



Swedish Civil
Contingencies
Agency

RESPONSE GUIDELINES FOR

Landslides



Response Guidelines for Landslides
Version 2.0/2013

Swedish Civil Contingencies Agency (MSB)

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Introduction

Natural disasters related to mass movements, such as landslides, can be complex and, therefore, difficult to risk assess. These response guidelines are intended as support for the analysis of risks and decision making during the emergency response operation. The guidelines are chronologically structured but the response measures and their sequence depend on the given situation.

The response guidelines include the following:

During imminent danger of landslides

Methodology for emergency response when there is an imminent danger of landslides.

During landslide emergencies

Methodology for emergency response during landslide emergencies.

Mass movement types

A brief guide to the most common mass movement types in Sweden classified by movement mechanism: description, where and when they can occur, triggering mechanism, effects, and warning signs.

Operational issues

A brief guide to zoning, evacuation signal, Assessment, Search and Rescue Levels, prioritizing strategy and marking.

During imminent danger of landslides

Work to the established response plan!

IMMINENT
DANGER

Warning signs

LISTEN OUT for cracking, rumbling, crunching sounds

PAY ATTENTION TO:

- Initial (minor) slides
- Erosion damage
- Poles, trees, etc. leaning in the same direction
- Newly developed/growing cracks
- Subsidence or bulges in the ground/buildings, e.g. doors and windows that will not open
- Breakages in pipes and cables in the ground
- Water escaping from the ground
- During rockfalls: loose boulders on the cliff face
- Sudden interruption in the flow of a watercourse, increased flow or water turbidity may indicate a fall/slide upstream

NOTE! There is more "Warning signs" information in the respective mass movement type sections (see *Mass movement types*).

Safety procedures

- Analyze and discuss only on safe ground
- If the ground starts to move:
 - Outdoors: evacuate to solid ground away from the direction of movement
 - Indoors (if impossible to get out): move away from windows and up to higher parts of the building; if impossible to escape, roll up like a ball and protect your head

Triggers

All activities that may trigger landslides must be avoided:

- increased load on the slope crest, e.g. parking of heavy vehicles
- reduced counterweight at the slope toe, e.g. excavation, erosion
- accumulation and infiltration of water into the ground (because of heavy precipitation, leaking water/sewage pipes, etc.)
- formation and subsequent bursting of landslide dams in watercourse (clear debris, redirect water)
- heavy disturbance/explosion/vibration

Imminent danger of landslides can be detected via:

- Unambiguous warning signs
- Measurement results (e.g. increased movement, increased pore pressure)

When there is an indication of a possible pre-stage to a landslide

- ✓ Take out available and relevant map data:
 - slope stability mapping
 - terrain/topographic maps
 - maps of built-up areas
 - soil maps

- map of grids (water/sewage, gas, electricity, telephones/data)
- map of protected and at-risk objects
- flood maps
- ✓ Analyze risks in the area, in consultation with a geotechnical expert, using support maps and observation. Pay particular attention to:
 - Topography of the immediate area
 - Slope elevation, angle and length
 - Soil type (clay or coarse-grained soil)
 - Presence of solid ground
 - If water is leaking out of the ground
 - Distance to watercourses and watercourse type, size, depth
 - Weather conditions
 - Distance to threatened objects/infrastructure and ongoing earthworks
- ✓ Assess if the situation is a pre-stage to a landslide and thus presents imminent danger

If the analysis of risks proves there is an imminent danger

- ✓ Identify and rank (according to probability, consequences and time frame) possible scenarios
- ✓ Establish the risk zone based on probable scenarios and cordon it off
- ✓ Warn the local population and evacuate the area if necessary

- ✓ Request shutdown of water/sewage, gas and electricity grids as needed. Ensure that there is feedback when the shutdown has been carried out!
- ✓ If there is a risk of explosion or an emission of hazardous substances, contact technical/environmental experts
- ✓ Inform municipal management and the relevant authorities and organizations
- ✓ Organize media information as needed
- ✓ Increase alert and preparedness level as the probable scenarios dictate
- ✓ Decide (in consultation with municipal management and geotechnical expert) on the possible need for geotechnical investigation and emergency soil-reinforcement measures
- ✓ Install (in consultation with the geotechnical expert) measuring and warning systems for monitoring
- ✓ Start a log-book including data for applications for compensation
- ✓ Observe and analyze possible future development of the event
- ✓ Analyze possible future development of the event
- ✓ Continually reassess the risk area
- ✓ When the imminent danger has passed, clarify the responsibilities of the land/property owner and inform them about the possible need for further measures

NOTES

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During landslide emergencies

Work to the established response plan!

✓ Warning signs for continued mass movement

LISTEN OUT for cracking, rumbling, crunching sounds

PAY ATTENTION TO:

- Steep scarps
- Ongoing erosion
- Leaning poles, trees, etc. behind the scarp
- Cracks, subsidence or bulges in the ground/buildings behind or adjacent to the landslide
- Doors and windows that will not open due to distortion
- Breakages in pipes and cables in the ground
- Water escaping from the ground
- During rockfalls: loose boulders on the cliff face
- Sudden interruption in the flow of a watercourse, increased flow or water turbidity may indicate a fall/slide upstream
- Debris that dams the flow of a watercourse poses a breakthrough risk
- Doors and windows that will not open

NOTE! There is more "Warning signs" information in the respective mass movement type sections (see *Mass movement types*).

Safety procedures

The following safety procedures should be common for all stakeholders and should, therefore, be communicated at an early stage of the operation:

- Formulate, record and communicate the evacuation plan to all emergency responders in the warm and hot zones
- Same way in and out of each sector (registration of all the personnel passing)
- Analyze and discuss only on safe ground
- Plan for the possible rescue of personnel in hot/warm zone from warm/cold zones (emergency teams, appropriate equipment)
- Always work in teams of at least two people (possibly connected to a safety harness and line in the warm zone)
- All emergency responders must be alert and communicate any changes in safety status
- If the ground starts moving:
 - Outdoors: evacuate to solid ground away from the direction of movement
 - Indoors (if impossible to get out): move away from windows and up to higher parts of the building; if impossible to escape, roll up like a ball and protect your head

Do not stay in landslide area longer than necessary!

Triggers

All activities that may trigger landslides must be avoided:

- increased load on the slope crest, e.g. parking of heavy vehicles
- reduced counterweight at the slope toe e.g. excavation, erosion

- accumulation and infiltration of water into the ground (because of heavy precipitation, leaking water/sewage pipes, etc.)
- formation and subsequent bursting of landslide dams in watercourse (clear debris, redirect water)
- heavy disturbance/explosion/vibration

Risks

All emergency responders must be aware of the following risks connected to landslide emergencies:

- continuous or renewed soil mass movement
- mud/debris flows
- flooding
- flood waves, for example, on the opposite shore
- steep, unstable slopes
- debris/sharp objects
- cavities under rubble
- live electrical cables
- building collapse and falling objects
- overturning vehicles
- local undermining of soil
- fall risks
- emissions of flammable and explosive substances, chemicals and hazardous dust, e.g. asbestos
- bursting of landslide dam and possible flood wave

En route to site

ASR Level 0: Research of affected area before arrival on site

- ✓ Open channels for information transfer to geo-technical expert
- ✓ Take out available relevant map data:
 - slope stability mapping
 - terrain/topographic maps
 - maps of built-up areas
 - soil maps
 - map of grids (water/sewage, gas, electricity, telephones/data)
 - map of protected and at-risk objects
 - flood maps
- ✓ Contact SOS for more information and state preliminary Forward Control Point, access route and any roadblocks
- ✓ Immediately requisition search dog teams
- ✓ Make an initial assessment of the need for additional resources
- ✓ Start a log-book including data for applications for compensation

At the incident site

- ✓ Relate first situation report to command support center

ASR Level 1: Wide Area Assessment

- ✓ Establish extent of affected area
- ✓ Assess the consequences of the incident (life, environment, property)
- ✓ Determine Emergency Response Objectives
- ✓ Notify the command support center about the location and extent of the affected area
- ✓ Identify mass movement type (see *Mass movement types*)
- ✓ Analyze risks in the area, in consultation with the geotechnical expert, using support maps and observation. Pay particular attention to:
 - Extent of the landslide
 - Whether the angle of the scarp is steep or gentle
 - Slope elevation, angle and length
 - Topography of the immediate area
 - Soil type: clay (loose or solid soil masses) or coarse-grained soil
 - Presence of solid ground
 - If water is leaking out of the ground
 - Distance to watercourses and watercourse type, size, depth
 - Weather conditions
 - Distance to threatened objects/infrastructure and ongoing earthworks

NOTE! Include additional risks in the analysis as per p.16

- ✓ Identify and rank (according to probability, consequences and time frame) possible subsequent scenarios based on the analysis of risks
- ✓ If the risk assessment proves that it is too dangerous to enter the area, conduct alternative measures as the situation allows

Before entering the risk area:

- ✓ Establish the risk zone based on probable subsequent scenarios; cordon off. Update continuously!
- ✓ Request immediate shutdown of the water/sewage, gas and electric grids. Ensure that there is feedback when the shutdown has been carried out!
- ✓ If there is a risk of explosion or an emission of hazardous substances, immediately contact technical/environmental experts
- ✓ Decide, establish, mark and communicate:
 - Forward Control Point
 - Approach routes to the FCP
 - Command post
 - Situation report
 - Zoning (see *Operational issues/Zoning*)
 - Evacuation plan:
 - Entry and exit routes
 - Evacuation signal (see *Operational issues/Evacuation signal*)
 - Safe sites

- Safety Officer
- Observers (assign to posts)
- Emergency teams for hot/warm zones
- Sectors (appoint officers) as needed
- Assembly points for the uninjured (also information point), injured and deceased
- Media information and photography/filming point
- ✓ Ensure registration of affected individuals
- ✓ Install warning-systems as needed
- ✓ Request medical assistance on behalf of the emergency responders on standby

When the risk area is entered:

- ✓ Evacuate the public as needed
- ✓ Position (set up landmarks, indicate on the map for the joint situation report)
- ✓ Collate data for missing persons
- ✓ Determine search prioritizing strategy (see *Operational Issues/Prioritizing strategy*)
- ✓ Carry out emergency geotechnical work as needed and take measures to reduce the risk of secondary effects

ASR Level 2: Sector Assessment

- ✓ Designate response personnel to go with search dog teams in order to mark and communicate victim finds to Command post
- ✓ Check first visible objects then entire area:
 - Identify and mark worksites (see Worksite marking, pp.49-50) and mark presence of any victims, life status and position (V marking, p.51)
 - **Object with no live or dead victims:** mark the object as clear (C marking, p.52)
 - **Object with no live victims:** indicate that the object only contains dead bodies (D marking, p.53)
 - Create a resources and logistics plan as a basis for potential requisition of additional resources, equipment and experts

ASR Levels 3-4: Rapid/Full Search and Rescue (worksites)

- ✓ Conduct search and rescue on identified worksites

NOTE! Stabilize as needed

- ✓ When an ASR level is completed or the operation is handed over: update marking on worksite (pp.49-50)
- ✓ Follow up: do the Emergency Response Objectives/ method/resources meet the need? Correct as needed
- ✓ Order meals, warm space, dry clothes etc. and organize personnel rotation
- ✓ When the imminent danger has passed, clarify the responsibilities of land/property owners and inform them about the possible need for further measures

Inform:

- ✓ Municipal management and the relevant authorities and organizations
- ✓ The public via mass media

Mass movement types

Falls

Coarse-grained soils or rock



Landslide in coarse-grained soil. Source: Geological Survey of Sweden archives/Nils Dahlberg

Description

- Very fast, sudden mass movement (free fall)
- Bedrock/boulders/rocks/gravel/sand fall, bounce, roll over each other and are crushed or bounce when they hit the ground
- Landslides in coarse-grained soils: most often on the surface, parallel to the slope
- Rockfall/rockslide: range depends on how the boulders hit the ground (crushed, bouncing) due to height, slope and speed

Where does it occur?

- On rock/coarse-grained soil
- On steep soil/rock slopes
- Along coasts/watercourses
- Where streams/rivers cut down into the sand layer (middle/northern Sweden)
- Rockfall/rockslide: in weathered, eroded or fractured bedrock



Rockslide. Source: Sunnmøre Police District

When does it occur?

In connection with:

- Temperature shifts around freezing point (0°C) (spring-autumn)
- Snow melt
- Heavy precipitation and high runoff (spring-autumn)
- Human intervention
- Steep riverbanks: dry periods, raised water table (spring flood)

Triggering mechanism

- Vibrations (e.g. blasting)
- Frost wedging/thawing
- Weathering
- Erosion at slope toe
- Changes in groundwater conditions
- Human impact, such as water control, excavation, blasting
- Root wedging

Effects

Falling material can:

- Be life-threatening and bury people
- Destroy and/or bury buildings/infrastructure
- Generate a flood wave; if the water is frozen: ice-floes can be crushed and thrown around
- Create landslide damming in watercourse resulting in:
 - an increase in the upstream water level (possible flooding)
 - risk of flood waves and downstream flooding as a result of any sudden breakthrough
 - blocked passage

Warning signs

- Erosion
- Growing cracks
- Sudden interruption or increased water flow may indicate a landslide upstream
- Small falls can be the prelude of a large fall
- Rockfall/rockslide: overhangs, loose boulders and cracks on the cliff face

NOTE! Be aware of the danger posed by fractured sections when temperature shifts around freezing point (0 °C).

NOTES

Mass movement types

Slides

Fine-grained soils



Landslide. Source: Swedish Geotechnical Institute

Description

- An initially coherent mass of soil that moves down a slope
- Suddenly and without warning or preceded by soil creeping/minor slide
- Very rapid progress
- Can cover very large areas
- Continuous sliding in a chain reaction until the topography and ground stability brings it to an end
- The type of continuous slide may depend on the position of the initial slide on the slope: higher up the slope they are usually advancing while further down they are usually retrogressive (there is an increased risk if the landslide deposits flow into a watercourse)

If QUICK CLAY

- Landslide deposits turn into a flowing, heavy fluid with no bearing capacity
- Landslide deposits (runout) flow over long distances across slightly inclined land



Quick clay slide. Source: Geological Survey of Sweden archives/Curt Fredén

- The slide can continue to solid ground
- Large areas can be affected

Where do they occur?

- On fine-grained soil (clay/silt)
- On the eroded banks of watercourses/lakes/coasts
- Usually, when the slope angle is greater than 1:10
- Particularly in the counties of Västra Götaland, Värmland, Västernorrland, Halland, Östergötland, Södermanland, Stockholm, Gävleborg and Dalarna
- Also in lakes/watercourses under the surface



Areas where landslides have occurred and ravines exist (clay/silt).
Source: Geological Survey of Sweden

If QUICK CLAY

- Particularly the West Coast, especially in the Göta river valley, but also on the East Coast, the southern Norrland coast and in Värmland
- Flatter areas further inland may be affected

When do they occur?

In connection with:

- Human intervention
- Erosion
- Snow melt
- Periods of heavy precipitation (spring-autumn)
- During low water levels in watercourses and lakes

Triggering mechanism

- Upsetting the equilibrium of the slope by:
 - reduced counterweight: e.g. erosion/excavation at slope toe, sinking water level in the adjacent watercourse
 - increased groundwater levels/saturated soil
 - increased ground load on the slope crest: e.g. heaps of soil or rubble
- Heavy disturbance

If QUICK CLAY

- NOTE! Initial slides in quick clay areas can trigger much larger slides

Effects

- Can be life threatening and bury people
- Buildings/infrastructure are broken up, buried, filled with landslide deposit/rubble, deformed, become unstable or collapse
- Can generate a flood wave; if the water is frozen: ice-floes can be crushed and thrown around
- Can cause landslide damming in watercourse resulting in:
 - increase in the upstream water level (possible flooding)
 - risk of flood waves and downstream flooding during any sudden breakthrough
 - blocked passage

If the ground is unstable, objects can continue to move in the landslide deposit

If QUICK CLAY

- A quick clay slide can move buildings and other objects hundreds of meters

Warning signs

- Soil/ground movements
- Initial (minor) slides
- Erosion damage
- Poles, trees, etc. leaning in the same direction
- Newly developed or growing cracks, subsidence or bulges in the ground/buildings
- Breakages of pipes and cables in the ground

- Water escaping from the ground
- Sudden interruption of flow in watercourses or increased flow may indicate a landslide upstream
- Increased turbidity in water courses
- Doors and windows that will not open

NOTE! Special attention is required in areas that have previously experienced landslides and during periods of heavy or prolonged precipitation.

If QUICK CLAY

- Initial slide in quick clay area
- Erosion/vibration

NOTES

Mass movement types

Moraine slides and debris flows



Moraine slide. Source: Swedish Geotechnical Institute

Description

- Sudden (without warning), very rapid mass movement
- Moraine slides: usually on the surface, parallel to the slope, can devolve into a debris flow

Debris flows:

- Masses of saturated soil, stone and organic material form a viscous liquid that slides down a slope
- High speed and long range
- Causes very severe erosion and gradually increasing volume: drags along or buries everything in its path (soil masses, rocks, boulders, vegetation etc.)

The masses accumulate in fan-shaped deposits that may be unstable

Where do they occur?

- On steep moraine slopes
- Debris flows: also in gullies/furrows filled with soil



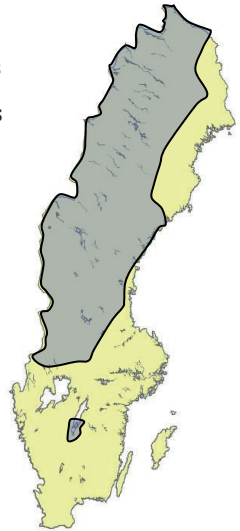
Debris flow. Source: Geological Survey of Sweden archives/Hanna Lokrantz

- Debris flows will typically reoccur in their previous furrows/existing channels
- NOTE! If channel is blocked, the debris flow can follow an alternative path, e.g. a road

When do they occur?

When the soil is saturated:

- After a period of heavy precipitation
- In conjunction with snow melt/heavy rain (summer)
- After removal of vegetation on slopes (logging, forest fires)



Triggering mechanism

- Moraine slides: upset slope equilibrium (decreased resistance/increased pressure)
- Debris flows: moraine slides in elevated, steep terrain

Topographic conditions for moraine slides and debris flows (gray zone). Source: Swedish Geotechnical Institute et al.

- Saturated soil, high surface runoff
- Extraordinary flows in small watercourses

Effects

Debris flows can be deadly and cause major injury and damage due to their sudden onset, high speed, the weight of soil masses, large kinetic energy and powerful erosion capacity that can include large items. They can:

- Bury people
- Destroy and/or bury buildings/infrastructure
- Create landslide dams in watercourses resulting in:
 - increase in the upstream water level (possible flooding)
 - risk of flood wave and downstream flooding during any sudden breakthrough
 - blocked passage

Warning signs

Moraine slides often occur without any obvious warning signs.

Debris flows:

- Rumbling noises and the sound of trees cracking and boulders knocking
- A trickle may precede a large debris flow

The following may be signs that a fall or slide has occurred upstream in a brook which will eventually result in a debris flow:

- Sudden interruption or increased flow
- Turbid water flow

Special attention is needed in areas where moraine slides and debris flows occur during:

- Heavy/prolonged or intense rainfall
- Snow melt
- After forest fires/logging

NOTE! It is particularly dangerous to stay in ravines and brooks at times when debris flows pose a threat.

NOTES

Operational issues

Zoning

Hot zone

Landslide area with risk of continuous movement.

Entry only if the risk assessment permits and then only for essential emergency services personnel.

Safety level: work in teams of at least two people, radio contact, emergency team in hot zone for possible rescue. No heavy vehicles.

Warm zone

Area where it is not possible to rule out the possible effects of landslide activity (soil movement) in the hot zone.

Safety level: radio contact, emergency team in cold zone for possible rescue.

Cold zone

Area where there is no landslide risk.

Safety level: no safety measures necessary.

IMMINENT
DANGER

EMERGENCY

FALLS

SLIDES

MORaine SLIDES
& DEBRIS FLOWS

OPERATIONAL
ISSUES

Evacuation signal

Evacuation: three short (1 second) blasts

— — —

Quiet in the area: one long (3 second) blast

—————

Resume work: one long (3 second) blast followed
by one short (1 second) blast

————— —

Assessment, Search and Rescue Levels

ASR Level 0: Research of affected area before arrival on site

ASR Level 1: Wide Area Assessment

ASR Level 2: Sector Assessment

ASR Level 3: Rapid Search and Rescue (worksites)

ASR Level 4: Full Search and Rescue (worksites)

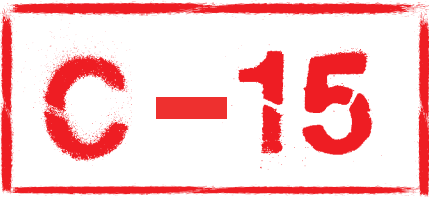
ASR Level 5: Total Coverage Search and Recovery

Prioritizing strategy

- Most people?
- Best access?
- Highest risk area?
- Greatest survival potential?

Marking

Worksite marking



Sector: **Charlie**
(capital letter)

Worksite: **15**
(number)

JT Officer in charge (OIC): **Johan Törnkvist** (initials)
ASR 2 ASR Level completed: **ASR 2**
03 Aug Date of completion: **3rd August** (DD MMM)
22:53 Time of completion: **22:53** (hh:mm)

Material: spray paint, fluorescent/builders crayon

Size: 50 cm

Color: strong with good contrast against the background

In the event of subdivision of a worksite:



Sector: **Charlie**
(capital letter)

Worksite: **15**
(number)

Sub-worksite: **b**
(small letter)

Arrow indicates loca-
tion of sub-worksite

JT

ASR 2

03 Aug

22:53

First unit

MB

ASR 3

04 Aug

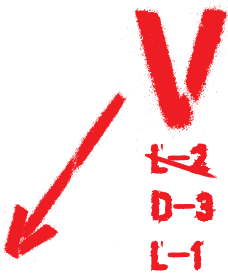
00:11

Second unit

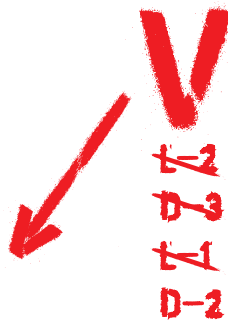
Marking to indicate life status and exact position of victims found at handover

- Large "V" indicates victim
- Marking is placed as close to victim as possible; if needed, optional arrow to clarify exact position of victim
- "L" indicates confirmed live victim
- "D" indicates confirmed deceased victim
- Digit indicates number of victims

NOTE! Note the hyphen between the letter and number.



- 2 live victims found,
1 rescued
- 3 dead victims found



- both live victims
rescued
- one dead body removed

Material: spray, fluorescent/builders crayon

Size: ca 50 cm

Color: strong with good contrast against the background

Rapid Clearance Marking following rapid and complete search establishing no live or dead victims

- A diamond shape with a large "C" indicates that the object is clear

NOTE! This marking is NOT used on worksites!



OIC: **Elma Svensson** (initials)

Date of completion: **4th August**
(DD MMM)

Time of completion: **00:22**
(hh:mm)

Material: spray paint, fluorescent/builders crayon

Size: approx. 20 x 20 cm

Color: strong with good contrast against the background

Rapid Clearance Marking following a rapid and complete search establishing that only dead bodies remain

- A diamond shape with a large “D” indicates dead bodies (Deceased)

NOTE! This marking is NOT used on worksites!



OIC: **Björn Magnusson** (initials)

Date of completion: **3rd August**
(DD MMM)

Time of completion: **22:55**
(hh:mm)

Material: spray paint, fluorescent/builders crayon

Size: approx. 20 x 20 cm

Color: strong with good contrast against the background

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