Effects of Landslides and Mudflows Associated with
the May 1980 Eruption of Mount St. Helens,
Northwestern U. S. A.

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INTRODUCTION

The immediate cause of the 18 May 1980 eruption of Mount St. Helens (fig. 1), a 2,950-m
volcano in the Cascade Mountains of the northwestern United States, was the collapse of the
bulging northern sector of the cone of the volcano, which had been weakened by earthquakes,
hydrothermal activity, and magmatic intrusion. This collapse immediately followed a magnitude-
5 earthquake and resulted in a 2.3-km³ rock slide that almost immediately degenerated into an
enormous, hot debris avalanche. Within about 10 minutes, avalanche lobes with an average
thickness of 45m, maximum thickness of 195m, and an accumulated volume of 2.8km³ had swept
some 24km down the valley of the North Fork Toutle River (fig. 2). About 60km² of this valley
was covered by hummocky-surfaced, poorly sorted debris ranging in size from clay to blocks
whose individual volumes were as great as several thousand cubic meters. The level of Spirit
Lake, a beautiful 5-km-long mountain lake north of the mountain, was catastrophically raised

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Figure 2. Index map of area near Mount St. Helens directly affected by the eruption of 18 May 1980.

60 m and water was displaced by avalanche material (Voight and others, 1981). In addition, the debris avalanche blocked tributaries to the North Fork Toutle River along this 24-km stretch, thus forming several new lakes.

During the next several hours, the debris avalanche was followed by floods of water derived from melted glaciers and snow. The inundation remobilized parts of the already saturated debris avalanche to form large debris flows/mudflows. (For sake of simplicity, I will refer to these debris flow/mudflow combinations as mudflows, even though that term is not completely accurate in this instance.) These mudflows continued downstream for 95 km beyond the toe of the debris avalanche, modifying a total of more than 120 km of river channel, including the main Toutle River and sections of the Cowlitz and Columbia Rivers (fig. 2) (Janda and others, 1981).

In addition to the mudflows derived from the debris avalanche, mudflows formed in other valleys from mixtures of catastrophically ejected coarse lithic debris, lapilli, ash, and possibly water and entrapped air, and from meltwater from debris-laden snow and ice on the slopes of the volcano (Janda and others, 1981). The largest of these mudflows coursed the entire length (45 km) of the South Fork Toutle River; from there, it flowed into the main Toutle River where
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it was joined by the mudflow from the North Fork (fig. 2). Smaller mudflows occurred in almost all drainages from the mountain, with significant flows along the Lewis River and its tributaries east and southeast of the mountain. This report discusses the effects of the debris avalanche and mudflows. Of particular note is the continuing danger of floods due to the potential for failure of the debris-avalanche blockages that have impounded the tributary lakes (including the new Spirit Lake).

EFFECTS OF THE DEBRIS AVALANCHE

Casualties

Although this catastrophic 2.8-km³ debris avalanche (fig. 3) ranks as the largest landslide within recorded history, it killed only 5-10 people. This low casualty rate was a direct result of the evacuation of residents and visitors from the area in anticipation of a possible eruption, major landslide, or both.

Destruction of Property

The area covered by the debris avalanche was noted both for recreation and commercial timber production. Spirit Lake was a haven for fishermen, campers, and sightseers; dozens of cabins and several lodges and campgrounds were situated along its scenic shoreline.

No major structures such as powerplants, large dams, or large buildings were located in the area overrun by the debris avalanche. However, civil works were affected as follows (Schuster, 1981):

1. Public and private buildings and attendant facilities in the vicinity of Spirit Lake were obliterated.

Figure 3. Debris avalanche in the upper valley of the North Fork Toutle River, southwestern Washington. View east from near the distal margin of the avalanche toward the devastated cone of Mount St. Helens, which is partially obscured by clouds in the left background. (Photograph by Austin Post, U.S. Geological Survey.)
2. Washington State Highway 504 was deeply buried from its terminus at timberline on Mount St. Helens to the end of the debris avalanche in the North Fork Toutle River valley, a roadway length of some 32km. Two major bridges were destroyed in this section of highway. In addition, many kilometers of U.S. Forest Service roads and private logging roads, five private bridges, and two U.S. Forest Service bridges were destroyed by the avalanche.

Potential for Floods

Until the surface of the debris avalanche has been covered by vegetation, it will be extremely susceptible to erosion. If the volume of eroded material washed downstream is large enough, it could reduce the size of the channels of the Toutle and Cowlitz River, resulting in increased likelihood of flooding of low-lying parts of the river valleys. To reduce the volume of sediment moving downstream, the U.S. Army Corps of Engineers, soon after the eruption, constructed a pervious embankment dam 1,300m long and 12m high on the North Fork Toutle River 2km downvalley from the toe of the debris avalanche. This dam served as a debris-retaining structure; water passed through it, but sediment was deposited in the reservoir. As of October 1981, about 7 million m³ of sediment had been excavated from this reservoir, and 1.5 million m³ had been removed from a similar, but smaller, structure on the South Fork Toutle River. However, because of lack of funds for continuing maintenance, both of these structures have failed, and sediment now moves downstream freely.

Tributary Lakes

The debris avalanche formed several new lakes by damming tributaries to and the main stem of the North Fork Toutle River, which was the outlet from Spirit Lake prior to 1980. The individual blockages could fail and cause severe downstream flooding (Jennings and others, 1981). As of July 1983, the only failures have been restricted to blockages holding back very small impoundments, resulting in minor flooding. However, three impoundments remain that are large enough to cause severe downstream flooding if released; these are Spirit, Coldwater, and South Fork Castle Creek Lakes (fig. 4). U.S. Geological Survey hydrologists are continuing to measure the levels of these lakes and the effects of the lakes on the ground-water levels in their debris blockages.

Spirit Lake is by far the largest of the three impoundments (August 1982 volume: 327 million m³) and has the broadest debris blockage (fig. 5). The debris avalanche raised both the basin

Figure 4. Map of area covered by debris avalanche (crosshatched) showing location of Spirit, Coldwater, and South Fork Castle Creek Lakes. These lakes were impounded by the debris avalanche.
floor and outlet of Spirit Lake; as of October 1980, lake level was approximately 60m below the lowest part of the crest of the embankment. At that time, the broad embankment was safe from

Figure 5. Truncated cone of Mount St. Helens in photograph taken on 24 May 1982, 2 years after the eruption. The west edge of Spirit Lake is in the left foreground and the broad debris-avalanche blockage that impounded the lake is at the foot of the mountain in the center of the photograph. Note the new dome growing in the crater. (Photograph by R.M. Krimmel, U.S. Geological Survey.)

Figure 6. Coldwater Lake and its debris-avalanche blockage, February 1982. Note bedrock spillway at left center of photograph and incised North Fork Toutle River flowing from right to left through the debris avalanche. (Photograph by R.M. Krimmel, U.S. Geological Survey.)
slope instability and piping, but Youd and others (1981) recognized that overtopping of the embankment by the rising lake could produce erosion and other serious problems in the future. By the summer of 1982, the rising lake level had reduced minimum freeboard to about 26m, indicating that overtopping (or piping of surface materials) possibly could occur during the next wet season. Either overtopping or piping could result in rapid breaching of the embankment and catastrophic flooding of populated areas downstream. Using a mathematical dam-break model, Swift and Kresch (1983) have arrived at a hypothetical flood/mudflow of catastrophic proportions if the Spirit Lake embankment were to breach. The peak discharge of the hypothetical flow down the North Fork Toutle River would be about 75,000m³/sec. Downstream towns on the Toutle and Cowlitz Rivers could be inundated to depths of as much as 20m. To stabilize the lake at a level low enough to prevent such a catastrophe, the U.S. Army Corps of Engineers, in the fall of 1982, installed 1,040m of 1.5-m-diameter pipe leading from Spirit Lake to the North Fork Toutle River. This culvert was laid just above lake level in a trench excavated into the embankment. Upon completion of the system, water was pumped from the lake through the culvert to maintain a constant lake level. This pumping scheme is intended to be only a temporary solution to the problem; in 1983, the Corps of Engineers plans to arrive at a long-term solution for maintaining lake level.

Coldwater Lake (fig. 6), if it had been allowed to overtop naturally, would have had an estimated maximum volume of about 128 million m³ by late 1981. To prevent overtopping and possible catastrophic breaching, the Corps of Engineers, during the summer of 1981, constructed a bedrock spillway for the lake which stabilized the volume at 83 million m³. Similarly, the volume of South Fork Castle Creek Lake is being maintained at about 24 million m³ by a spillway excavated through its blockage.

Because of continuing erosion and rising ground-water levels in the blockages, the just described measures do not guarantee the stability of any of the three blockages, particularly if a strong earthquake should occur in the area. For this reason, the U.S. Geological Survey is continuing study of the stability of the blockages in regard to erosion, piping, or slope failure. In addition, warning systems based on sudden drop of water level have been installed on each of the lakes.

EFFECTS OF MUDFLOWS

The largest and most destructive mudflows associated with the May 1980 eruptions were in the valleys of the North and South Fork Toutle River and in the Cowlitz River downstream of its confluence with the Toutle (fig. 2). However, mudflows along the tributaries of the Lewis River on the east, southeast, and south sides of the mountain were large enough to destroy forest roads and bridges and to flow into Swift Reservoir. Although these 1980 mudflows were
devastating in their impacts on channels and flood plains (fig. 7). they were smaller and less extensive than some Holocene mudflows from Mount St. Helens (Janda and others, 1981).

**Toutle River Mudflows**

Because mudflows in the valley of the North Fork Toutle River were formed primarily by remobilization of material in the debris avalanche, they affected the valley only downstream from the terminus of that feature. Conversely, the mudflow in the valley of the South Fork Toutle River (fig. 8) originated on the slopes of the mountain, and affected the entire length of the valley.

The Toutle River mudflows destroyed or badly damaged about 200 homes and had the following effects on civil structures:

1. About half of the 28km of Washington State Highway 504 in the valley of the North Fork Toutle River downstream from the terminus of the debris avalanche was buried under as much as 2m of sediment. Mudflows in this drainage also buried many kilometers of private logging roads and Cowlitz Country roads. In addition, 17km of private logging railway was destroyed. Most of the buried lengths of highways and roads were resurrected merely by removing the sediment. The railroad was abandoned, however.

2. The mudflows, and giant log jams they carried, destroyed or badly damaged 17 bridges (11 highway and 5 railway) in the Toutle River valley (example, fig. 9). Most of these were modern concrete and (or) steel structures, the longest being a 160-m steel-girder bridge spanning the Toutle River on Washington State Highway 504 near the town of Toutle.

3. Two large logging camps on the North Fork Toutle River and one on the South Fork were covered by as much as 2m of sediment. Much of the equipment in these camps was badly damaged (example, fig. 10).

4. Water-supply and sewage-disposal systems owned by residents, companies, and local governments along the Toutle River were destroyed or badly damaged.

**Cowlitz River Mudflows**

Mudflows from the Toutle River first issued into the Cowlitz River, about 70km downstream from Mount St. Helens, early in the afternoon of May 18, some 4–5 hours after the beginning of the main eruption. The first to arrive were those originating in the South Fork Toutle River valley. Although the mass of sediment and water coming from the Toutle River was diluted considerably by the large volume of water in the Cowlitz, it could still be classified as a mudflow as it passed down the Cowlitz (Janda and others, 1981). The mudflows and accompanying flood originally deposited more than 38 million m$^3$ of sediment in the Cowlitz River valley (Bechly, 1980). This total will continue to increase for several years as new sediment is washed into the Cowlitz from the mountain, the debris avalanche, and mudflows in the Toutle River valley. To restore the original channel and to remove new sediment, the U.S. Army Corps of Engineers, as of October 1981, had excavated about 43 million m$^3$ of sediment from the river.

The mudflow, flooding, and accompanying deposition of debris drastically affected operations of water-supply and sewage-disposal systems for cities and towns on the Cowlitz River flood plain.
For example, the water intake and treatment system for the City of Longview (population 30,000), which takes its water from the Cowlitz River 21 km downstream from the mouth of the Toutle River, was completely clogged by sediment and debris and was out of service for several weeks (Edtl, 1980).

**Sedimentation in the Columbia River**

The Cowlitz River mudflow and floods originally deposited about 34 million m$^3$ of sediment in the Columbia River 100–120 km upstream from where the Columbia enters the Pacific Ocean (fig. 2) (Bechly, 1980). This material can be considered part of the mudflow system; however, it consisted mainly of pumiceous sands and fine gravels, because most clay-and silt-size materials were distributed farther downstream or were carried into the Pacific Ocean.

An immediate effect of this sedimentation was the blocking of the Columbia River to ocean-going freighter traffic to and from the deep-water port of Portland, Oregon. During the next few months after the eruption, the Corps of Engineers removed some 11.5 million m$^3$ of sediment in dredging a new channel about 12 m deep and 180 m wide. The total amount of sediment removed from the Toutle, Cowlitz, and Columbia Rivers from May 1980 to October 1981 was nearly 77 million m$^3$.

The Trojan Nuclear Plant, with a rated electrical-power production of 1.13 million kW, is probably the most important civil-works structure along the segment of the Columbia River affected by sedimentation from the mudflow. This plant, which is located on the Oregon shore 8 km upstream from the mouth of the Cowlitz River, is cooled by water pumped from the Columbia River immediately adjacent to the plant. Soundings made a few days after the eruption showed that as much as 12 m of sediment had been deposited in the channel adjacent to the plant, resulting in a new bottom depth of only 11 m. However, because the intake structure for the cooling system was located at a

![Figure 9](image-url). The 75-m St. Helens bridge on Washington State Highway 504. A, before 18 May 1980 (photograph by D.R. Crandell, U.S. Geological Survey). B, after 18 May when it was washed out by the mudflow on the North Fork Toutle River. This steel structure was carried about 1/2 km downstream.

![Figure 10](image-url). Logging-company employee bus badly damaged and partially buried by mudflow on the North Fork Toutle River. Bus was unoccupied when hit by mudflow.
depth of only 3m, this posed no serious threat to the plant.

**Mudflows on the Lewis River and Its Tributaries**

Mudflows occurred in tributary valleys of the Lewis River on the east, southeast, and south sides of Mount St. Helens (fig. 2). These mudflows buried several kilometers of U.S. Forest Service recreational and timber-haul roads, and destroyed 16 bridges on these roads. However, the most serious hazard posed by these mudflows was to Swift Dam and Reservoir, which are about 15km south and southeast of Mount St. Helens (fig. 2). Swift Dam is a 156-m-high earthfill dam; it impounds a reservoir that had a gross capacity of about 930 million m³ before the eruption. Two years before the eruption, Crandell and Mullineaux (1978) noted that, if Swift reservoir were at maximum pool, a large mudflow entering the reservoir at high velocity could possibly create a wave large enough to overtop the dam and cause flooding downstream.

Based on the Crandell and Mullineaux recommendations, the reservoir was drawn down to a level 123 million m³ below maximum pool level during the spring of 1980, in anticipation of a possible eruption. The May 18 eruption sent 12.5 million m³ of sediment, debris, and water into the reservoir. This volume was handled easily by the lowered reservoir.

**CONCLUSIONS**

Civil works and operations in the vicinity of, and downstream from, Mount St. Helens were heavily impacted by the debris avalanche and mudflows associated with the 18 May 1980 eruption. Some of the effects of these mass movements are continuing and are still subject to mitigative studies and measures.

This report has described examples of the effects of landslides and mudflows on structures and other developments that are vital to the economic well-being of an entire region. Many of these effects were specifically predicted in volcanic-hazards assessments for Mount St. Helens and other volcanoes in the Cascade Range (for example, Crandell and Mullineaux, 1978). Now that these effects are within the experience of those who deal with land-use planning, there is hope that potential landslide and mudflow hazards associated with volcanic eruptions will no longer be disregarded but will help to guide future land-use planning in the vicinity of other volcanoes.

**REFERENCES**


1980年5月のセント・ヘレン山の火山噴火による
地すべりと泥流

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今年、9月14日、長野県西部玉川村周辺を震央とするマグニチュード6.9の直下型地震を原因として、御岳山に巨大崩壊が発生した。この巨大崩壊の外に何箇所かの大規模崩壊が発生し、死者行方不明者総数29名の犠牲者が出た。これら大規模崩壊を起因として岩屑流が発生したと伝えられており、発生機構について調査研究されているところです。

一方、米国セント・ヘレン山の火山噴火によっても巨大な岩屑流（debris avalanche）が発生したと伝えられており、この調査が続けられています。1983年7月、日本で、地すべり、土石流、土質基礎に関する、UNESCO Expertによる講演会が開催され、Schuster博士により、その概要が報告されました。このたび同博士からの講演内容が論文として地すべり学会に投稿されました。その論文の内容について概略報告したいと考えます。

1980年5月の火山噴火により、セント・ヘレン山に巨大崩壊が発生したが、崩壊発生前にマグニチュード5の地震があった。巨大崩壊は2.3km³の岩盤すぺり（rock slide）であり、巨大な岩屑流（debris avalanche）をもたらした。この岩屑流の堆積状況、平均厚さ45m、最大厚さ196m、土質2.8km³で、10分間に下流ノース・ホーク・タルト川の泥流42kmにわたって流下した。このためスピリット湖は60mも水位が上昇したほか、いくつかの新しいせき止め湖が形成された。

数時間後には、この岩屑流は、融水水、融雪水の氾濫水によって泥流となって流下している。

岩屑流は、その体積において歴史上最も大量のものであったが、わずかに5〜10名の犠牲者を出したにすぎなかった。これは当地域、噴火や地すべりの発生が予期される危険地域のため住民が少なかったことによるものである。

岩屑流の堆積土の表面は、植生が回復するまで極度の侵食が危惧されている。そのため、河川水路断面の減少に伴い洪水の発生が予想され、岩屑流堆積地帯末端から2kmのところに、長さ1,300m、高さ12mの透過堤防が建設された。この堤防は崩壊の堆積を促し、水のみ透過する機能のものとして建設されたが、貯水池内に著しい土砂堆積が見られている。

岩屑流によって、いくつかの新しいせき止め湖が形成されたが、そのうちスピリット湖、コクルドウォーター湖、NAUS・フォーク・キャップル湖（図-4）には、その破堤による洪水の危険が残されており、U.S.G.S.ではその洪水位の観測を継続している。

スピリット湖は上記三つのせきとめ湖のうち最大のもので、湖水位上昇による侵食や越流の危険が確認されており、せき止め湖破堤の際の洪水氾濫について、検討が実施され、そのときのノース・ホーク・タルト川でのピーク流量は75,000m³/secになると予想されている。そのため、U.S. Army Corpsは、スピリット湖の水位を一定に保つため1.5m直径のパイプを敷設した。しかしこの工事は一時的なもので、1983年に恒久対策の検討を始めている。

ノース・ホーク・タルト川の泥流は、主に岩屑流堆積層の再移動によるものであるが、NAUS・フォーク・タルト川の泥流は、セント・ヘレン山度面から発生している。このタルト川の泥流は200戸の人家を破壊した。

タルト川からの泥流は、5月18日の午後、主要の噴火の約4〜5時間後、セント・ヘレン山から70km下流のコクリッツ川に流入した。これら泥流の土塊は、コクリッツ川において、河川水によって希査化されると考えのも、コクリッツ川を通過するときはまだ泥流の挙動をなしており、38百万m³の堆積がコクリッツ川に見られた。

詳細な内容については紙面の都合上できませんでしたので、ぜひ原論文の一読をおおすすめする次第です。

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