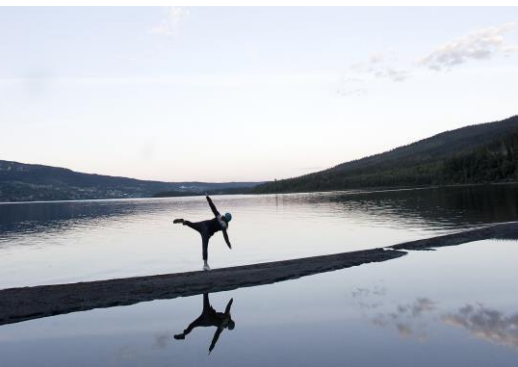


Sustainable Ground Construction

– an Action Plan in a Changing Climate



SGI Publication 35E

Document reference:
SGI (2017) *Sustainable Ground Construction – an Action Plan in a Changing Climate*. SGI Publication 35E,
Swedish Geotechnical Institute, Linköping.

Reference number: 1.1-1603-0231

Assignment number: 16081

Orders:

Swedish Geotechnical Institute
Information Service
SE-581 93 Linköping
Phone: 013-20 18 04
Email: info@swedgeo.se

Download this publication as a PDF document
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Sustainable Ground Construction

– an Action Plan in a Changing Climate

Foreword

You have before you the Action Plan for Sustainable Ground Construction in a Changing Climate. It examines the future through to 2030 and it has been produced based on the Swedish Geotechnical Institute (SGI) societal remit to develop and mediate knowledge about ground construction and land use. Sustainable ground construction is of vital significance to the growth and development of Sweden and the well-being of humanity and the environment. Land provides the physical conditions for housing, transport, industrial production and social services. Land also offers a multitude of ecosystem services that are central to the health and welfare of human beings. Sweden is about to embark on a major spatial planning process while at the same time climate change and heightened environmental considerations present new challenges that need to be addressed effectively within the public planning and civil engineering sectors.

In 2016, SGI conducted a survey of stakeholder requirements and views on how sustainable ground construction can be achieved. Discussions took place with some 200 stakeholders from more than 70 different organisations. I would like to express my sincere appreciation to them for all their valuable and perceptive contributions. It is obvious that everyone is firmly in agreement that Sweden must adapt planning, construction and management to the new climate conditions that are emerging. It is also clear that there is currently a lack of understanding of the impact of climate change, as well as a lack of risk assessment models and concrete guidelines for ground construction and its adaptation. If they are to deal with this situation, planners and clients must be given the means and information they require to lay down stipulations in conjunction with the procurement of new buildings or the management of existing buildings. Politicians must have the requisite planning and construction data and know-how at their disposal to reach the right decisions.

The Action Plan comprises SGI's work on climate change adaptation for sustainable ground construction and a survey of the ground construction initiatives taken by other public sector bodies. The Action Plan does not claim to be all-encompassing or regulatory, but instead aims to highlight the potential of working together to bring about sustainable ground construction from a holistic perspective. Resources are limited and fundamental mistakes need to be avoided as society adjusts to a changing climate. Community stakeholders affected by ground construction need to work together to initiate further action to adapt the building and civil engineering sectors to changing climate conditions. Greater awareness of the implications of climate change must permeate all our decisions.

It is my hope that the Action Plan will offer guidance on how greater account can be taken of the future impact of climate change on land and how geotechnical risks can be pre-empted or mitigated. No individual body can meet this challenge unaided and continued dialogue, expanded collaboration and improved coordination between stakeholders within building and civil engineering, public administration and research are essential to bring about sustainable ground construction.

I have every confidence that the Action Plan will be of benefit to you in your work, both now and in the future.

Linköping, February 2017



Åsa-Britt Karlsson, Director-General

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The Action Plan in brief

Climate change is expected to have serious implications for large sections of the infrastructure and the built environment. The vision adopted by the government for societal adaptation to climate variability and change is to develop a society that is sustainable and robust in the long term and which actively addresses climate change by alleviating vulnerability and capitalising on opportunities (Government Communication 2015/16:87). Spatial planning needs to take greater account of changes in ground conditions and the suitability of the ground for construction. Coastal communities must adapt construction practices to the rise in sea level and increased flows. Surface water management needs to be planned and adapted to changing climate conditions.

The Action Plan is a wide-reaching initiative aimed at promoting greater collaboration and to build on the outcome of a dialogue with some 200 stakeholders from more than 70 organisations in industry, public administration and academia, during which they presented their views on what needs to be done.

The purpose of the Action Plan is to provide a basis for concrete measures, future discussion and inter-agency collaboration within the geoconstruction sector, involving municipal authorities, regions and county councils, county administrative boards, the construction and civil engineering sector, national public sector bodies, colleges and universities and research institutes. The Action Plan highlights what needs to be achieved, how it can be achieved and who can take the initiative to ensure that different measures are implemented to ensure sustainable geoconstruction in a variable and changing climate. The measures decided on and how they can be implemented have been formulated based on proposals that have been put forward and the needs that have been conveyed by stakeholders and incorporated into the Action Plan. The formulation of the Action Plan draws particular support from the SGI directive relating to the remit to act as a driving force and to assume a coordinating role within the Institute's specific field of operations.

Vision 2050

The built environment in Sweden is adapted to climate change as well as the need by people to live and travel safely and with due consideration given on every level to the environment and nature. The interaction between development of the built environment and sustainable ground construction will contribute to a healthy and attractive living environment for people and at the same time it will safeguard the natural environment.

Goals 2030

- **A digital knowledge base** that focuses on ground conditions in a changing climate is in place for the whole of Sweden and is an integral part of spatial planning.
- Stakeholders in industry and public administration have sufficient **knowledge, expertise and capability** regarding sustainable ground construction to reach long-term decisions in which due consideration is given to ground conditions in a changing climate.
- **Ecosystem-based and resource-optimised solutions** that focus on ground conditions in a changing climate have been developed, are widely known and are used in conjunction with ground construction and the management of buildings and facilities.

Spatial planning

Physical planning is crucial to the robustness and flexibility of society to meet the consequences of a changing climate. Within spatial and physical planning, decisions made today will have ramifications in the long term and we must plan in a way that buildings and the infrastructure are adapted to changing physical conditions. The Action Plan contains proposals for how:

- Account can be taken of the effects of climate change on ground conditions on all planning levels.
- Digital maps can be created for ground-related risks in a changing climate.
- Increased support and guidance can be provided in conjunction with the interpretation and use of documentation regarding ground conditions.

Planning and construction

In planning and construction, account must be taken of changing climate loads. Methods for underpinning foundations and ground reinforcement must be adapted to new conditions. There is considerable potential for improving productivity by paying greater attention to ground conditions during construction and civil engineering work. The Action Plan includes proposals for how:

- Increased account of ground conditions in a changing climate can be integrated into the planning and building of new geoconstructions.
- Buildings, facilities, land and water areas can be planned and built in a robust way and with climate change as a key factor.

Management

Climate change adaptation of our existing buildings and infrastructure represents a challenge. It is also vital due to the extensive cultural heritage and cultural capital in general that is embodied in the structures. A large number of buildings and facilities are located in vulnerable areas and are not even adapted to the present-day climate. The Action Plan includes proposals for:

- How buildings and facilities can be given long-term protection against the effects of climate change on ground conditions.
- Who will assume responsibility for the different measures and who will meet the cost.
- How blue and green structures within and close to built-up areas can be used as a resource to increase resilience and protect against flooding.
- How a management model for changing shorelines can be established.

Demolition and reinstatement

As a result of climate change, there will probably be buildings, facilities and built environments which from an economic or safety point of view are not viable to adapt to a changing climate and which will need to be relocated. The effects of climate change could contribute to an increase in the spread of pollutants from contaminated areas and landfill sites. The Action Plan includes proposals for how:

- Support can be provided in the light of the future need to demolish and relocate a built environment.
- Risks and actions associated with contaminated areas can be assessed in the light of a variable and changing climate.

Build-up of knowledge

Research and development through collaboration between academia, the public sector and industry is a key factor when producing new knowledge about the effects of climate change on ground conditions and thus the constructability of the ground in a changing climate. The Action Plan includes concrete proposals for how:

- The effects of climate change on ground conditions and on new and existing geoconstructions can be developed.
- Knowledge about cost-effective, ground-related climate change adaptation measures for existing buildings and infrastructure can be developed.
- Improved conditions for the build-up of knowledge can be established within the framework of international collaboration.

Implementation and communication

SGI intends to pursue climate change adaptation work within geoconstruction based on the ambitions and timetable set out in the Action Plan. Implementation of the Action Plan will be founded on communication, coordination and suitable methodology for follow-up and evaluation.

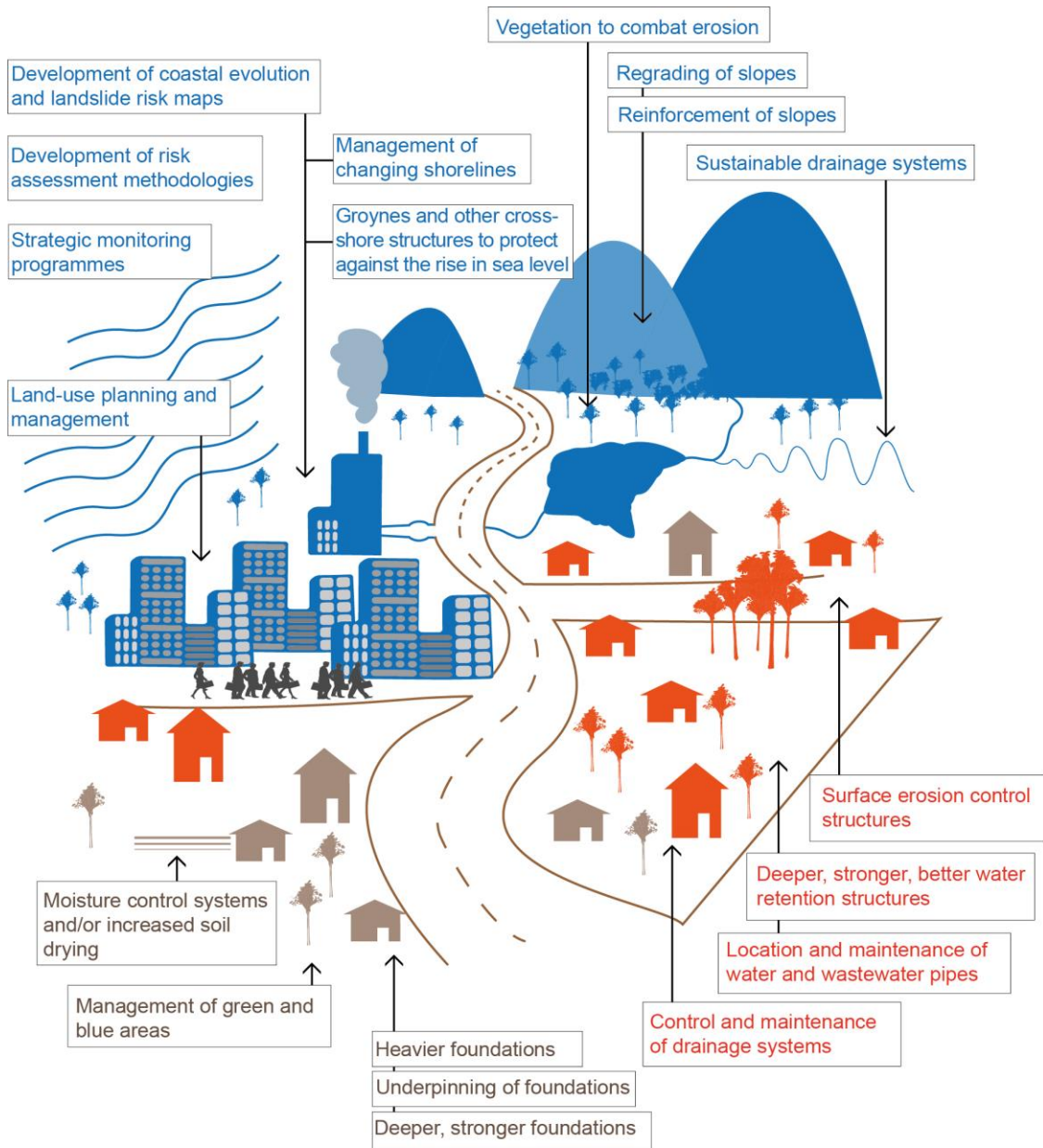


Figure 1 Illustration of potential measures for sustainable ground construction. Adapted from Shaw et al. (2007).

1. An initiative to promote greater collaboration

1.1 SGI's initiative

Climate change is expected to have serious implications for large sections of the built environment and infrastructure unless action is taken. Analysis of needs and appropriate measures must evolve through dialogue and collaboration. The Action Plan is a wide-reaching initiative aimed at promoting greater collaboration and is based on the outcome of a dialogue with some 200 stakeholders from more than 70 organisations in industry, public administration and academia, all of which had the opportunity to present their views on what needs to be done. The Action Plan has been circulated for consultation to almost 400 organisations (municipal authorities, national and regional authorities and agencies, regional governing bodies, county councils and representatives from industry and academia). The response in the almost 90 submissions has been overwhelmingly positive – not only with regard to the initiative for a joint action plan for the ground construction sector, but also for the holistic approach adopted in the Action Plan in relation to ground construction issues.

The design of the Action Plan is supported in particular by the SGI directive relating to its remit to act as a driving force and assume a coordinating role within its field of operations by identifying the current level of knowledge and mediating new knowledge in order to improve the effectiveness of the planning and construction process. The envisaged actions and how they can be implemented have been formulated in line with the proposals and needs conveyed by stakeholders who are involved in and affected by the Action Plan.

Throughout the entire planning and construction process, ground construction impacts on a number of different sectors and the responsibilities of other public sector bodies. The Action Plan intends to highlight the potential presented by working proactively to promote sustainable ground construction from a holistic perspective. By doing so, greater energy and momentum can be mobilised and our decisions will be permeated by greater awareness of the consequences of climate change.

SGI's directive

SGI is an administrative agency specialising in geotechnical and geoenvironmental issues. According to directive SFS 2009:945, SGI will act as a driving force in issues relating to safe, economic and environmentally adapted spatial development within the geotechnical field. Within the framework of its operations, SGI will also work to ensure that the national environmental quality goals are achieved and it will contribute with documentation and expert knowledge in the work being pursued by the government, both nationally and within the EU. SGI will contribute to improving the efficiency of the planning and construction process by producing new knowledge and new methods within its field of operations and assuming a coordinating role to identify the current level of knowledge and mediate new knowledge as it emerges. SGI will contribute to improving the efficacy and quality of the planning and construction process by drawing on its expertise to provide public sector agencies, municipal authorities and other bodies with advice and in collaboration with these organisations introduce new technology and apply the results that materialise from research and development.

1.2 Purpose and target group

The Action Plan for Sustainable Ground Construction aims to create a joint framework for the different stakeholders in society and with the fundamental challenge of adapting ground construction and the existing built environment to a variable and changing climate. Sustainable ground construction is an important prerequisite for future spatial planning and Swedish growth and development. No individual organisation can act in isolation and collaboration is vital.

Ground construction refers to all types of geotechnically related work associated with planning, construction, management and the demolition and reinstatement of buildings and facilities. The term ‘sustainable’ refers to resource-efficient, cost-effective ground construction using basic ecosystem mechanisms and human needs as a starting point.

The purpose of the Action Plan is to provide a basis for concrete measures, continued dialogue and collaboration between stakeholders who are affected by ground construction. The Action Plan target group comprises municipal authorities, regional bodies and county councils, county administrative boards, the building and civil engineering sector and national authorities and agencies that are involved in climate change adaptation work.

1.3 Points of contact with other initiatives and action plans

Prior to 2016, the government allocated specific funding to public sector bodies to develop action plans for climate change adaptation within their sectoral areas of responsibility. Funds have also been allocated for 2017 and a number of public sector bodies have produced action plans with support from grants from other sources.

The Action Plan for Sustainable Ground Construction is therefore part of the national structure for several action plans related to climate change adaptation. These climate change adaptation action plans have been produced by national bodies and are available via the Climate Change Adaptation Portal.

To date, Sweden does not have an overall national strategy and action plan for climate change adaptation although the government has announced that a strategy for the Swedish climate change adaptation programme will be launched within the current mandate period, i.e. by 2018 at the latest. In 2013, the European Commission adopted a climate change adaptation strategy for the European Union (EU) (COM (2013) 216). The EU climate change adaptation strategy will be renewed before 2018.

Regional action plans for climate change adaptation, produced by county administrative boards throughout the country, have been in place since 2014. The county administrative boards are responsible for coordinating regional climate change adaptation work. This involves compiling regional background material dealing with expected climate effects, and includes geoengineering issues. At present, local climate change adaptation plans are being developed by municipalities and by certain regions and county councils.

There are several action plans and/or strategies that are linked directly to the Action Plan for Sustainable Ground Construction. Implementation of these action plans presupposes that close collaboration is maintained between the organisations responsible. Apart from direct contact between the authorities, the Public Agency Climate Change Adaptation Network offers a forum for an exchange of experience and knowledge in conjunction with implementation of the measures.

The geodata strategy is a national plan that describes how an efficient geodata infrastructure can be created in Sweden (Swedish National Land Survey, 2016). The geodata strategy is of central significance to the availability of planning documentation for sustainable ground construction that is suited to purpose. It is stated in the geodata strategy that if geodata from public administration is to have full effect in the community, it must be easy to use and be readily available. With the aid of machine interfaces that offer long-term stability, access to geodata can be integrated into different operating systems.

The Action Plan is closely linked to the Swedish Transport Administration action plan for climate change adaptation of facilities and the management of the transport infrastructure. For the sake of clarity, where the measures affect soil stability – on road embankments for example – measures are also included in the SGI Action Plan.

For measures linked to drinking water and information about different types of land and rock, reference is made to the Geological Survey of Sweden Geological Survey of Sweden action plan and to the Swedish National Food Agency Handbook on Drinking Water Supply. The National Food Agency also intends to produce a climate change adaptation action plan during 2017.

In the Action Plan for Sustainable Ground Construction, risks and measures in contaminated areas are linked to climate change. For measures with associated means of control and socioeconomic ramifications associated with the national management of contaminated areas, reference is made to the Swedish Environmental Protection Agency national plan for allocation of government subsidies for post-treatment (Swedish Environmental Protection Agency, 2016) and to the Swedish Environmental Protection Agency's proposed staged objectives for post-treatment of contaminated areas (Swedish Environmental Protection Agency, 2013).

The Action Plan for Sustainable Ground Construction also touches on the action plans prepared by the Swedish Forest Agency, the Swedish Board of Agriculture and the Sami Parliament, and where ground conditions in a changing climate are a key element. Measures related to forestry operations that are dependent on ground conditions are dealt with in the Action Plan although climate change adaptation measures within the forestry sector are mainly dealt with in the Swedish Forest Agency action plan. The effects of climate change on forests and the need to adapt forestry operations are presented by the Swedish Forest Agency (Swedish Forest Agency, 2016).

As regards land use in agriculture, the need for climate change adaptation measures is addressed in the Swedish Board of Agriculture action plan. Land use, e.g. in the form of buffering using meadowland located close to built-up areas to improve the capacity to deal with the consequences of serious weather events such as flooding (Swedish Board of Agriculture, 2016 and 2013), have a direct bearing on sustainable ground construction and presuppose close collaboration with stakeholders in the agricultural sector.

For work on preserving biological diversity and ecosystem services in a changing climate, reference is made to the Swedish Environmental Protection Agency action plan 'Preservation and Sustainable Utilisation of Biological Diversity in a Changed Climate' (Swedish Environmental Protection Agency, 2015).

Climate change also affects our cultural heritage and a change in ground conditions could give rise to physical damage to buildings and the landscape. For details of the work on climate change adaptation linked to cultural heritage, reference is made to the Swedish National Heritage Board action plan 'Climate Change Adaptation and Energy Efficiency' (Swedish National Heritage Board, 2015).

The National Board of Housing, Building and Planning is a national agency for public planning, construction and living. Its activities include the provision of advice and the mediation of knowledge to planners and other parties working with public planning or construction, including

climate change adaptation issues. The National Board for Housing, Building and Planning has also published a number of reports linked to climate change adaptation (National Board of Housing, Building and Planning, 2016, 2011).

The Action Plan does not address initiatives aimed at taking account of land use based on competing demands. Nor does it include measures for how old Water Court rulings affect the scope for development and construction in attractive locations.

The purpose of the Action Plan does not include proposing measures linked to possible changes in legislation, or how the legislation can be applied. Nor does the purpose of the Action Plan include highlighting uncertainties in ownership, right of disposal or responsibility for a particular issue. The need for possible adapted legislation and responsibility will be handled in the government enquiry 'Reinforced Work for Adaptation to Climate Change' (Committee Directive 2015:115).

2. In what way do we need to adapt ground construction?

2.1 Challenges and opportunities

Climate change is expected to have serious consequences for the majority of buildings and infrastructure. The government's vision for societal adaptation to a changing climate is to develop a society that is sustainable and robust in the long term and which actively combats climate change by alleviating vulnerability and capitalising on opportunities (Government report 2015/16:87). Society will also work to mitigate the risk of disasters in accordance with the international Sendai Framework for Disaster Risk Reduction 2015-2030 (UNISDR, 2015). Spatial planning also needs to take account of new ground conditions and the suitability of land for construction. Sustainable ground construction will have a clear impact on 11 of the 17 global goals set out in the UN Agenda 2030 (United Nations, 2015). The need for solutions to deal with the effects of climate change also provides scope for innovation in the form of new products and services. Concrete examples are slopes, infrastructure and the foundations of buildings that need to be adapted to changing groundwater levels and water flows. A further example is coastal communities that need to adapt construction to rising sea levels or increased flows. Sweden can lead the way towards sustainable ground construction in a changing climate. By generating new knowledge and new solutions, export opportunities can be created, benefiting Swedish trade and industry and promoting employment. Establishing conditions for more coordinated and effective initiatives to address climate change adaptation of ground construction is vitally important.

Nowadays there is widespread awareness of climate change and there is a great deal of knowledge and data to support climate change adaptation work. And yet climate change adaptation work is still hampered by uncertainty in many areas as we do not know how the climate or society in the future will evolve. The climate scenarios that have been set out contain areas of uncertainty and will change in line with advances in research and the degree to which society succeeds in mitigating emissions. Climate change adaptation for sustainable ground construction will therefore focus to a certain extent on making far-reaching decisions and identifying flexible solutions under uncertain conditions.

2.2 Climate change adaptation and sustainable ground construction

The climate is changing (Swedish Meteorological and Hydrological Institute, 2015). Wetter winters and drier summers will affect ground conditions and the risk of flooding in already developed areas, and it will be even more important that ground conditions are secured in conjunction with new development. The effects of climate change will also change the conditions for deciding where it would be appropriate to build from a sustainability point of view, where buildings and infrastructure should be located, and how they should be dimensioned and designed, including choice of materials. We need to adapt our cities and buildings to cope with higher temperatures and changes in precipitation. A number of coastal communities and infrastructures in southern and central Sweden will be highly vulnerable to the effects of rising sea levels. This could lead to widespread costs resulting from damage and the loss of natural and cultural values. The construction sector is one of the largest industrial sectors in Sweden, with an annual turnover of more than 530 billion kronor. The built environment, with homes, buildings of cultural and historical importance, roads, railways and other facilities and properties, make up around half of the national wealth in Sweden (Swedish Construction Federation, 2015).

It is important to highlight opportunities in the light of the challenges facing sustainable ground construction. There is scope for innovation, such as the development of models to facilitate decisions relating to how a change in land use can be integrated into the planning process, as well as robust constructions, construction materials, new company and marketing models, processes for transforming waste into resources, facilitation of non-toxic ecosystem services, and cost-effective systems for mapping and monitoring changes in ground conditions. Sustainable ground construction thus offers both challenges and opportunities in spatial planning.

The constructability of land is related, among other things, to geological and geotechnical properties, soil contaminants, the risk of landslides, rockfalls and erosion and the risk of subsidence and flooding, as well as ecological functionality.

2.3 The impact of climate change on ground conditions and the constructability of land

Climate change affects ground conditions and consequently a large number of geoconstructions and the constructability of land are also affected. The term geoconstructions refers to supporting or bearing constructions that consist entirely of soil or rock, or the function of which is dependent on the properties of the surrounding soil or rock. Examples of geoconstructions are the foundations of buildings and infrastructure, natural or constructed slopes, naturally adapted and more traditional erosion protection, infills, excavated material, piling, steel sheet piling, supporting walls and landfill.

Climate change means that geoconstructions are increasingly exposed to changing load levels due to changes in the groundwater level, changes in water flows into the sea, lakes and watercourses, changes in water flow below and on the land surface, and changing drought and frost conditions. The demands that are currently being made in terms of dimensioning and construction need to be adapted to changing loads. A number of shoreline areas are already unsuitable for habitation and construction. Further land areas are in need of extensive preventive and adaptive measures if they are to be suitable places for people to live and for buildings to be constructed. In Sweden, there are around 80,000 suspected contaminated areas, of which 1,800 are deemed to pose a major threat to human health and the environment. The effects of climate change could in different ways intensify environmental risks and health risks in contaminated areas and landfill areas. This applies not only to the bioavailability, toxicity and mobility of the contaminants, but also to how they are transported and spread.

Higher groundwater levels cause a reduction in soil stability and an increase in pressure on geoconstructions. This could lead to reduced protection against landslides and rockfalls on natural and constructed slopes, reduced protection against breaching of support constructions, and a reduced level of protection of underground constructions against land heave. Reduced groundwater levels could result in subsidence in loose soil and porous bedrock and reduced resistance in constructions. They could also cause organic material, such as timber piles, to rot. In the case of fluctuating groundwater levels, the leaching and spread of contaminants could increase. A change in groundwater conditions could also be of significance to processes such as the degradation and deposition of contaminants by impacting on parameters such as oxygen supply and biological activity.

Increased flows in watercourses affect the capacity of the water to loosen and transport soil, which could result in increased erosion along the watercourses. The erosion could in turn lead to the increased spread of contaminants. Measures taken to prevent erosion in areas that are particularly prone to erosion is a problem that could have subsequent effects both upstream and downstream. Erosion generates low resistance on the slopes leading down to a watercourse, thus reducing protection against landslides and rockfalls. Increased water flows could also cause erosion around geoconstructions where the foundations are located in the watercourse itself, which could jeopardise their functionality. Reduced water flows that result in low water levels could reduce resistance on slopes leading down to a watercourse, thus reducing the level of protection against landslides and rockfalls.

Increased water flows on and below the land surface could result in increased erosion, ravine formation, landslides and rockfalls. It could also lead to an increased risk of internal erosion and the removal of material in layered soils and porous rock. These processes could result in a weakening of geoconstructions, as well as subsidence and an increased spread of contaminants from polluted areas.

Higher sea levels and water levels in lakes lead to an increase in the load on geoconstructions that were previously above the water surface and which are now exposed to water erosion. Geoconstructions below the ground surface, such as piles and foundations, are exposed to greater pressure. Storms, with strong gusts of wind in combination with high water levels, sometimes lead to short-term yet powerful flooding and erosion, which would require substantial margins to be incorporated when dimensioning and carrying out maintenance. The continuous rise in the sea level along the coasts of southern Sweden will persist for several centuries at least. Conversely, low water levels lead to reduced pressure on geoconstructions. This could result in lower resistance on slopes, thus heightening the risk of landslides and rockfalls and reducing the stability of support constructions.

Erosion along the coast results in significant sediment transport and soil loss. In the areas where the eroded material accumulates, ground conditions are changed substantially due to the increase in soil volumes. If measures to prevent erosion are taken in the area where erosion poses a problem, this could have consequences at the former deposition sites along the coast. A change in water flows into the sea and into lakes also gives rise to changes in sediment transport. A continuous influx of material from inland areas to the coast is a key feature in many low-lying coastal areas if the coastline is to be maintained. If the influx of material is reduced, the ground conditions at the estuary will gradually change. In combination with rising sea levels, the loss of land could increase. Ground conditions in coastal areas are also affected by measures taken to prevent erosion upstream in watercourses that flow into the sea.

A higher average annual temperature in combination with long periods of low precipitation or no precipitation, could lead to drought, which in turn could result in vegetation withering and dying. This would lead to a reduction in the protective effect of vegetation against erosion of the land surface. A change in average temperature could affect both the chemical processes (such as gaseous emission of volatile substances) and the toxicity of the contaminants. Shorter periods of ground frost and more ground frost periods would affect geoconstructions. This could take the form of bearing problems for roads, railways and airports, and the foundations of constructions exposed to wind being affected as a result of greater sensitivity to storms during the winter.

For industrial and historical reasons, many contaminated areas are located beside lakes and watercourses. This means there could be locations that are particularly vulnerable to soil movement, erosion and flooding, which would lead to the risk of an increased spread of contaminants. The effects of climate change could heighten vulnerability to natural disasters of this nature. When assessing environmental and health risks in contaminated areas and the need for remediation measures, it is important to take account of the geotechnical conditions and the effects that a changing climate could entail.

New geoconstructions need to be built that are robust and durable and which are dimensioned in a way that they resist future climate loads throughout the whole of their lifespan. Existing geoconstructions also need to be upgraded or protected to withstand future climate loads during the remainder of their lifespan.

It is important that spatial planning in the years to come proceeds in a way that account can be taken of future climate loads and geotechnical and geoenvironmental risks. There is a considerable need for research and development initiatives to provide the support and recommendations sought by county councils and municipal authorities.

3. Action plan for sustainable ground construction

3.1 Vision and goals

The vision behind the Action Plan is focused on 2050 as part of the establishment and implementation of Swedish and international climate policy goals (UNFCCC, 2015). The goals in the Action Plan are focused on 2030 in order to link into and contribute to the goals set out in the UN Agenda 2030 and the Sendai Framework. The assessment made by SGI is that it could have a significant impact on Sweden achieving 11 goals and 30 targets in UN Agenda 2030 (SGI, 2016). For many of the targets, current initiatives at SGI are sufficient but for several others there is considerable potential for them to have a greater impact and make a greater contribution, which is clarified in the measures set out in the Action Plan.

The measures in the Action Plan for Sustainable Ground Construction are focused on 2020 and will contribute to meeting the Swedish environmental goals, particularly two environmental quality goals: Good built environment and Non-toxic environment. The Action Plan has a direct bearing on the interim objective of achieving a more holistic view of land use and the need for coordination within state administration to be reinforced.

Vision 2050

The built environment in Sweden is adapted to climate change as well as the need by people to live and travel safely and with due consideration given on every level to the environment and nature. The interaction between development of the built environment and sustainable ground construction will contribute to a healthy and attractive living environment for people and at the same time it will safeguard the natural environment.

Goals 2030

- **A digital knowledge base** that focuses on ground conditions in a changing climate is in place for the whole of Sweden and is an integral part of spatial planning.
- Stakeholders in industry and public administration have sufficient **knowledge, expertise and capability** regarding sustainable ground construction to reach long-term decisions in which due consideration is given to ground conditions in a changing climate.
- **Ecosystem-based and resource-optimised solutions** that focus on ground conditions in a changing climate have been developed, are widely known and are used in conjunction with ground construction and the management of buildings and facilities.

3.2 Public planning

Physical planning is of crucial significance to how well buildings will be adapted to a changing climate. The physical environment often sets the limit for how robust and flexible society is in meeting the effects that ensue from a changing climate. Within the spatial planning and physical planning, decisions made today will have implications in the long term, and we must plan in a way that buildings and infrastructure are adapted to changing physical conditions. Climate change affects ecosystems and ground conditions both directly and indirectly through changes in land use (Swedish Environmental Protection Agency, 2015). To achieve success, account must be taken on all planning levels, from the regional level down to the detailed level, for construction on and in the ground. Water planning must be included. In order to develop appropriate climate adaptation solutions on the regional and municipal level that are sustainable in the long term, basic knowledge of how the ground is affected by climate change is needed, likewise knowledge about the effects of the measures that have been taken to date.

What needs to be done?

- Ensure that the long-term effects of climate change on ground conditions are taken into account on all planning levels (regional plan, comprehensive plan, local plan, area stipulations, road and rail plans).
- Produce digital maps that describe ground conditions in a changing climate.
- Provide increased support and guidance when interpreting and using digital documentation that describes ground conditions.

How can it be achieved and who will take the initiative?

The effects of climate change on ground conditions on all planning levels can be integrated.

- SGI produces guidelines as a basis for the planning work conducted by municipalities and county councils dealing with how future climate loads can be taken into account in conjunction with ground construction and how they can be handled in conjunction with the drawing up of comprehensive plans and local plans.
- SGI continues to develop the ongoing work by supporting municipal authorities and county councils in the planning process with regard to geotechnical safety issues and by taking into account climate changes.
- SGI develops the public authority network for coastal erosion in order to satisfy the needs of municipalities, county councils and other public sector bodies.
- SGI works in collaboration with municipalities to produce guidelines to determine which demands on the suitability of the ground for construction ought to be incorporated in the planning phase and in building permits.
- SGI develops guidelines to provide local authorities with support early on in the planning phase to weigh up conflicting goals and development potential for ecosystem services at specific locations.

- The county councils, working in collaboration with SGI and the water authorities, develop knowledge and working methods related to how sustainable ground construction can be integrated with water planning on all levels as part of the planning process for buildings and other community structures.
- The municipalities plan in a way that account is taken of the effects of climate change on ground conditions, as well as flood risks and surface water management in the long term, both in general terms and in the detailed planning of buildings and other community structures.
- Municipalities plan for buildings and facilities with due regard given to the distance to water.
- County councils and municipal authorities stipulate that risks linked to contaminated zones within the planning areas are assessed based on the long-term effects of climate change.

Digital maps for ground-related risks in a changing climate can be produced.

- SGI continues to map and make available documentation related to landslide risks along exposed watercourses and shorelines in the present and future climate.
- SGI, in collaboration with the Geological Survey of Sweden, the Swedish Meteorological and Hydrological Institute and the Swedish Civil Contingencies Agency, develops methods for estimating the effects of climate change on ground conditions.
- SGI, in collaboration with the Swedish Meteorological and Hydrological Institute and other authorities concerned, produces scenarios regarding the effects of climate change on ground conditions.
- SGI, in collaboration with the Swedish National Land Survey, the Swedish Civil Contingencies Agency, the Geological Survey of Sweden, the Swedish Association of Local Authorities and Regions and the Swedish Transport Administration, continues to develop and disseminate information about the geoengineering portal.
- SGI, in collaboration with the Geological Survey of Sweden, the Swedish Civil Contingencies Agency, the Swedish National Land Survey and the Swedish Meteorological and Hydrological Institute, develops instruments for conducting general surveys dealing with vulnerability to erosion along relevant sections of the coast and on lakes and watercourses. This will be based on the Swedish Meteorological and Hydrological Institute documentation dealing with expected highest sea levels and on the documentation commenced by the Geological Survey of Sweden dealing with erosion conditions along the coasts.
- SGI, in collaboration with the Geological Survey of Sweden, the Swedish Meteorological and Hydrological Institute, the Swedish Civil Contingencies Agency, the Swedish National Land Survey and other agencies concerned, continues to harmonise its data and documentation regarding landslides, rockfalls and erosion and make the documentation available.
- The Geological Survey of Sweden, in collaboration with SGI, maps the areas where there could be quick clay.
- The Geological Survey of Sweden, in collaboration with SGI, the Swedish Civil Contingencies Agency and the Swedish National Land Survey, produces a mapping plan for landslides, rockfalls and erosion.

- The Geological Survey of Sweden, in collaboration with SGI, makes available in digital form existing planning documentation for underground constructions in larger towns and cities and investigates the need for further documentation in the light of undertakings that are classified.
- The Swedish Civil Contingencies Agency continues to carry out general stability surveys with due consideration given to climate change and making these available digitally.
- The Swedish National Land Survey and the Swedish Maritime Administration continue to map and keep information up to date according to the National Shoreline Development Plan.
- The Swedish Maritime Administration, in collaboration with the Geological Survey of Sweden and the Swedish National Land Survey, produces documentation for a national survey programme aimed at creating high-resolution data relating to shorelines and coastal zones, equivalent to the new height data model for use on land.

Increased support and guidance in conjunction with the interpretation and use of documentation dealing with ground conditions can be provided.

- SGI investigates the potential for increasing the capacity to provide views on and support for plans that are developed on the local and regional level, and with the requisite account taken of the shortened referral and consultation time in the planning process.
- SGI continues to work on developing guidelines for naturally adapted erosion protection.
- SGI, in collaboration with the Geological Survey of Sweden and the Swedish Civil Contingencies Agency, prepares an overview of existing guidelines related to ground conditions in order to incorporate a long-term perspective into a changing climate.
- SGI, in collaboration with the Swedish Civil Contingencies Agency and the Geological Survey of Sweden, develops guidelines specially adapted to municipal authorities and county administrative boards for how documentation dealing with the effects of climate load on ground conditions can be interpreted and used in spatial planning.
- The Swedish Forest Agency, in collaboration with SGI, develops guidelines for how the effects of climate change on erosion can be addressed through adapted forestry practices and adapted vegetation in ravines and on steep slopes.

3.3 Planning and construction

During planning and construction, account must be taken of changing climate loads. Foundation and ground reinforcement methods must be adapted to new conditions. There is considerable potential to improve productivity by taking greater account of ground conditions during construction and civil engineering work. There are also societal savings to be made by reducing the cost of damage resulting from errors and shortcomings in the construction process. If the geotechnically related cost of damage arising in conjunction with construction could be reduced by 10 per cent, this would mean an annual saving to society of almost one billion kronor (SGI, 2013). The cost of damage and loss could increase if the effects of climate change on ground conditions are not factored into the construction process. Geotechnical errors and shortcomings could also lead to fatal injuries. Preventing this type of damage and injury could lead to substantial savings. Uncertainty or shortcomings in the data and documentation on geological and geotechnical conditions are important factors behind the cost of damage and injury.

What needs to be done?

- Integrate considerations relating to ground conditions in a changing climate into the planning and building of new geoconstructions.
- Buildings, facilities, land and water areas are planned and built robustly, with due account taken of a changing climate.

How can it be achieved and who will take the initiative?

Taking greater account of ground conditions in a changing climate can be incorporated into the planning process for new geoconstructions.

- SGI maps the causes and consequences of a failure to take account of climate loads in relation to geoconstructions in an effort to prevent the cost of damage from rising.
- SGI examines how more extensive geotechnical support can be offered to municipalities in complicated building permit cases.
- SGI, in collaboration with the construction and civil engineering industry, produces guidelines on how clients can take account of changing climate loads when planning and dimensioning geoconstructions.
- SGI, in collaboration with the Swedish Civil Contingencies Agency, municipalities, the construction industry and colleges and universities, prepares an overview and adapts existing geotechnical documentation requirements to different investigation levels based on ground conditions in a changing climate.
- SGI, in collaboration with the Swedish Meteorological and Hydrological Institute and other authorities concerned, produces scenarios related to the impact of climate change on new and existing geoconstructions.
- SGI, in collaboration with the construction and civil engineering industry, evaluates, and if necessary updates, existing models for stability computation as well as the expected effects of stability-improvement measures on ground conditions in a changing climate.

- The Geological Survey of Sweden, in collaboration with SGI and other stakeholders concerned, investigates how underground construction can be used as a climate change adaptation measure for new and existing buildings.
- The construction and civil engineering industry continues to develop and use new digital models (construction information models), in which account is taken of ground conditions, as a source of support in planning, construction and management.
- Municipalities, property owners and property developers make demands in conjunction with the planning and procurement of development projects to ensure account is taken of the fact that ground conditions will change as a result of the effects of climate change.
- The Swedish Transport Administration creates robust transport facilities by adapting functional requirements governing new constructions and redevelopment of the transport infrastructure to a changing climate.

Buildings, facilities, land and water areas can be planned and built with account taken of climate change.

- SGI, in collaboration with industry representatives and the Swedish Standard Institute, works to develop and revise standards within the construction sector to ensure they are adapted to a changing climate.
- SGI, in collaboration with the Swedish Transport Administration, produces a tool for assessing the robustness of different foundation and reinforcement methods in a changing climate.
- SGI, in collaboration with industry representatives and municipalities, develops various tools in order to be able to weigh up building costs, climate change adaptation and environmental consequences in conjunction with underpinning of foundations.
- The Swedish Meteorological and Hydrological Institute, in collaboration with SGI, the National Board of Housing, Building and Planning, the Swedish Civil Contingencies Agency, the Swedish Environmental Protection Agency and the Swedish National Heritage Board, carries out a preliminary study of the potential for working systematically with climate change adaptation within the framework of public procurement.
- The Swedish Transport Administration, in collaboration with SGI, the National Board of Housing, Building and Planning and the construction industry, reviews and possibly adjusts estimated lifespans for constructions and materials based on climate changes.
- The Swedish Transport Administration identifies, analyses and continuously reduces climate-related risks as an integral part of the maintenance, new construction and redevelopment of facilities.
- Municipalities and property owners make demands for climate-adapted solutions through the public procurement process and in dialogue with developers.
- The building and civil engineering industry takes the initiative to adapt Swedish classification systems and frames of reference for a built environment to a changing climate.
- Research funding bodies, in collaboration with the construction and civil engineering industry and public sector bodies, support innovations and the development of climate services within spatial planning.

3.4 Management

Adapting existing buildings and infrastructure to a changing climate is a challenge. But it is also vital in the light of the extensive cultural heritage and cultural capital in general that they embody. A large number of buildings and facilities are located in vulnerable areas and are not even adapted to the present-day climate. Adapting existing structures is costly. Strategies and solutions need to be developed for how buildings and facilities can be renovated and adapted cost-effectively to a changing climate. It can also involve adapting the immediate surroundings by employing various protective measures to reduce the risk of negative impact in the form of injury to human beings and harm to natural and cultural values. Many measures could ideally be taken in conjunction with normal maintenance and new investment. Climate change will lead to shorter intervals between the inspection, operation and maintenance of buildings.

What needs to be done?

- Give buildings and facilities long-term protection against the effects of climate change on ground conditions.
- Clarify who is responsible and who will cover the cost of different measures.
- Use blue and green structures within and close to built-up areas as a resource for increased resilience and protection against flooding.
- Establish a management model for changing shorelines.

How can it be achieved and who will take the initiative?

Buildings and facilities can be given long-term protection against the effects of climate change on ground conditions.

- SGI, in collaboration with the authorities and the construction and civil engineering industry, produces guidelines where the impact of the load generated by a changing climate on existing geoconstructions is taken into account.
- SGI, in collaboration with the Swedish Civil Contingencies Agency and the Swedish Meteorological and Hydrological Institute, compiles and disseminates good examples of measures that are being taken to assure the stability of land for buildings and facilities used for activities that are of importance to society.
- SGI, in collaboration with the construction and civil engineering industry, investigates the conditions for establishing a database to monitor the effects of climate change over time on the constructability of land.
- SGI, in collaboration with the Geological Survey of Sweden and the Swedish Transport Administration, make a risk assessment of the sensitivity of underground facilities and tunnels to the effects of climate change.
- SGI, in collaboration with the Swedish National Heritage Board and the county administrative boards, produces guidelines for how ground conditions in settings that are of cultural and historical interest can be managed optimally, and how the subterranean foundations of buildings can be adapted to a changing climate.
- The Swedish Meteorological and Hydrological Institute in collaboration with the Swedish Civil Contingencies Agency, SGI, the Geological Survey of Sweden, the county

administrative boards and the municipalities, continues to develop consequence-based warnings about extreme weather events in order to minimise risks associated with land stability and the spread of contaminants.

- Coastal communities, in collaboration with SGI, the county administrative boards, other public sector bodies and industry, investigate adaptation and measures taken to safeguard against erosion and rising sea levels.
- Coastal municipalities, in collaboration with SGI, the county administrative boards and other agencies, investigate how risk management plans for rising sea levels and the subsequent effects on ground conditions can be formulated.
- The Swedish Transport Administration rectifies systemic shortcomings, such as underdimensioned drums, to reduce climate-related georisks.
- The Swedish Transport Administration has a very high level of preparedness and knowledge to handle the acute effects of the impact of climate change on the transport infrastructure.
- Property owners and other bodies with operational responsibility adapt the foundations of buildings to changing ground conditions.

Responsibility and who will cover the cost of different measures can be clarified.

- SGI, in collaboration with the insurance, construction and civil engineering industries, investigates and makes available information about the cost of possible future damage if account is not taken of changing ground conditions.
- Municipal authorities, the insurance industry, building developers and other parties within the building and civil engineering industry, develop business models for partnering and other forms of collaboration related to long-term investment and where account is taken of a changing climate.

Blue and green structures within and close to built-up areas can be used as a resource to increase resilience and protection against flooding.

- SGI continues its work on developing erosion and flood protection adapted to nature and producing guidelines for how protective measures can be put in place and managed.
- Municipalities and county administrative boards continue, in collaboration with the Swedish Meteorological and Hydrological Institute, the Geological Survey of Sweden, SGI and the Swedish Agency for Marine and Water Management, to develop knowledge and to work to increase the water retention capacity of the landscape by reinstating or creating more areas for water, such as natural flood plains, meandering watercourses and wetlands.
- The Swedish Environmental Protection Agency continues to coordinate work on a green infrastructure on the national level in collaboration with the county administrative boards, the Swedish Agency for Marine and Water Management, the Swedish Board of Agriculture, the National Board of Housing, Building and Planning, the Swedish Transport Administration, the Swedish Forest Agency, the Swedish National Heritage Board and other authorities, agencies and stakeholders that are affected.
- County administrative boards, with support from the Swedish Environmental Protection Agency and the National Board of Housing, Building and Planning, continue to develop and put into effect regional action plans for a green infrastructure.
- Municipalities develop the existing green structure and building development structure with the addition of multifunctional areas to suppress the effects of climate change.

A management model for changing coastlines can be established.

- SGI takes the initiative, together with the Swedish Agency for Marine and Water Management, the Swedish National Land Survey, the Swedish Maritime Administration and the Geological Survey of Sweden, to collaborate on how monitoring and future management of changing shorelines can proceed.
- SGI continues to arrange *Kustmöte* (Coastal Conference) and *Vattendragmöte* (Watercourse Conference) as national fora for an exchange of knowledge on how a management model can be designed, established and implemented.
- SGI, in collaboration with colleges and universities, continues with the development of solutions for both erosion and flooding that are adapted to nature.
- SGI initiates a dialogue with the authorities regarding the conditions for establishing a climate change adaptation zone along shorelines and river banks where the extent and design will be adapted to ecosystem values, land suitability and societal vulnerability.
- The Geological Survey of Sweden, in collaboration with the Swedish Maritime Administration, the Swedish Agency for Marine and Water Management and SGI, establishes a monitoring programme for bathymetric measurements of changes on the seabed and on the beds of lakes and rivers, and the transport of sediment along the coast and in watercourses.
- The Swedish Maritime Administration, in collaboration with the Geological Survey of Sweden, will initiate, gather and make available existing bathymetric data and documentation and other high-quality information.

3.5 Demolition and reinstatement

Climate change will probably result in certain buildings, facilities and built environments not being viable to adapt to a changing climate, either economically or in terms of safety. Critical thresholds where technical measures and the cost of maintenance, adaptation or ground stabilisation are no longer feasible will need to be identified. Demolition and replacement with climate-adapted buildings or facilities could be an alternative if the ground can still be deemed suitable for construction. In other cases, when the ground is considered to be unsuitable for new construction, demolition could be necessary, followed by relocation to another area. As regards cultural and historical values that need to be preserved, the relocation of buildings to another area could be the only sustainable alternative to ensure our cultural heritage is preserved. The effects of climate change could in different ways affect risks to the environment and health arising from contaminated areas and landfill sites. When assessing the risks and the need for remediation measures, it is important to take into consideration geotechnical conditions and effects that a change in climate could entail.

What needs to be done?

- Develop support to deal with a future need for demolition and relocation of buildings.
- Risks resulting from contaminated areas and their remediation need to be assessed in the light of a changing climate.

How can this be achieved and who will take the initiative?

Support to address a future need for demolition and relocation of a building.

- SGI continues to develop tools to deal with vulnerable coastal communities from a technical, economic and social point of view in conjunction with a rise in sea level, as well as its effects on ground conditions and the need for relocation.
- SGI, in collaboration with the Swedish National Heritage Board, the National Board of Housing, Building and Planning and the county administrative boards, produces guidelines for how the effects of climate change on ground conditions and the consequences for our cultural heritage need to be taken into account in conjunction with the relocation of buildings of cultural and historical importance.
- SGI, in collaboration with the Swedish Civil Contingencies Agency and other stakeholders, develops a model that defines critical thresholds, beyond which practical measures and the cost of climate change adaptation of an existing built environment and ground constructions are not justifiable from a sustainability point of view.

Risks and remediation of contaminated areas can be assessed in the light of a changing climate.

- SGI highlights the need by the Swedish Environmental Protection Agency and the Geological Survey of Sweden to produce a common database for contaminated areas in addition to the areas listed by the county administrative board as part of its remit.
- SGI, in collaboration with the Geological Survey of Sweden, the Swedish Environmental Protection Agency and the county administrative boards, coordinates initiatives that will

result in a knowledge base and the requisite expertise to deal with contaminated areas in the light of climate change.

- SGI, in collaboration with the Swedish Environmental Protection Agency and the the Swedish Civil Contingencies Agency, formulates guidelines for making an in-depth risk assessment of contaminated land and natural disasters.
- SGI, in collaboration with the Swedish Environmental Protection Agency and the the Geological Survey of Sweden, formulates guidelines for a risk evaluation of contaminated areas and climate change.
- The county administrative boards, in collaboration with *Miljösamverkan Sverige* (Environmental Collaboration Sweden), produces a description of how climate change adaptation can be integrated into the monitoring of contaminated areas and environmentally hazardous activities.
- Municipalities, county administrative boards and the Swedish Environmental Protection Agency consider the consequences of climate change in conjunction with prioritisation of sites requiring post-treatment.

3.6 Build up of knowledge

Research and development in collaboration with academia, the public sector and industry is a key factor in developing new knowledge about the effects of climate change on ground conditions and land constructability. Current societal challenges are interdisciplinary and presuppose collaboration across traditional knowledge areas and disciplines, including social science. These societal challenges are also transnational and require internationalised research, strategic alliances and interdisciplinary approaches. Involvement in international collaborative ventures, broad-based involvement by industry, public sector bodies and the local population, internationally composed project teams and the adoption of interdisciplinary approaches have proved to be key success factors in research related to spatial planning (Swedish Research Council Formas, 2015).

What needs to be done?

- Develop knowledge and expertise and communicate the need to implement the measures set out in the Action Plan for Sustainable Ground Construction according to the Communication Plan (see Chapter 5).
- Develop and disseminate knowledge about the effects of climate change on ground conditions and on new and existing geoconstructions.
- Develop and disseminate knowledge about cost-effective, land-related climate change adaptation measures linked to ecosystem services for existing buildings and infrastructure.
- Create better conditions for a build-up of knowledge in international collaboration and its subsequent application in order to enhance the level of knowledge and expertise in Sweden.

How can it be achieved and who will take the initiative?

Knowledge-enhancing initiatives related to the effects of climate change on ground conditions and the long-term constructability of land can be developed and communicated to stakeholders.

- SGI, in collaboration with other research agencies, research institutes and colleges and universities, develops improved investigation and computation methods for the assessment of soil types and soil stability that take into account the impact of a changing climate.
- SGI, in collaboration with other research agencies, research institutes and colleges and universities, carries on research into computation models as well as reinforcement and foundation construction methods to deal with a changing climate.
- SGI, in collaboration with other research agencies, research institutes and colleges and universities, carries on research that investigates how a planning process that includes a future need for relocation as a result of climate change can be developed.
- SGI, in collaboration with other research agencies, research institutes and colleges and universities, carries on research into the handling of potential conflicts between goals and synergies pertaining to the suitability of land for building (based on soil stability, spread of contaminants, surface water management, flood risks, water and sewage solutions, natural and cultural values and regional development potential).
- SGI, in collaboration with other research agencies, research institutes and colleges and universities, carries on research into how site-specific documentation for sustainable

ground construction and climate change adaptation can be better integrated into local and regional planning routines and development strategies.

- SGI, in collaboration with other research agencies, research institutes and colleges and universities, carries on research into changes in ground conditions in relation to local meteorological and hydrological conditions over time.
- SGI, in collaboration with the stakeholders concerned, develops methods and tools for assessing the risk of landslides, rockfalls and erosion in different types of soil and rock, and in combination with other risks.
- SGI, in collaboration with the stakeholders concerned, continues to develop the ‘Knowledge programme for shoreline areas’.
- SGI, in collaboration with the stakeholders concerned, develops methods for monitoring, following up and evaluating measures related to the effects of climate change on the constructability of land.
- Research funding bodies encourage needs-motivated research to increase the level of knowledge about the effects of climate change on ground conditions.

Knowledge regarding cost-effective, land-related climate change adaptation measures for existing buildings and infrastructure can be developed.

- SGI, in collaboration with other research agencies, research institutes and colleges and universities, continues with its training initiatives and a build-up of knowledge aimed at protecting existing buildings and infrastructure and investing in the processing and dissemination of knowledge in a way that it is also accessible to non-specialists.
- SGI, in collaboration with the construction and civil engineering sectors, public sector bodies and colleges and universities, identifies, collects and highlights good examples on the national or international level of how ecosystem-based solutions have been used as climate change adaptation measures in conjunction with ground construction.
- Research funding bodies encourage research that identifies barriers and knowledge requirements in order to reach well-founded decisions in cross-sectoral ground construction issues, and how a cross-sectoral perspective can be integrated into the existing (control) processes applied by administrative bodies.

Better prerequisites for the build-up of knowledge through international collaboration can be created.

- SGI, in collaboration with other research agencies, research institutes and colleges and universities, carries out a systematic external analysis of sustainable ground construction in other countries in an effort to identify suitable interdisciplinary methods for ascertaining and dealing with conflicting goals.
- SGI, in collaboration with national stakeholders and international partners, takes the initiative to coordinate and apply for funding for a large international project dealing with sustainable ground construction in a changing climate.
- SGI, in collaboration with national stakeholders, takes the initiative for establishing a centre of excellence dealing with sustainable ground construction in a changing climate.
- SGI, in collaboration with other research agencies, research institutes, colleges and universities and research funding bodies, makes use of the collective knowledge of sustainable construction derived from traditional, local, national and international sources, and makes this available and relevant to municipalities and other stakeholders.

4. Implementing the Action Plan

4.1 Collaboration for sustainable ground construction

The Action Plan shows clearly that sustainable ground construction cannot be achieved based on the formal responsibility of one or even a small number of organisations or public sector bodies. Extensive build-up of knowledge about the effects of climate change on ground conditions is necessary if correct planning and management decisions are to be made. Collaboration across sector boundaries and between the public sector, industry and academia, is vital to success. SGI's aim behind the Action Plan is to contribute to the current development of national climate change adaptation work based on SGI's societal remit to identify and mediate knowledge requirements within ground construction.

The dialogue between stakeholders that took place during the preliminary work on the Action Plan highlighted the considerable need for collaboration and coordination. Many stakeholders have expressed a need for the adoption of a holistic view of adaptation of ground construction to climate variability and change. SGI lacks the authority, or does not have sole authority, to implement several of the measures that were sought by different stakeholders during the preliminary work and which are now included in the Action Plan. The Action Plan should therefore be seen as a starting point for a continued dialogue about what needs to be done, how it can be done, and who will take the initiative for ensuring that different activities are implemented.

The Action Plan as a whole is focused on 2030 whilst it is proposed that the measures are initiated by 2020 at the latest. Many measures will take considerably longer to develop or implement and will extend beyond 2020. SGI undertakes, based on its responsibilities as a public body and available resources, to be involved in and develop the measures that have been highlighted by SGI, either as initiator or partner (see Chapter 3 and Table 1), and to be available for collaboration on measures in which other stakeholders would like to be involved.

All the other stakeholders in ground construction who are described as potential initiators and implementers of the different measures set out in Chapter 3, must by necessity assess whether, and if so when, each measure can be implemented based on the stakeholder's own prioritisation and available resources. The measures listed in Chapter 3 have therefore not been assigned a timeframe or prioritisation.

The measures where SGI is responsible have been integrated into its operating plan for 2017 based on available resources. The measures will be planned for in the same way each year through to 2020. SGI will also continue working to secure acceptance for and communicate the Action Plan and its measures according to a separate communication plan. An annual follow-up of the implementation of the Action Plan will take place according to a separate follow-up and evaluation plan.

4.2 Timetable for measures 2017-2020

SGI intends to pursue the work on climate change adaptation within ground construction based on the ambitions set out in the Action Plan. It is necessary to continue to develop documentation, provide support in the interpretation and use of the documentation, and prioritise and implement sustainable adaptation measures. To achieve the goals set out in the Action Plan by 2030, communication, collaboration, coordination and suitable methodology for follow-up and evaluation are required.

More precise working plans and communication plans based on the Action Plan will be developed each year and will be made available on the SGI website.

The timetable below outlines the work process for 2017-2020. The timetable and the work process include prioritisation of new measures that SGI will commence. This will be preceded by a dialogue with different stakeholders and recipients of the data and know-how that need to be produced. For those measures that presuppose collaboration between several stakeholders, agreements will need to be reached regarding financing. Annual activity plans will be available on the SGI website.

2017

- A synthesis report that describes the effects of climate change on ground conditions.
- A continued dialogue with stakeholders about joint measures and possible financing solutions.
- A continued dialogue with stakeholders to specify the orientation and level of the planning documentation and guidelines that are prioritised most to ensure they are directly applicable in the light of existing needs.
- Produce a plan to initiate and implement different measures and with a more precise timetable based on the dialogue with stakeholders.
- Continued work on current measures as outlined in Table 1.
- Develop a knowledge package covering the effects of climate change on ground conditions that will be directed mainly at decision-makers.
- Produce documentation regarding base levels for follow-up.
- Communication according to a separate activity plan.
- Follow-up of work that is being conducted according to the follow-up plan.

2018

- Based on the prioritisations set out in 2017, work will commence on producing documentation and guidelines that can be used as support when assessing the effects of climate change on ground conditions.
- Continued dialogue and introductory work on the measures that have been prioritised based on the dialogue with stakeholders that took place during 2017.
- Continued work on documentation for base levels prior to follow-up and evaluation.
- Communication according to a separate activity plan.
- Follow-up of work done under the follow-up plan.

2019-2020

- Communication according to a separate activity plan.
- Follow-up of the work done under the follow-up plan.
- Evaluation of the degree to which the goals set out in the Action Plan have been achieved.
- Production of an action plan for work after 2020 in order to achieve the established goals through to 2030.

4.3 Financing

Financing of SGI activities for the different measures is contingent on the annual allocation of grants by the government and the receipt of external research grants each year. The SGI grant allocation for 2017 is financed via the climate change adaptation grant (government expenditure area 20, grant 1:10) and the administration grant (government expenditure area 18, grant 1:7, and government expenditure expense area 20, grant 1:4). See also Swedish Parliament (2016). In total, SEK 16.5 million will derive from the climate change adaptation grant and SEK 46.0 million from the administration grant. External grant revenue for 2017 is budgeted at SEK 5.8 million. Funding through the climate change adaptation grant will be used for SGI's current activities as listed in the Action Plan and summarised in Table 1 (column 1). In the case of other grant and subsidy revenue, around one-third, i.e. approximately SEK 50 million, will be assigned to current activities during 2017 (see Table 1, columns 2 and 3).

SGI also carries on fee-funded activities, which supplement and in some cases reinforce activities under the Action Plan. The fee-funded activities are not included in the list below.

The new activities that are planned will commence gradually as current activities come to an end and in conjunction with receipt of possible additional grant and subsidy revenue.

National funding alternatives

The government's proposal for setting up a national funding programme for sustainable spatial planning opens up new opportunities to develop knowledge and methods for adapting ground construction to a changing climate (Government Bill 2016/17:50). The proposed research programme will be set up at Formas and will include an increase in the Formas grant by SEK 75 million through to 2020. The government has also proposed a 10-year national research programme dealing with climate change, which will be set up at Formas with a grant of SEK 130 million through to 2020.

Several other research and innovation programmes are also in place. These affect a number of the measures set out in the Action Plan and could make funding available for potential ground construction development projects:

- Challenge-driven innovation: sustainable and attractive cities – Swedish Innovation Agency Vinnova programme for cross-border innovation projects for targeted societal challenges.
- Innovations for a sustainable society: environment and transport – Swedish Innovation Agency Vinnova programme for research and innovation to achieve Sweden's environmental quality goals.
- Smart Built Environment – Strategic innovation programme (Swedish Innovation Agency Vinnova, Swedish Energy Agency and Swedish Research Council Formas) within the spatial planning and digitalisation.
- InfraSweden2030 – Strategic innovation programme (Swedish Innovation Agency Vinnova, Swedish Energy Agency and Swedish Research Council Formas) within the transport infrastructure aimed at reinforcing competitiveness and sustainability development at Swedish infrastructure companies.
- RE:Source – Strategic innovation programme (Swedish Innovation Agency Vinnova, Swedish Energy Agency and Swedish Research Council Formas) within the resource and waste sector.

Table 1 Summary of SGI’s current and new activities under the Action Plan as well as a plan for financing activities. The activities are the same as those presented in Chapters 3-6. The details in the table describe how available funding for climate change adaptation measures in 2017 is allocated for current projects as well as proposals regarding the type of funding for new activities in 2017-2020. The internal allocation of current and new activities is dependent on the annual allocation of grants and could therefore change from 2018 onwards.

SGI’s undertakings according to the Action Plan	Activities funded through climate change adaptation grants (status)	Activities funded through administration grants (status)	Activities funded through internal R&D grants and/or external grants (status)
PUBLIC PLANNING			
Integrate the effects of climate change on ground conditions on all planning levels		Planning support (current) Collaboration between public sector bodies, including the development of the existing public authority network for coastal erosion (current and new)	R&D: Guidelines that take into account climate loads (new) R&D: Guidelines, demands at the planning/building permit stage (new) R&D: Guidelines, weighing up of conflicting goals and ecosystem services (current and new)
Produce digital maps covering the effects of climate change on ground conditions	Landslide risk mapping (current) Vulnerability mapping, coastal erosion (current and new) Harmonisation of maps (current) Cooperation between public sector bodies (current)	Cooperation between public sector bodies (current and new) Geoengineering sector portal (current)	R&D: Effects of climate change on ground conditions (new) R&D: Scenarios, ground conditions (new)
Provide support and guidance in conjunction with the interpretation and use of documentation regarding ground conditions	Guidelines, erosion protection adapted to nature (current)	Planning support, increased capacity (new) Collaboration between public sector bodies, including a review of available guidelines (current and new)	R&D: Guidelines, naturally adapted erosion protection (current) R&D: Guidelines, interpretation of documentation on climate loads (new) R&D: Guidelines for forestry, erosion and sloaps (new)
PLANNING AND CONSTRUCTION			
Integrate greater regard for ground conditions into the planning and building of new geoconstructions	Development, evaluation and updating of computation models (new)	Collaboration between public sector bodies regarding the demand specification (current) Investigate support in complicated planning consent cases (new)	R&D: Mapping, lack of consideration (new) R&D: Guidelines, climate loads, geoconstructions (new) R&D: Review, demand specification R&D: Scenarios, consequences of climate change (new) R&D: Underground construction (new)
Carry out planning and construction of robust buildings and facilities as well as land and water areas	Standardisation work (current and new) Collaboration with public sector bodies, procurement (current)	Standardisation work (current)	R&D: Tool, assessment of robustness (new) R&D: Geocalculations, further development (current and new)

MANAGEMENT			
Achieve long-term protection of buildings and facilities against the effects of climate change on ground conditions	Investigate conditions for a database of climate change effects on the constructability of land (new)	National coordination, shoreline erosion (current)	R&D: Guidelines, geoconstructions (new) R&D: Measures (new) R&D: Risk assessment, underground facilities (new) R&D: Warning information (current) R&D: Guidelines, ground conditions, buildings of cultural and historical significance (new)
Clarify matters relating to responsibility		Standardisation work (current) National coordination, shoreline erosion (current) Planning support (current)	R&D: Future cost of damage (new)
Use blue and green structures for increased resilience and protection against flooding	Guidelines, naturally adapted erosion protection (current) Public sector collaboration (current)	National coordination, shoreline erosion (current) Public sector collaboration (current)	Guidelines, naturally adapted erosion protection (current)
Establish a management model for changing shorelines	Guidelines, erosion protection adapted to nature (current)	Public sector collaboration around monitoring and future management of shorelines (new) Coastal Conference and Watercourse Conference (current) Public sector collaboration, including investigation of the climate change adaptation zone and establishment of a bathymetric monitoring programme (current and new)	Guidelines, naturally adapted erosion protection (current)
DEMOLITION AND REINSTATEMENT			
Support to meet a future need for demolition and relocation of a building			R&D: Tools, vulnerable coastal communities (current) R&D: Guidelines, relocation of buildings of cultural and historical importance (new) R&D: Critical thresholds, adaptation and demolition (new)
Assess risks associated with contaminated areas and measures required to reinstate contaminated areas in the light of a changing climate		Public sector collaboration related to a database and a knowledge base (current)	R&D: Guidelines, in-depth risk assessment, natural disasters (current) R&D: Guidelines, risk evaluation, climate change (new)

BUILD-UP OF KNOWLEDGE			
Effects on ground conditions and geoconstructions	Development of ground conditions (current) Development, risk assessment, landslides, rockfalls and erosion and in combination with other risks (current)	Knowledge programme, shoreland (current)	R&D: Improved computation and investigation methods, soil properties (current) R&D: Foundation work and reinforcement (current) R&D: Planning process that includes relocation (new) R&D: Conflicting goals and synergies (new) R&D: Integration into regional and local planning routines and development strategies (current) R&D: Climate effects, ground conditions (current) R&D: Risk assessment, landslides, rockfalls and erosion and in combination with other risks (current) R&D: Monitoring, follow-up and evaluation of measures (new)
Cost-effective climate change adaptation measures for existing buildings and infrastructure	Processing and dissemination of knowledge (current)	Training and education initiatives (current)	Training and education initiatives (current) R&D: Ecosystem-based climate change adaptation measures (new)
Improvement of conditions for the build-up of knowledge as part of national and international collaboration		R&D: External analysis (new) Initiative: establishment of a centre of excellence (current) Collaboration between public sector bodies regarding collective knowledge (current and new)	R&D: Project coordination (new)
COMMUNICATION			
Communication initiatives according to the Communication Plan	Communication (current and new)	Communication (current and new)	Communication (current and new)
FOLLOW-UP AND EVALUATION			
Follow-up and evaluation according to the Follow-up Plan	Follow-up (current) Identify base levels (new) Evaluation (new)	Follow-up (current) Collaboration between public sector bodies (current)	R&D: Base levels (new)
COORDINATION			
General coordination of the Action Plan	Updating, networking, promotion of collaboration (current and new)		

5. Communication

A Communication Plan has been produced for the Action Plan for Sustainable Ground Construction. The aim behind the Communication Plan is to secure acceptance of the Action Plan among the stakeholders concerned and to increase knowledge about how society can achieve sustainable ground construction in a changing climate. The aim is to create conditions for adopting a uniform view of sustainable ground construction among the stakeholders concerned and to implement the proposed measures. The communication process will contribute to clarifying the roles of the various parties involved.

The Action Plan is directed at relevant stakeholders within:

- Industry: building developers, geoengineering and environmental geoengineering companies, sector organisations.
- Public administration: civil servants and decision-makers in the public sector bodies affected by spatial planning issues (municipal authorities, regions, county councils, county administrative boards and national authorities and agencies).
- Academia: researchers at Swedish colleges and universities and research institutes.

Knowledge must be packaged and communicated in different ways for different target groups. Information and training initiatives must not only provide increased awareness of sustainable ground construction, but also contribute to behavioural changes and actions that reinforce the development of sustainable ground construction.

For the Action Plan to be implemented, participation is required in the form of interested parties collaborating on different initiatives. It is important to create opportunities for a dialogue regarding implementation. Information therefore needs to be disseminated through many different channels and on repeated occasions.

6. Follow-up and evaluation

The follow-up process that forms part of the Action Plan will be ongoing. Aims and activities that are formulated in the Action Plan will be integrated in stages into SGI's operating areas with effect from 2017. Follow-up of activities that have been implemented and how development will proceed towards established goals will take place each year in conjunction with the annual SGI operational follow-up. An evaluation of goal fulfilment and results will be made in 2020, although preparations prior to the evaluation will commence in 2017.

Follow-up and evaluation are two separate activities:

- Follow-up is an ongoing process of examination. It is an indication of the direction that needs to be followed to arrive at a particular goal. Are we heading in the right direction? Is everything proceeding according to plan? Do we need to change course? Is more support required to continue towards the goal in question?
- Evaluation is a subsequent assessment at a certain time. Have we achieved the goal? How do we know when we have arrived, either wholly or in part? Is the goal still relevant? How has the process progressed and what lessons can we learn from the process?

Even if follow-up and evaluation are two distinct activities, they can also be regarded as two different phases in the same process. The follow-up is a means of documenting and establishing the extent of the contributions (time, money, resources) made to satisfy the goals and ongoing activities. The evaluation phase examines and evaluates interim results, the effects and the process (Figure 2).

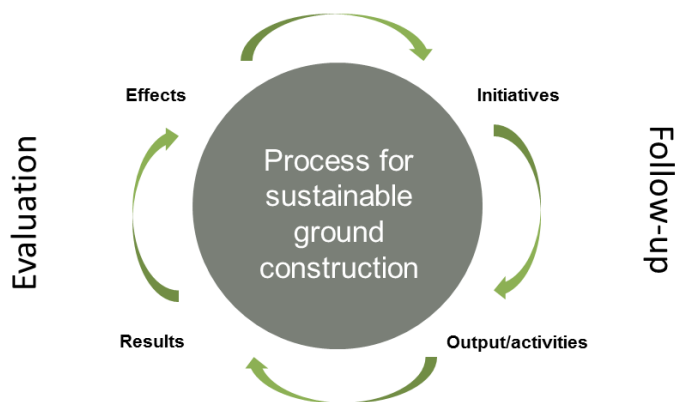


Figure 2 Description of the follow-up and evaluation process.

Examples of questions that will be taken into account as part of follow-up and evaluation

- What will be followed up and evaluated? Why? How? When?
- Who is responsible for data collection, collation and analysis?
- How will feedback be presented to the providers?
- How will the results be used? What will happen then?
- How can the lessons learned from the evaluation be accessed and used?
- How can experience be disseminated to other stakeholders?

6.1 Follow-up plan

Follow-up is an ongoing assessment of initiatives and activities that are carried out to achieve stated goals. Following up activities when there are several parties involved who have been instructed to carry out a large number of activities is an extensive task. Municipal authorities, county administrative boards, sector agencies and industry organisations ought to be responsible for their respective follow-up activities. However, suitable fora could be required that offer the opportunity for the parties involved to check with each other and to learn from each other as they implement their action plans.

SGI intends to arrange an annual workshop on the follow-up of the measures set out in the Action Plan. During the workshop, stakeholders will have the opportunity to be involved in and take part in an exchange of experience. The workshop will also be an opportunity to map which activities will need to be prioritised in the future and to identify remaining challenges. Ideally, the workshop will be arranged within existing fora for climate change adaptation. The follow-up includes a descriptive assessment of the work involved in implementing activities. Each follow-up will be documented and analysed and the lessons learned will be communicated to all the stakeholders.

6.2 Process indicators for evaluation

Process indicators are used in the first instance to trace how far the work on implementing the measures for sustainable ground construction has proceeded and how the measures will contribute to achieving the three goals. The assessment is that process indicators in the Action Plan could also be used in the national system for reporting to the EU and other international fora.

The measures will be discussed during the annual follow-up workshop run together with the stakeholders concerned.

Similar to the work on the “Method for following up national climate change adaptation work in Sweden” (Swedish Meteorological and Hydrological Institute 2016), implementation of the measures is assessed based on whether they are implemented (green), in progress (yellow), or not yet initiated (red). See Table 2.

6.3 Result and effect indicators for evaluation

Result and effect indicators will be used to gain a better understanding of measures that have led to expected effects or unintentional consequences in the task of achieving the goals. It could be difficult or almost impossible to measure the actual effect of a measure as there could be a considerable time lag from the point at which a measure is implemented until the effect can be quantified. It could also be complicated to trace a direct causal link between an action and its impact. Consequently, result indicators have been developed specifically to evaluate whether the goals and measures in the Action Plan have had an impact in the short term, i.e. through to 2020.

Status reports that could form the basis for appropriate base levels must be produced by the bodies concerned in order to assess whether or not an activity has generated an expected result. The task of establishing indicators and base levels will continue during 2017-2020, after which the activities in the Action Plan will be initiated.

The degree to which goals are fulfilled (potential effects) will be evaluated during 2020. The work will be implemented in collaboration with the stakeholders concerned and will be coordinated as far as possible with the evaluations that will be made by other authorities through their action plans.

Indicators must be realistic and must be based on quantifiable information. In 2017-2018, the SGI process will begin to produce base levels for goal fulfilment within SGI activities. As far as possible, use will be made of existing data and collations to produce the base levels. The work on base levels could possibly be coordinated with work conducted by the new analysis function which the government has proposed will be set up at Formas. The analysis function will collate and communicate environmental research. The evaluation work in the Action Plan could benefit from the work being done by the analysis function and contribute to the compilation of data, information and know-how within sustainable ground construction.

Evaluation of goal fulfilment includes how the goals have contributed to meeting Sweden's environmental goals, the goals in the Sendai Framework and the goals set out in the UN's Agenda 2030. Examples of result and effect indicators for the three goals set out in the Action Plan for Sustainable Ground Construction in a Changing Climate are presented in Table 3.

Table 2 Measures and process indicators sorted by the different elements of the spatial planning process.

Measure	Implemented (green) Completed	In progress (yellow) 25 %, 50 %, 75 %	Not yet initiated (red) Work not yet initiated
PUBLIC PLANNING			
Ensure that the long-term effects of climate change on ground conditions are taken into account on all planning levels (regional plan, comprehensive plan, local plan, area stipulations, road and rail plans).			
Produce digital maps that describe ground conditions in a changing climate.			
Provide increased support and guidance when interpreting and using digital documentation that describes ground conditions.			
PLANNING AND CONSTRUCTION			
Integrate considerations relating to ground conditions in a changing climate into the planning and building of new geoconstructions.			
Buildings, facilities, land and water areas are planned and built robustly, with due account taken of a changing climate.			
MANAGEMENT			
Give buildings and facilities long-term protection against the effects of climate change on ground conditions.			
Clarify who is responsible and who will cover the cost of different measures.			
Use blue and green structures within and close to built-up areas as a resource for increased resilience and protection against flooding.			
Establish a management model for changing shorelines.			
DEMOLITION AND REINSTATEMENT			
Develop support to deal with a future need for demolition and relocation of buildings.			
Risks resulting from contaminated areas and their remediation need to be assessed in the light of a changing climate.			
BUILD UP OF KNOWLEDGE			
Develop and disseminate knowledge about the effects of climate change on ground conditions and on new and existing geoconstructions.			
Develop and disseminate knowledge about cost-effective, land-related climate change adaptation measures linked to ecosystem services for existing buildings and infrastructure.			
Create better conditions for a build-up of knowledge in international collaboration and its subsequent application in order to enhance the level of knowledge and expertise in Sweden.			

Tabell 3 Examples of result indicators and base levels for the three goals set out in the Action Plan.

Goals for sustainable ground construction	Result indicator	Base level year (method)
A digital knowledge base that focuses on ground conditions in a changing climate is in place for the whole of Sweden and is an integral part of spatial planning.	Number of digital knowledge bases that focuses on ground conditions in a changing climate available per county	2017 (desk study)
	Coverage of digital knowledge bases (in %) of Sweden's surface	2017 (desk study)
	Number of references digital knowledge bases that focuses on ground conditions in a changing climate in regional plans, comprehensive plans, local plans or other regional development plans	2017 (desk study)
Stakeholders in industry and public administration have sufficient knowledge, expertise and capability regarding sustainable ground construction to reach long-term decisions in which due consideration is given to ground conditions in a changing climate.	Number of stakeholders in industry and public administration considering themselves to have sufficient knowledge, expertise and capability regarding sustainable ground construction, to reach long-term decisions in which due consideration is given to ground conditions in a changing climate	2018 (survey)
	Number of courses and educations on sustainable ground conditions in a changing climate per year	2018 (available and relevant data)
	Number of guidelines on sustainable ground conditions in a changing climate published and presented for decision makers	2018 (literature study, available and relevant data for the annual follow-up workshop)
	Number of decision makers participating as partner or reference in different measures	2018 (available and relevant data for the annual follow-up workshop)
Ecosystem-based and resource-optimised solutions that focus on ground conditions in a changing climate have been developed, are widely known and are used in conjunction with ground construction and the management of buildings and facilities.	Number of stakeholders considering themselves to have knowledge of and are using resource-optimised solutions for sustainable ground constructions in a changing climate	2018 (survey)
	Number of ecosystem-based solutions developed with support of knowledge bases from SGI in cooperation with other concerned stakeholders	2018 (literature study, available and relevant data for the annual follow-up workshop)

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Name of organisations – translation English to Swedish

Name in English	Name in Swedish
Geological Survey of Sweden	Sveriges geologiska undersökning
Government	Regeringen
National Board of Housing, Building and Planning	Boverket
Sami Parliament	Sametinget
Swedish Agency for Marine and Water Management	Havs- och vattenmyndigheten
Swedish Association of Local Authorities and Regions	Sveriges kommuner och landsting
Swedish Board of Agriculture	Jordbruksverket
Swedish Civil Contingencies Agency	Myndigheten för samhällsskydd och beredskap
Swedish Construction Federation	Sveriges Byggindustrier
Swedish Energy Agency	Energimyndigheten
Swedish Environmental Protection Agency	Naturvårdsverket
Swedish Forest Agency	Skogsstyrelsen
Swedish Geotechnical Institute	Statens geotekniska institut
Swedish Innovation Agency Vinnova	Sveriges innovationsmyndighet Vinnova
Swedish Maritime Administration	Sjöfartsverket
Swedish Meteorological and Hydrological Institute	Sveriges meteorologiska och hydrologiska institut
Swedish National Food Agency	Livsmedelsverket
Swedish National Heritage Board	Riksantikvarieämbetet
Swedish National Land Survey	Lantmäteriet
Swedish Parliament	Riksdagen
Swedish Research Council Formas	Forskningsrådet Formas
Swedish Standards Institute	Swedish Standards Institute
Swedish Transport Administration	Trafikverket



Statens geotekniska institut

Postadress: 581 93 Linköping

Tel: 013-20 18 00

E-post: sgi@swedgeo.se

www.swedgeo.se
