其中 1972 年 6 月於秀茂坪和港島半山發生的山泥傾瀉災難，在不少市民心中都留下難以磨滅的印記。隨着科技進步，香港在維護斜坡安全方面的工作亦有不少轉變。藉着秀茂坪和寶珊道山泥傾瀉的災難事件發生五十年，就讓我們從過去走到現在，訪尋當中一些鮮為人知或已經被人遺忘的故事，一起回顧歷史，居安思危。

In the 1960s and 1970s, “landslide” was a word that popped up frequently in the news of Hong Kong. Among those incidents, the two landslide disasters in Sau Mau Ping and the Mid-Levels of Hong Kong Island in June 1972 left an emotional scar on many people. Since then, thanks to technological advancements, slope safety in Hong Kong has progressed substantially. Five decades after the tragic landslides at Sau Mau Ping and Po Shan Road, we take this opportunity to revisit history and reflect on what can be done to prevent similar tragedies in the future.

回溯歷史

山泥傾瀉話當年

History of the Tragic Landslides on June 18, 1972



↑ 秀茂坪山泥傾瀉的災區 (The landslide disaster area of Sau Mau Ping)

1972年6月16日，大雨開始下過不停。三天之內，天文台錄得共653毫米的雨量，每日雨量超過200毫米，是有紀錄以來6月份連續三日最高降雨量，差不多是全年平均雨量的三成。就在6月18日的中午時分，秀茂坪曉光街對下一幅40米高的填土坡突然崩塌，大量泥土一湧而下，數秒之間淹蓋了臨時安置區內的78間木屋，多達71人死亡。

禍不單行，當晚接近九時，港島半山寶珊道附近一幅天然山坡突然崩塌。泥石帶着巨大動能捲走旭龢道11號一幢六層高的建築

Starting from June 16, 1972, it rained non-stop for three days with a total rainfall of 653 mm (or over 200 mm per day), making it the highest 3-day total rainfall in June on record and accounting for almost 30% of the average annual rainfall. Around noon on June 18, a 40 meter-high fill slope below Hiu Kwong Street of Sau Mau Ping suddenly collapsed. An enormous amount of debris washed down within seconds, destroying 78 huts in the resettlement area and killing 71 people.



↑ 寶珊道山泥傾瀉的情景 (The aftermath of the landslide at Po Shan Road)

物，並繼續沖向12層高的旭龢大廈，將它徹底摧毀。倒塌的旭龢大廈撞上旁邊一幢尚未入伙的建築物，將它最高的四層削去。山泥傾瀉持續不足十秒，67人被奪去性命。

兩場慘劇共導致138人死亡，是本港因雨災引致的單日最高死亡人數。1972年6月18日可說是香港山泥傾瀉歷史上最黑暗的一天。對親歷其境的人來說，那種山崩土淹、地動山搖的震撼畫面，至今仍然歷歷在目……

秀茂坪下邨居民張鵬輝當時年約20歲，聽到巨響後走出去看過究竟：「那時很多山泥沖下來湧向第5、第6座，數秒之間那些木屋全被淹沒，心想那些居民應該凶多吉少。我很少向人提及這件事，這場災難在我心中埋藏了多年。在我成長的年代，山坡多數沒有人管理，現在則安全得多。」

當年只有10歲的翁舜華與家人同樣居於秀茂坪下邨，回想起當時的情景仍然猶有餘

The troubles did not end there. Shortly before 9 p.m. on the same day, a natural hillside above Po Shan Road in the Mid-Levels of Hong Kong Island tumbled down. The landslide debris gathered momentum as it washed down, striking a six-storey building at No. 11 Kotewall Road and the 12-storey Kotewall Court, causing both to collapse completely. The collapsing Kotewall Court struck another unoccupied building next to it and shaved off the top four storeys. The landslide, lasting less than 10 seconds, took 67 lives.

The two tragedies resulted in 138 deaths, the highest fatalities in a single day in our city due to rainstorms. That day, June 18, 1972, was the darkest day in the history of landslides in Hong Kong. For those who lived through it, the landslide was so terrifying that it seems like just yesterday that disaster struck...

Cheung Pang-fa, a resident of Lower Sau Mau Ping Estate, was about 20 years old in 1972. After hearing a thunderous noise, he went to check things out. "I saw a large amount of mud being washed down towards Blocks 5 and 6. The huts were completely buried within seconds and I thought, those residents probably won't survive this," he said. "I seldom mention this incident to anyone and I've kept this memory in my heart for years. When I was growing up, most slopes were not attended to. It's much safer nowadays."

Yung Shun-wa, aged 10 in 1972, was also living at Lower Sau Mau Ping Estate with her family at that time. Recounting the dreadful experience, she said, "We were afraid that the mud might rush into our home. We were living on the second floor and the mud had indeed reached the staircase of our level. Luckily



↑ 張鵬輝 (Cheung Pang-fa)

悸：「那時很擔心山泥會繼續沖入我們的家。我們居於2樓，山泥其實已經沖到我們那層的樓梯口，幸好有外牆擋着。」事發時，比她大3歲的姐姐翁舜芝正前往同邨另一座建築物做暑期工，她回憶道：「我落樓後，只見很多山泥高速湧過來，我很害怕。幸好當時聽媽媽的話，走離斜坡較遠的樓梯，否則我應該已經遭山泥活埋了。」



↑ 翁舜華(左)與翁舜芝(右) (Yung Shun-wa [left] and Yung Shun-chi [right])

though, the mud was stopped by the external wall of our building.” Her sister Yung Shun-chi, 13 at the time, was heading to a summer job at another block of the same estate when the landslide struck. She recalled, “After going down the stairs, I saw a huge volume of mud coming towards me at high speed and I was so terrified. Fortunately, I had followed my mom’s advice and taken the staircase further away from the slope, otherwise I might have been buried by the mud.”

Fire services officer Wu Keung was involved in the rescue work of the Po Shan Road landslide. He recalled, “We had to carry our equipment and reach the site on foot. After turning a corner, we were stunned to see nothing but mud, a hillside full of mud instead of buildings.” Working around the clock, it still took them three months to completely restore the site. Victims retrieved at later stages of the cleanup work had already been reduced to skeletal remains. After so many years, the memory of this tragedy still pains him.

“I saw the mud from the opposite slope pushing the huts towards us. Debris from the broken huts were washed down together with the victims as the slope disappeared in seconds. Having seen this disaster with my own eyes, I realised we can’t take happiness for granted. One can lose his home and family in the blink of an eye and there is no second chance,” said Michael Lau, who was 13 when he witnessed the tragedy of the Sau Mau Ping landslide in 1972. “In the past five decades, I’ve witnessed the improvement of slope safety in Hong Kong. I know many people must have made a lot of effort behind the scenes. After learning what the Geotechnical Engineering Office (GEO) has been doing over the years from my son, who works there, I am even more convinced of this.” Inspired



↑ 胡強 (Wu Keung)

1972年秀茂坪山泥傾瀉災難目擊者劉蕊(當年13歲)：「當時見到對面山坡的泥一直把木屋推過來，泥中夾雜着房屋碎片和受災人士，之前的山坡頃刻間消失了。親眼目睹這次災難，令我深深體會到幸福並非必然，兩三秒之間就可以家破人亡，不會再有第二次機會。這五十年間，我見證了香港斜坡安全的進步，明白到背後有很多人在默默耕耘。從任職土力工程處的儿子了解到他們的工作之後，更加肯定了這點。」聽到父親講述當年目睹山泥傾瀉災難事件的親身經歷，求學期間中學老師分享母校的建校過程如何受當年事件影響，不知不覺地在一位年輕人心中埋下種子，令他立志成為土力工程師，為守護香港的斜坡安全、為守護市民的生命和財產出一分力。劉蕊的儿子土力工程師劉斯俊



↓ 劉蕊與兒子劉斯俊 (Michael Lau and his son Samuel Lau)

博士說：「我本身對工程有興趣，加上兒時父親和中學老師跟我分享『六一八』的故事對我有啟發，我就決定修讀土木工程，並在畢業之後加入土力工程處工作。現時我主要負責公眾教育，希望能夠將斜坡安全的資訊傳揚開去，令公眾人士，尤其是年輕一輩，都會時刻注意山泥傾瀉的風險，將知識薪火相傳。我相信我们的工作避免了许多人命傷亡。」

土力工程處處長張偉文博士闡述「六一八」事件的成因：「秀茂坪塌下的山坡在60年代其實是一個山谷，後來在附近找來泥土填成山坡。當時沒有岩土工程設計概念，斜坡工程的施工準則和監督亦沒有像現時般嚴謹，估計當時填泥非常鬆散。連場大雨之下，液化了的泥土就好像地氈一樣滑下。而寶珊道對上是一幅天然山坡，山坡倒下的時候就好像滾雪球一樣，最後有約2萬立方米的泥石沖了下來。我們的調查找出了三大成因：首先是山坡的土質容易讓水滲透，其次是



↑ 張偉文處長 (Dr. Raymond Cheung, Head of the GEO)

by the personal experience of his father in the catastrophic landslide and the sharing of his schoolteacher on how the incident affected the construction of his school, a young man made up his mind to become a geotechnical engineer to safeguard the slopes, as well as the lives and properties of the public of Hong Kong. “I started to develop an interest in engineering when I was a child. Then my father and my schoolteacher shared the tragic story of the 6.18 Landslide

Disaster with me,” said Dr. Samuel Lau, a geotechnical engineer and son of Michael Lau. “I decided to pursue a career in civil engineering and joined the GEO after graduation. I am currently responsible for public education. I hope to spread the word about slope safety to the public, in particular young people, so that they can always stay vigilant about landslide risks and pass on the knowledge to the next generation. I believe our work has effectively prevented tragedies from happening and save lives.”

Dr. Raymond Cheung, Head of the GEO, explained how the 6.18 Landslide Disaster happened. “The collapsed slope at Sau Mau Ping was a valley in the 1960s and became a fill slope afterwards. As people didn’t have much idea about geotechnical design and the requirements for slope works were not as stringent as they are nowadays, we can assume that the soil was very loose at that time. After continuous downpours, the soil became liquified and slid down like a carpet. As for Po Shan Road, it involved a natural hillside. When it collapsed, it gathered momentum and the situation snowballed. As much as 20,000 cubic meters of mud was washed down. According to the investigation



↓ 山泥傾瀉過後留下一片泥海 (The landslide left behind a sea of mud)

罕見的持續大暴雨令地下水位急升，而最後是附近一個建築工地正進行深層挖掘，支撐不足令泥土下墜。」

四年後，另一宗山泥傾瀉慘劇於 1976 年 8 月 25 日再次在秀茂坪發生。在熱帶風暴愛倫吹襲之下，天文台在兩天內錄得約 500 毫米雨量，秀茂坪邨第 9 座後面的填土坡在早上 9 時左右塌下，釀成 18 人死亡。該處與 1972 年慘劇的事發地點相隔只有約 200 米。

鑑於山泥傾瀉的悲劇時有發生，政府於 1977 年成立土力工程處，專責斜坡安全的工作，務求減低山泥傾瀉對市民大眾生命的威脅。

前土力工程處處長陳健碩工程師講述當時的首要工作：「當年沒有監管岩土工程的法例或斜坡安全標準。處方在 1979 年出版了第一版的《斜坡岩土工程手冊》作為標準的『天書』。我們亦於 1980 年訂立法例，規定私人業主鞏固危險斜坡，並在新建斜坡時須提交圖則以供審批。」



↑ 陳健碩前處長 (Raymond Chan, former Head of the GEO)

after the incident, there were three causes. First of all, the soil was highly permeable. Secondly, the unusual continuous downpours gave rise to a surge in the groundwater level. Lastly, a construction site nearby was conducting deep excavation works and the lack of adequate support caused the soil to collapse.”

Four years later, another deadly landslide occurred at Sau Mau Ping on August 25, 1976. Hit by tropical storm Ellen, Hong Kong saw roughly 500 mm of rainfall in two days. At around 9 a.m., the fill slope behind Block 9 of Sau Mau Ping Estate collapsed, killing 18 people. The landslide was only 200 meters away from the site of the 6.18 Landslide Disaster in 1972.

In view of the frequent occurrence of landslides, the government set up the Geotechnical Control Office (later renamed as the Geotechnical Engineering Office) in 1977 to focus on slope safety, with a view to minimising the threats posed by landslides to the lives of the public.

Raymond Chan, the former Head of the GEO, talked about their priorities when the office was first set up. “In those days, there was no legislation or standard for regulating geotechnical works or slope safety,” said Chan. “The first edition of the Geotechnical Manual for Slopes was published in 1979 as a slope safety standard. We also enacted legislation to deal with private slopes in 1980, requiring private landowners to upgrade dangerous slopes and submit plans for approval before new slopes can be built.”

風雨同渡 斜坡安全半世紀

Hong Kong's Slope Safety System and Notable Landslides in the Past

天災無情 人間有愛

在山多平地少的香港，加強維護斜坡安全對於減低山泥傾瀉的風險起着關鍵作用。天災無情，但人間有愛，只要在人力所及的範圍內做好工作，就可以盡量避免災難事件重演。

自成立以來，土力工程處逐步建立一套全面的斜坡安全管理系統，從不同層面降低山泥傾瀉的潛在風險。然而，山泥傾瀉風險會隨著人口增長、斜坡老化和日趨頻繁的極端天氣而上升，土力工程處需要不斷改進其斜坡安全管理系統，希望令身處山坡附近的居民可以安枕無憂。張偉文處長表示：「我們主要從三方面去控制山泥傾瀉風險。第一，我們會管制新發展項目和審核岩土工程設計，以控制新發展所帶來的風險。第二，我們會透過鞏固和維修政府斜坡、推動私人斜坡維修，以及在天然山坡採取風險緩措施，以降低現有發展所面對的山泥傾瀉風險。第三，香港山多，山泥傾瀉風險永遠不可能是『零』，但我們會盡力減低所造成的影響，例如發布山泥傾瀉警告、提供山泥傾瀉緊急服務，以及教育公眾採取預防措施等。」



↑ 黃志明工程師 (Ir. Wong Chi-ming)

岩土工程專家黃志明工程師在香港執業超過 40 年，他指出：「不論是工務工程，還是私人發展項目，土力工程處都在岩土工程監管方面發揮重要角

Battling the Elements with a Caring Heart

With Hong Kong's mountainous terrain, enhancing slope safety is the key to minimising the occurrence of landslides. While the elements may be relentless, with the utmost effort, it is still possible to avoid disasters from happening again.

Ever since its establishment, the GEO has progressively developed a comprehensive slope safety system to tackle the different aspects of potential landslide risks. However, as population grows, slope degradation and increasingly frequent extreme weather events can heighten the risk of landslides, the GEO continues to improve the slope safety system to help ensure the safety of residents who live near slopes. According to Dr. Raymond Cheung, Head of the GEO, “We control landslide risks mainly from three aspects. Firstly, we regulate new development projects and review the design of geotechnical works to control their landslide risks. Secondly, we upgrade and maintain government slopes, promote private slope maintenance and implement risk mitigation measures on natural hillsides, so as to minimize the landslide risks of existing development. Thirdly, although the risk of landslides for a mountainous place like Hong Kong can never be reduced to ‘zero’, we try our best to lessen the impact.

色。土力工程處會在土地規劃階段提供岩土工程方面的專業意見，指出各種岩土工程限制，並在有需要時在地契上加入特定的岩土工程條款。在工程設計及建造階段，土力工程處亦會審核各種岩土工程設計及突擊巡查正在進行工程的建築地盤，確保設計及施工質素符合標準。業內人士起初或許對此新設部門有些意見，但經過多年磨合，大家都明白監管岩土工程的需要，土力工程處的嚴格監管令香港避免了很多與斜坡及岩土工程有關的意外。」

努力不懈 成果漸現

自 1977 年成立以來，土力工程處一直致力減低香港的山泥傾瀉風險，並推行「防止山泥傾瀉計劃」，鞏固有潛在危險的人造斜坡。因應氣候變化和香港的持續發展，土力工程處的工作方針這些年來亦與時並進，務求與無情的天災競賽。

維護斜坡安全的工作並非一蹴而就，而是需要專業人員多年來辛勤工作累積下來，才會漸漸取得成果。雖然香港在二十一世紀仍然不時出現大大小小的山泥傾瀉事件，但自從政府開始有系統地處理斜坡安全問題之後，由 1980 年代開始，山泥傾瀉的災情以至人命傷亡情況都較之前大為減輕。

一九八零年代

1982 年夏天，香港各處的寮屋區接連發生不同規模的山泥傾瀉事故。往後數年，同類的不幸事件繼續在各處發生，部分寮屋區的居民更屢次受災。

這段期間，因寮屋區山泥傾瀉而死亡的人數超過 30 人。隨着政府於八十年代初開始為全港的寮屋登記，並透過非發展性清拆計劃有序地清拆寮屋和安置居民，寮屋區的山泥傾瀉問題亦漸露曙光。

For instance, we issue landslip warnings, provide landslide emergency services and raise public awareness of precautionary measures.”

Geotechnical engineering specialist Wong Chi-ming, who has been practising in the field in Hong Kong for over 40 years, said, “the GEO has played an important role in exercising geotechnical control over both public works and private development projects. In planning new developments, the GEO provides professional geotechnical advice, points out any geotechnical constraints and imposes specific geotechnical clauses in the land leases when needed. In the design and construction stage, the GEO audits the geotechnical design and carries out surprise site inspections to ensure that the design and quality of geotechnical works are up to standard. While some stakeholders might have had doubts about the GEO when it was first set up, after years of ironing out differences, they all acknowledge the need for geotechnical control and agree that the stringent regulations and controls by the GEO have prevented many accidents related to slope failures or geotechnical engineering from happening in Hong Kong.”

Noteworthy Achievements of Untiring Efforts

Since its establishment in 1977, the GEO has been striving to reduce the risk of landslides in Hong Kong. The Landslip Preventive Measures Programme (LPMP) was put in place to deal with man-made slopes with potential risks. In response to climate change and the continuous development of Hong Kong, the GEO has also adjusted its strategies over the years in a race against the relentless elements to prevent disasters.

The work of maintaining slope safety



↑ 觀龍樓 D 座對下砌石牆及斜坡塌下，部分地基外露。(The masonry wall and a slope below Block D of the Kwun Lung Lau building collapsed, exposing part of the foundation.)

一九九零年代

自土力工程處成立以來，轄下的「防止山泥傾瀉計劃」按風險為本的原則處理了大批不合標準並靠近樓宇和繁忙道路的斜坡。經過他們多年的努力，在九十年代初期，沒有發生像七八十年代的嚴重山泥傾瀉災難。然而，九十年代中後期發生的數宗致命山泥傾瀉事件，再次提醒工程人員及市民仍然要面對山泥傾瀉的風險，以及維護斜坡安全對保障生命和財產的重要性。

1994 年 7 月 23 日，天文台發出山泥傾瀉警告，大雨持續 48 小時未有休止。堅尼地城觀龍樓 D 座對下的部分砌石牆及斜坡突然塌下，導致 5 名途人遇難。當時率先到達現場的消防車，剛巧由曾經參與「六一八」事件救援工作的胡強擔任主管。他憶述拯救的難度：「現場漆黑一片，我們只聽到泥石下傷者求救的聲音。其中一位生還者不斷請求我們先救她的女兒，但因為位置的關係，我們得先移開山泥救出那位母親，然後再徒手挖掘半小時左右，才可以把她的女兒救出。」

is a long-term effort. It takes years of hard work by professionals to achieve noteworthy results. Entering the 21st century, even though landslides of various scales still occur occasionally in Hong Kong, the resulting damage and casualties have been far less severe, continuing a trend since the 1980s, when the government began to take a systematic approach to addressing the issue of slope safety.

The 1980s

In the summer of 1982, landslides of various degrees occurred one after another in the squatter areas of the territory. In the following years, similar disasters continued to happen in different places. At some squatter areas, residents suffered landslides repeatedly.

During this period, over 30 people were killed due to landslides in squatter areas. As the government started to register squatter structures in the early 1980s, as well as to clear squatter huts and rehouse residents through the Non-Development Clearance Programme, glimmers of hope emerged for addressing the landslide issue in squatter areas.

The 1990s

After its establishment, the GEO upgraded a large number of substandard slopes adjacent to residential buildings and major roads in accordance with a risk-based priority ranking system under the LPMP. In the early 1990s, years of untiring effort resulted in a time of relative safety, with severe landslide disasters like those in the 1970s and 80s seemingly a thing of the past. However, several fatal incidents took place in the mid to late 1990s, serving as reminders to engineers and the public that Hong Kong was still prone to

觀龍樓事件後翌年，政府決定增撥資源，落實「五年加速防止山泥傾瀉計劃」。此外，土力工程處亦成立由國際岩土專家組成的斜坡安全技術檢討委員會，審視及檢討土力工程處在斜坡安全的工作及成效。處方亦對山泥傾瀉的發生進行系統性研究，從而提出改善斜坡設計及建造的建議。此外，土力工程處由九十年代開始使用泥釘加固斜坡，使斜坡安全的情況進一步改善。

landslides, and that it was crucial to maintain slope safety to protect lives and properties.

On July 23, 1994, the Hong Kong Observatory issued a landslip warning amid almost 48 hours of torrential rain. At the Kwun Lung Lau building in Kennedy Town, part of the masonry wall and a slope below Block D suddenly collapsed, killing five people. The first fire engine on the scene happened to be under the charge of Wu Keung, who had participated in the rescue operation of the 6.18 Landslide Disaster. He recalled how difficult it was to rescue the survivors, “The site was in complete darkness and we could only hear survivors crying for help under the debris. One of them kept asking us to help her daughter first. However, we had to save her first as she was more accessible. We manually removed the debris to get her out and kept digging further with our hands for another 30 minutes or so before we could reach her daughter.”

In the year after the Kwun Lung Lau incident, the government launched the 5-year Accelerated Landslip Preventive Measures Project to allocate more resources to tackle the risk of landslides. The GEO also set up the Slope Safety Technical Review Board (SSTRB) comprising renowned geotechnical experts from across the globe to examine and review GEO's work and effectiveness in slope safety management. The GEO also conducted systematic studies of landslides to come up with recommendations for improving slope design and construction practice. Apart from this, the GEO started applying soil nails to reinforce slopes in the 1990s, thus further enhancing slope safety in Hong Kong.

The 21st Century

While natural hillside landslides do occur



↑ 泥石流湧至荃灣老圍。(The debris flow rushed into Lo Wai, Tsuen Wan District)

山泥傾瀉風險已經大幅減低。另一方面，在都市化影響下，越來越多的發展項目靠近陡峭的天然山坡。因此，天然山坡的山泥傾瀉風險與日俱增，其風險水平與人造斜坡相若。因此，土力工程處在 2007 年着手籌劃「長遠防治山泥傾瀉計劃」，把工作擴展至天然山坡的山泥傾瀉風險緩減工程，以合理可行的方法，將山泥傾瀉的風險盡量減低。

2005 年及 2008 年的兩場暴雨，令天然山坡山泥傾瀉的問題更備受關注。在 2005



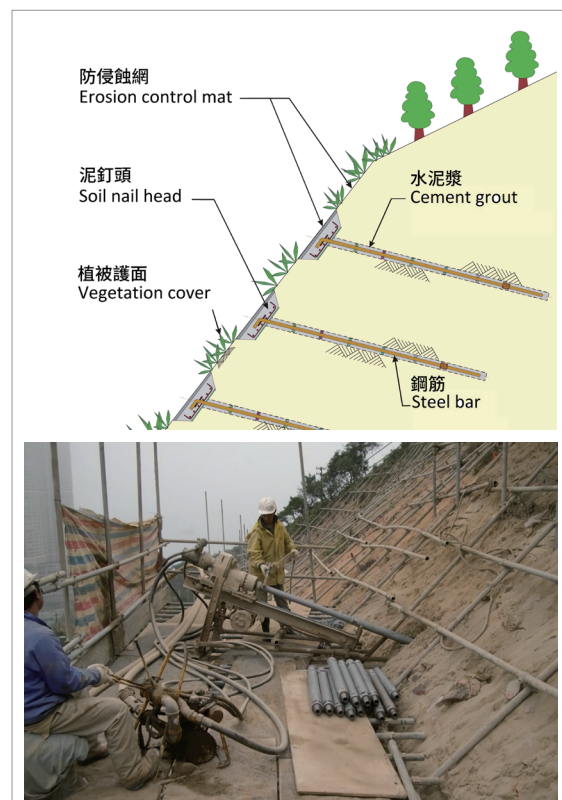
↑ 西大嶼山引發了多宗天然山坡山泥傾瀉。(At the western part of Lantau Island alone there were numerous incidents of natural terrain landslides)

in Hong Kong from time to time, the government had been focusing its resources on man-made slopes since the LPMP was implemented in 1977. This was because a considerable number of substandard slopes had not yet been stabilized in those early days and were of relatively higher risk due to their proximity to residential buildings and busy roads.

After 30 years of hard work, the overall risk of landslides for man-made slopes was significantly mitigated. On the other hand, the landslide risk from natural hillsides was now comparable to the risk from man-made slopes, due to the encroachment of more urban developments on steep natural hillsides. In light of this, in 2007, the GEO started working on the Landslip Prevention and Mitigation Programme (LPMitP) to extend its work to the mitigation of natural terrain landslide risk, aiming to further reduce the risk of landslides in Hong Kong by practicable measures.

The issue of natural hillside landslides was brought to public attention by the rainstorms in 2005 and 2008. A total of 229 landslides resulting from the rainstorm from August 16 to 22, 2005, was reported, including a series of natural hillside failures in different parts of the territory on August 20.

On June 7, 2008, a 4-hour rolling rainfall of 384 mm was recorded at Lantau Island, triggering more than 2,400 natural terrain landslides in the area. One landslide blocked a 200-meter section of the North Lantau Highway with soil debris and muddy water, causing the closure of this artery that connected the city to the Hong Kong International Airport for as long as 16 hours. In the same morning, 13 landslides were reported in the Tai O area, with debris volume ranging from 25 to 2,000 cubic meters, blocking the roads to Tai O. The



↑ 泥釘工作原理(上)及建造泥釘現場環境。(How soil nails work (upper) and how they are constructed on site)

二十一世紀

在香港，天然山坡山泥傾瀉時有發生，但由於早年仍有很多不合標準的人造斜坡尚未鞏固，而且這些人造斜坡大多靠近住宅樓宇和繁忙道路，風險相對較高，所以政府的「防止山泥傾瀉計劃」自 1977 年推行以來，一直集中資源處理人造斜坡。

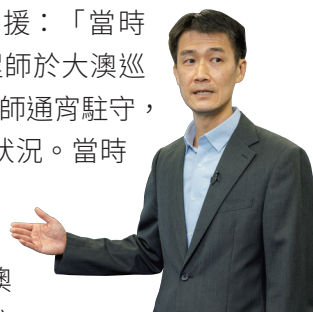
經過 30 多年的努力，人造斜坡的整體

年 8 月 16 至 22 日，土力工程處共接獲 229 宗山泥傾瀉報告，包括在 8 月 20 日發生接連多宗與天然山坡有關的山泥傾瀉。

2008 年 6 月 7 日，大嶼山 4 小時內錄得的最高雨量達 384 毫米，單在大嶼山就引發了 2,400 多宗天然山坡山泥傾瀉。連接市區與機場的北大嶼山公路有 200 米路段因天然山坡山泥傾瀉而被泥石及洪水淹蓋，截斷了通往機場的重要運輸通道長達 16 小時。同日早上，大澳共有 13 宗山泥傾瀉報告，塌下的山泥體積由 25 立方米至 2,000 立方米不等，堵塞了大澳通往外間的道路，加上流動及固網電訊設備均出現故障、食水供應中斷，數以千計居民的生活大受影響。

土力工程處副處長（九龍及新界）岑家華憶述 2008 年大嶼山泥傾瀉之後

如何為居民提供支援：「當時我們派出 18 名工程師於大澳巡查，並安排 3 名工程師通宵駐守，以便隨時即場評估狀況。當時同事幾乎每天都早出晚歸，靠輪船進出大澳。白天在大澳調查崩塌的山坡和安



↑ 岑家華副處長 (Lawrence Shum, Deputy Head of the GEO)

排緊急維修，並勸喻居民撤離受泥石崩塌影響的居所。晚上還要趕回辦公室處理文件，爭取盡快開通道路及修復受損設施。如是者，忙了一個月後，來往大澳的道路終於通車，居民可以回復昔日生活，我們才放下心頭大石。」

為了全面地處理好天然山坡和人造斜坡的山泥傾瀉風險，土力工程處於 2010 年開展「長遠防治山泥傾瀉計劃」。由於天然山坡的覆蓋範圍比人造斜坡大得多，在天然山坡進行大規模的斜坡鞏固工程，勞民傷財之餘，對自然生態亦有嚴重影響。如果採取風險緩減措施，例如透過山坡下的泥石壩和柔性防護網阻擋塌下的泥石湧入民居或道路而造成傷亡，除了成本較低之外，還可以避免

damages to mobile and fixed-line telephone networks and the water mains added to the nightmare of thousands of residents.

Lawrence Shum, Deputy Head of the GEO (Mainland), recalled how they provided support to the Tai O residents after the landslides in 2008. He said, “We sent 18 engineers to Tai O for site inspection and had 3 engineers stationed there so they could make immediate on-site evaluations when required. At that time, my colleagues travelled to and from Tai O by ferry early in the morning and late at night nearly every day. By day, we inspected landslides and arranged for urgent repair works. We also urged residents to evacuate from affected buildings. At night, we went back to the office to handle the relevant paperwork, aiming to restore public services disrupted by the landslides as soon as possible. After working day and night for over a month, we were so relieved when the roads leading to Tai O were finally restored and the Tai O residents could resume normal life again.”

To manage the landslide risks of both natural terrain and man-made slopes in a more holistic manner, the GEO launched the LPMitP in 2010. As natural hillsides cover a much larger area than man-made slopes, it would have been both costly and environmentally damaging to stabilize natural hillsides on an extensive scale. Using risk mitigation measures such as rigid barriers or flexible barriers to prevent debris from reaching houses or roads and resulting in casualties not only comes at a lower cost, but also avoids undue impact to the environment.

As of the end of September 2022, some 6,450 government man-made slopes have been stabilized, with risk mitigation measures implemented for more than 400 vulnerable natural hillsides and safety screening studies



↑ 泥石壩 (Rigid barrier)



↑ 柔性防護網 (Flexible barrier)

對環境造成不必要的影響。

截至 2022 年 9 月底，土力工程處已鞏固了約 6,450 幅政府人造斜坡，為超過 400 幅天然山坡完成風險緩減工程，並為約 6,350 幅私人人造斜坡完成了安全篩選研究。

自土力工程處成立後，山泥傾瀉導致的死亡人數已大幅減少，香港自 2008 年起已經再沒有出現奪命的嚴重山泥傾瀉事故。時至今日，「山泥傾瀉」這標題只是偶然在媒體中出現，但這並不表示市民可以因而掉以輕心。

優化管理 應對挑戰

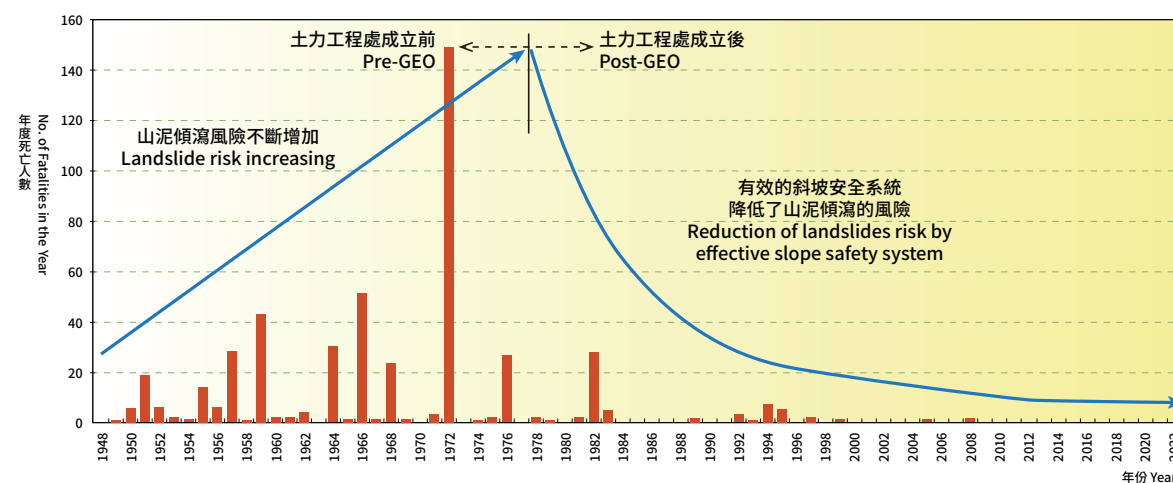
近年，全球暖化令極端天氣加劇的問題迫在眉睫。以往天文台總部每小時雨量破紀錄的

completed for about 6,350 private man-made slopes.

Since the establishment of the GEO, fatalities caused by landslides have dropped substantially and Hong Kong has not seen a fatal landslide since 2008. Nowadays, the topic “landslide” only appears occasionally in the media. However, this does not mean that the public can overlook the risk of landslides.

Embrace Challenges with Enhanced Management

In recent years, extreme weather fueled by global warming has become an ever more urgent issue. The hourly rainfall record as



↑ 山泥傾瀉導致的死亡人數 (Number of fatalities caused by landslides)



↑ 土力工程師在山泥傾瀉現場視察 (Geotechnical engineers inspect a landslide site)

情況數十年才發生一次，但最近十數年卻屢破紀錄。為了應對極端天氣帶來的挑戰，並抓緊創新科技所帶來的機遇，土力工程處從預防、應變和教育等三方面做好準備：

1. 居安思危：持續鞏固及維修斜坡以抗禦特大暴雨，並透過研究山泥傾瀉事件及運用

↓ 在斜坡鞏固工程中加入綠化元素 (Greening measures in slope upgrading works.)



reported by the Hong Kong Observatory Headquarters used to take decades to break. In the last decade or so, however, that record has already been rewritten several times. To combat the challenges of extreme weather and to take advantage of the opportunities made possible by innovation and technology (I&T), the GEO is taking a three-pronged approach, namely prevention, preparedness and education:

1. Planning Ahead: continuous stabilizing and maintenance of slopes to counteract extreme rainstorms; investigating landslide incidents and making use of I&T to review slope safety policies and technologies for continuous enhancement of the slope safety system of Hong Kong.
2. Enhancing Emergency Preparedness: understanding how nature works and learning to live in harmony with it; enhancing emergency preparedness to cope with the rise in overall landslide risks due to urban development, slope

- 創新科技，不斷檢討斜坡安全的政策和技術，從而優化香港的斜坡安全系統；
2. 掌握先機：了解大自然運作及學懂與之共存之道，提升應變能力以應對因城市發展、斜坡老化和極端天氣帶來整體山泥傾瀉風險的上升；
3. 防災避險：加強社區應對山泥傾瀉風險的警覺和知識。

當天文台發出山泥傾瀉警告或八號或以上熱帶氣旋警告信號時，土力工程處的緊急控制中心便會啟動，由一共十三隊以土力工程師及技術主任所組成的專責隊伍輪班當值。接獲山泥傾瀉報告後，他們會無懼風雨到現場視察，協助各政府部門

進行緊急工程，務求盡快恢復受影響的公共服務。土力工程處近年亦建立了「聯合運作平台」，提升各政府部門實時共享緊急資訊的能力，以協助政府評估災情及調配緊急服務，為市民提供適時協助。



↑ 許海航副處長 (Thomas Hui, Deputy Head of the GEO)

除應對極端天氣帶來的挑戰，土力工程處更致力在鞏固斜坡的工作中加入綠化及生態保育等元素，使斜坡與周邊環境融為一體，並建立一個能維持生物多樣化的生態環境。土力工程處副處長（防止山泥傾瀉）許海航表示：「我們會盡量保留原有植物並採用原生物種重鋪人造斜坡植被或修葺山泥傾瀉殘痕。若發現工程範圍或其附近存在稀有動植物品種，我們會對其加以保護，並在有需要時進行生態調查。」

degradation and extreme weather.

3. Building Resilience: stepping up outreach and education efforts to raise public awareness of landslide risks and how to respond in such situations.

When a landslide warning or typhoon signal number 8 or above has been issued by the Hong Kong Observatory, the GEO will activate its Emergency Control Centre, which is manned by one of the 13 dedicated teams of geotechnical engineers and technical officers on a rotational basis. If a landslide report is received, geotechnical engineers will brave the wind and rain to reach the scene to assist government departments in conducting emergency works so that public services can be restored as soon as possible. In recent years, the GEO has also developed the Common Operation Picture, which is a platform for real-time sharing of emergency information to facilitate the government's assessment of the situation and enhance the coordination of government departments' emergency responses to provide timely assistance to members of the public.

Besides combating the challenges of extreme weather, the GEO also adopts greening and conservation measures in slope upgrading works so that the slopes blend in with the surrounding environment and foster biodiversity. Thomas Hui, Deputy Head of the GEO (Landslip Preventive Measures) said, "We'll try our best to keep the original plants and use native species for restoring vegetation covers on man-made slopes or landslide scars wherever practicable. If we find rare animal and plant species within or near the project area, we'll exercise special care to conserve them and conduct an ecological survey if needed."

創新技術 與時並進迎挑戰

Innovation and Technology to Tackle Challenges

不斷求進 居安思危

在過去數十年間，土力工程處的工程人員除了不斷提升專業技能和應變能力之外，還引入及自行研發了不少嶄新的斜坡安全技術，令香港的斜坡安全較五十年前大大提升。土力工程處副處長（港島）張秉業表示：「我們將創新科技的發展及應用定為重點工作，成立督導委員會制訂相應策略。我們選定了四個主要的科技領域去發展應用項目，包括機械及自動化技術、數碼科技、人工智能及嶄新技術。我們希望在提升服務質素之餘，亦能與業界產生協同效應。」土力工程處亦成立了專家審核小組，鼓勵業界在制定工程方案時積極引入創新科技。



↑ 張秉業副處長 (Sammy Cheung, Deputy Head of the GEO)

寶珊排水隧道

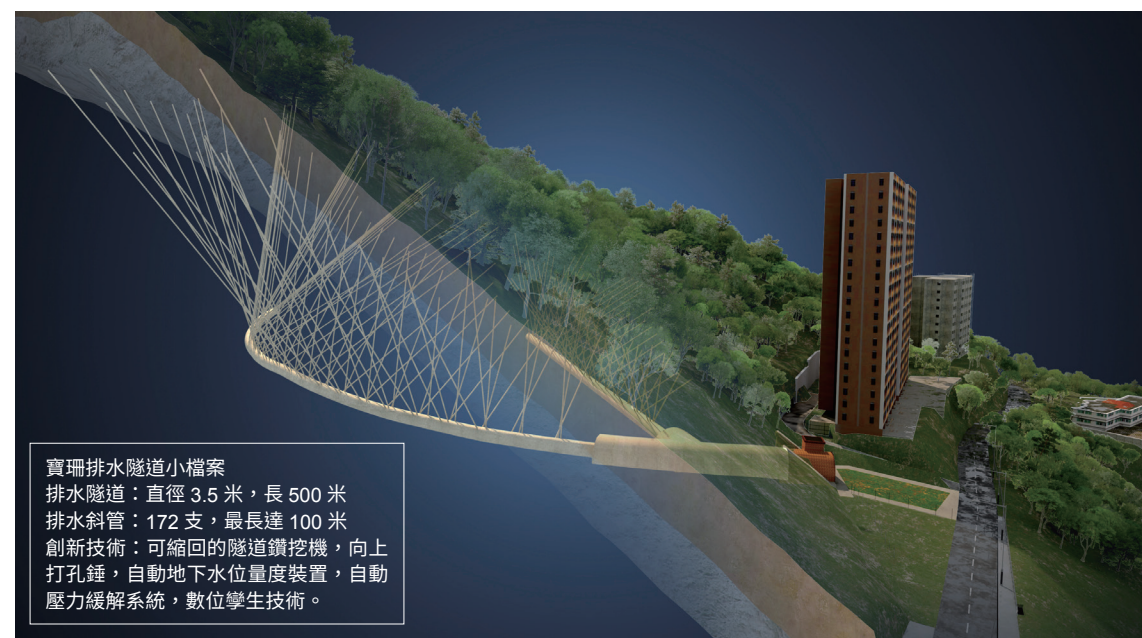
為了令 1972 年寶珊道的大規模山泥傾瀉不再重演，土力工程處設計及建造了寶珊排水隧道，以創新的地下水位調控系统控制該地段的地下水位。當排水斜管壓力計的數據超過預設值，系統中的虛擬「雙胞胎」會即時向工程人員通報，令他們可以迅速調節水位，減少發生大型山泥傾瀉風險。

Planning Ahead with Continuous Improvements

In the past few decades, engineers at the GEO have been enhancing their professional skills and emergency preparedness while introducing and developing various innovative slope safety technologies. As a result, slope safety in Hong Kong has significantly improved compared to 50 years ago. Sammy Cheung, Deputy Head of the GEO (Island), said, “We've given high priority to the development and application of innovation and technology. A steering committee has been established to formulate relevant strategies. We've identified four key technological areas for implementing various projects, namely automation and robotics, digital technology, artificial intelligence and novel technology. We hope to enhance our services while creating synergy with the industry.” In addition, the GEO has established an Expert Panel to encourage and facilitate practitioners in bringing new innovative solutions into the practice.

Po Shan Drainage Tunnel

To prevent large scale landslides like the 6.18 Landslide Disaster at Po Shan Road from happening again, the GEO designed and built the Po Shan Drainage Tunnel, which uses an innovative groundwater regulation



寶珊排水隧道小檔案
排水隧道：直徑 3.5 米，長 500 米
排水斜管：172 支，最長達 100 米
創新技術：可縮回的隧道鑽挖機，向上打孔錘，自動地下水位量度裝置，自動壓力緩解系統，數位孿生技術。

↑ 寶珊排水隧道的原理 (How the Po Shan Drainage Tunnel works)

智能泥石壩

智能泥石壩系統主要由安裝在泥石壩上的物聯網裝置組成。土力工程處副處長（規劃及標準）楊暉女士解釋智能泥石壩如何運作：「泥石壩一般位於天然河道或山坡，所以堆積在泥石



↑ 楊暉副處長（上）講解智能泥石壩如何運作（下）(Jenny Yeung, Deputy Head of the GEO [upper], explains how the Smart Barrier [lower] works.)

system to control the groundwater level in the area. When the readings from the manometers of the sub-vertical drains exceed a preset threshold, the virtual “digital twins” of the Drainage Tunnel in the system will immediately identify the location(s) and notify the GEO's engineers so that they can take prompt actions to regulate the groundwater level to reduce the risk of major landslides.

Smart Barrier

The Smart Barrier System comprises IoT (Internet of things) devices installed on debris-resisting barriers. Jenny Yeung, Deputy Head of the GEO (Planning and Standards), explained how it works. She said, “Many barriers are located at natural stream courses or hillsides, where accumulation of landslide debris behind the barriers may easily go unnoticed. We therefore developed the Smart Barrier System. When landslide debris hits the impact switches, the system will immediately send alert signals to the monitoring officers



↑ 無人機裝有自行開發的播種器，配合香港的情況。(The drone is equipped with a seeder developed specifically for Hong Kong's environment.)

and continue to provide them with data and images for arranging follow-up actions. The officers can also command the system to collect additional real-time measurements and images remotely, thus enabling us to take prompt actions in case of emergency situations.”

Using Drones for Inspection and Seeding

To avoid losing time-critical data, the GEO uses drones to quickly reach landslide sites for inspection and to collect data for three-dimensional modelling. In addition, the Office started to try broadcasting seeding by drones in 2019 to revegetate landslide scars at remote pilot sites, with a view to speeding up the restoration of vegetation on natural hillsides.

Introduction of Robotic Dogs

The GEO introduced two robotic dogs, known as “SPOT”, to Hong Kong in August 2020. Local I&T companies were engaged

使用無人機勘察及播種

土力工程處亦借助無人機在斜坡崩塌後第一時間搜集山泥傾瀉的數據，製作三維圖像，

壩後方的泥石難以被察覺。有見及此，土力工程處研發「智能泥石壩」系統，當感應器被泥石撞擊時，系統會即時向監察人員發出警報，並持續將數據和影像傳送給他們，以便適時安排跟進行動。監察人員亦可控制系統以收集更多實時數據和影像，令部門能更快地應對緊急的山泥傾瀉事故。」



↑ 機械狗 (Robotic dog)

以免重要資料隨時間消失。此外，他們由2019年開始試驗以無人機在偏遠山坡的山泥傾瀉殘痕上播種，希望加快植物生長，令天然山坡得以盡快回復天然原貌。

引入機械狗

土力工程處於2020年8月從外地引入兩隻機械狗，並與本地科創公司合作，訓練機械狗在山泥傾瀉現場收集數據，並利用測量儀器取得數據製成三維地形數碼模型。工程人員可以遠程控制機械狗進行視察，並將現場影像即時回傳至緊急控制中心。

斜坡安全 攜手維護

土力工程處十分着重提高市民對斜坡安全的認識，希望他們多加留意山泥傾瀉警告，對風險保持警惕。他們亦透過公眾教育和屋宇署發出的「危險斜坡修葺令」，以助私人斜坡的業主履行維修斜坡的責任。

土力工程處近年在寶珊排水隧道內設立「山泥傾瀉科技展學館」，並定期舉辦導賞參觀，向公眾傳達斜坡安全的重要性。

to train the robotic dogs so that they can collect important information from landslide sites for 3D digital landscape modelling. Engineers can remotely steer the robotic dogs to survey the site and transmit real-time images to the Emergency Control Centre.

Concerted Efforts for Slope Safety

The GEO places great emphasis on raising public awareness of slope safety, reminding residents to pay attention to landslip warnings issued on rainy days and to remain vigilant. The Office also helps ensure that owners of private slopes meet their responsibility of slope maintenance through public education programs and “Dangerous Hillside Orders” issued by the Buildings Department.

In recent years, the GEO set up the Landslide Sci-Tech Chamber inside the Po Shan Drainage Tunnel, offering regular guided tours to convey the importance of slope safety to the public.



↑ 斜坡安全巡迴展覽 (A roving exhibition of slope safety)

無懼風雨 維護香港斜坡安全

半個世紀以來，土力工程人員一直緊守崗位，致力維護香港的斜坡安全，與市民風雨同渡。全賴他們多年的努力，近年山泥傾瀉發生的

次數和規模，以至傷亡人數都大大降低。

香港許多地區皆屬丘陵地貌，城市發展往往要在靠近斜坡的地方進行，甚至需要開墾山坡。經過多年以來的風吹雨打，部分斜坡亦開始老化，加上極端天氣帶來更頻密的特大

暴雨，山泥傾瀉的風險依然存在。市民除了在下雨天要特別留意山泥傾瀉的風險並遠離斜坡之外，日常生活中亦應該養成綠色低碳的生活習慣，令極端天氣減少出現，從而降低山泥傾瀉的風險。

展望將來，土力工程處會繼續無懼風雨維護香港的斜坡安全，並透過公眾教育令更多市民，尤其是年輕一輩，時刻注意山泥傾瀉的風險，將知識薪火相傳。



↑ 探訪居所位於斜坡附近的村民。
(Outreach workers visit people who live near slopes)

Serving with Dedication and Perseverance

In the past 50 years, geotechnical engineers have been serving the community with dedication to ensure slope safety in Hong Kong, weathering challenges together with the public. Thanks to their hard work through the years, the frequency and scale of landslides as well as related casualties have significantly decreased in recent years.

With a mountainous terrain, Hong Kong's urban expansion and development often encroach upon steep hillsides, in some cases even involving building on hillsides. After years of being exposed to the elements, some of the slopes have started to degrade. Coupled with increasingly frequent rainstorms brought about by extreme weather, the risk of landslides remains a possibility. Apart from remaining vigilant and staying away from slopes on rainy days, members of the public can contribute by practising a greener lifestyle, so as to help reduce the occurrence of extreme weather, thereby lowering the risk of landslides.

Looking ahead, the GEO will continue to maintain slope safety in Hong Kong, whatever the challenges. It will also continue to educate the public, in particular young people, to always be watchful of landslide risks, passing on the knowledge to our next generation.

土木工程拓展署網站：<https://www.cedd.gov.hk>

香港斜坡安全專題網站：<https://hkss.cedd.gov.hk>

Facebook 專頁：Geo Channel 土力場 <https://www.facebook.com/hkss.geo>

Instagram 專頁：Geo Channel 土力場 <https://www.instagram.com/ceddgeohk/>

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