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Chapter 7 Cumulative Impact Assessment

In order to assess possible cumulative impacts that may arise due to the implementation of the five projects described, the method of Causal Loop Diagrams (CLD) was used (see Chapter 3.3.3). For each individual project CLDs has been made and then put together for the purpose of a cumulative impact assessment (CIA). The result is presented in figure 7.1 and 7.2. The green boxes (in operation CLD) and the light red boxes (in construction CLD) have been identified as the environmental and socio-economic parameters in which cumulative impacts may arise. The CLDs is divided into construction and operation phases since different cumulative impacts could come from different phases. The CLDs exclusively looks at causalities between variables of the system, it does not consider the in- and outflow of people and material. The CLDs constructed are still dynamic systems, even without feedbacks.

The cumulative impacts are summarized in table 7.1 and 7.2, showing which projects that together could create cumulative impacts on the established parameters. As seen in table 7.1 and 7.2, cumulative effects can be counted in two ways, both through number of actions that relate to each environmental parameter and the number of projects that have an impact on each parameter. The chosen parameters are those that more than one project have an impact on. The number of actions affecting one parameter can be both direct and indirect. For example, all impacts on biodiversity go through other parameters like soil contamination and air quality before it reaches the parameter biodiversity. Though the number of actions affecting a parameter can't help establish which environmental and/or socio-economic parameters that could be most affected. Before that can be established, the magnitude and significance of each impact needs to be assessed.

7.1 Construction Phase

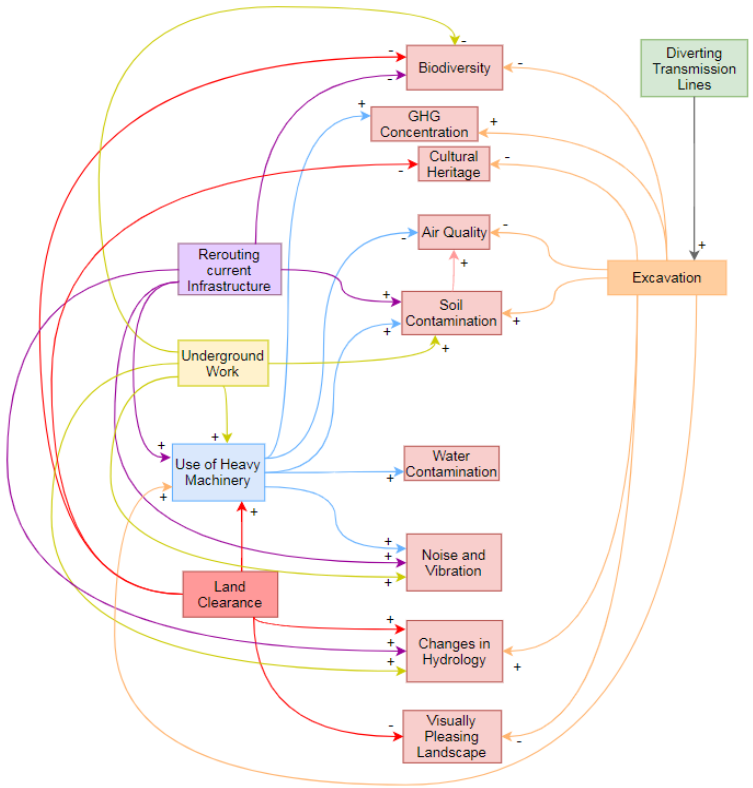


Figure 7.1. Causal loop diagram over the construction phase and cumulative impacts. Environmental aspects in the red boxes, and the actions taken during construction in purple, yellow, blue, green, dark red and beige.

7.1.1 Biodiversity

All five projects will have an impact on the biodiversity in the Arlanda region through five actions listed below.

- Increase of *excavation*, direct impact.
- Increase of *land clearance*, direct impact.
- Increase of *rerouting current infrastructure*, direct impact.
- Increase of *underground works*, direct impact.

Transformation of the landscape (from forest and agricultural land to industrial airport) involves destruction of habitat, leading to a decreased biodiversity. Also noise pollution from constructing the projects makes the area less attractive for different species to live.

7.1.2 Water Contamination

All five project will contribute to water contamination during the construction phase through one action.

- Increase of *use of heavy machinery,* direct impact.

During the construction phase of the different projects, heavy machinery will be used. Those machines will contaminate the water through leakage of chemicals. The chemicals leaked from machines used for different projects can accumulate in the water and reach toxic levels.

7.1.3 Soil Contamination

All five project will contribute to soil contamination during the construction phase through four actions.

- Increase of *excavation*, direct impact.
- Increase of *use of heavy machinery*, direct impact.
- Increase of *underground work*, direct impact.
- Increase of *rerouting current infrastructure*, direct impact.

Since construction of all projects entail excavation, use of heavy machinery, underground work and rerouting current infrastructure, it could lead to cumulative effects between the projects implementation. Although, this would only be the case if the construction sites would take place in the same time and same area.

7.1.4 GHG Concentration

All five projects will emit greenhouse gases during the construction phase through two actions.

- Increase of *use of heavy machinery*, direct impact.
- Increase of *excavation*, direct impact.

In the construction phase, heavy machinery will be used for diverting transmission line, excavation works, rerouting current infrastructure, underground works, and land clearance. All the machinery will emit greenhouse gases. If the construction works are executed at the same time, the emitted greenhouse gases will increase the GHG concentration in the air.

7.1.5 Noise and Vibrations

All five projects will contribute to noise pollution and vibrations in the area through three actions.

- Increase of *use of heavy machinery*, direct impact.
- Increase of *rerouting current infrastructure*, direct impact.
- Increase of *underground work*, direct impact.

During the construction phase, all noise and vibration is created from physical construction-related actions, and their associated traffic actions. This occurs in every project area which together accumulate the levels of noise and vibrations at Arlanda airport and along the transport corridor between Stockholm and Arlanda airport.

7.1.6 Air Quality

The air quality is affected by all projects in the construction phase through two actions.

- Increase of *excavation*, direct impact.
- Increase of *use of heavy machinery*, direct impact.

Air quality is impacted by dust and particles released during the construction phase. If the projects would be constructed at the same time the air quality in the Arlanda region might deteriorate at a faster pace.

7.1.7 Damage to Cultural Heritage

All project cause damage to cultural heritage through three actions.

- Increase of *excavation*, direct impact.
- Increase of *land clearance*, direct impact.

Cultural heritage, in this context, includes archaeological sites in the project areas. The archaeological sites will be, when present, impacted at all construction sites where hard structures will be built through working with soil. Since the construction of all projects would entail removing cultural heritage sites, the total value of cultural heritage at Arlanda airport and along the transport corridor between Stockholm and Arlanda airport would be decreased.

7.1.8 Visually Pleasing Landscape

All projects affect the physical landscape in the construction phase, leading to a less visually pleasing landscape through two actions.

- Increase of *excavation*, direct impact.
- Increase of *land clearance*, direct impact.

The visual value of the landscape might be compromised during the construction phase of the different project. Construction works lead to a disruption in the landscape view, like and soil piles resulting from excavation works, resulting in a changed landscape from forest and agricultural land into urban areas. However, if the projects would be constructed at different times the visual impact on the landscape would not be cumulative.

Table 7.1. Shows which projects that impacts environmental aspects. When minus is present, the project has one or more negative actions affecting the environmental aspect. The column Number of Actions summarizes the actions in all projects.

Construction Phase	**Projects**					**Number of Actions**
	Runway	Terminal	Park City	Transport	Logistic & Cargo City	
Biodiversity	-	-	-	-	-	4
Water contamination	-	-	-	-	-	1
Soil contamination	-	-	-	-	-	4
GHG concentration	-	-	-	-	-	2
Noise and Vibration	-	-	-	-	-	3
Air quality	-	-	-	-	-	2
Cultural heritage	-	-	-	-	-	2
Visually pleasing landscape	-	-	-	-	-	2

7.2 Operation Phase

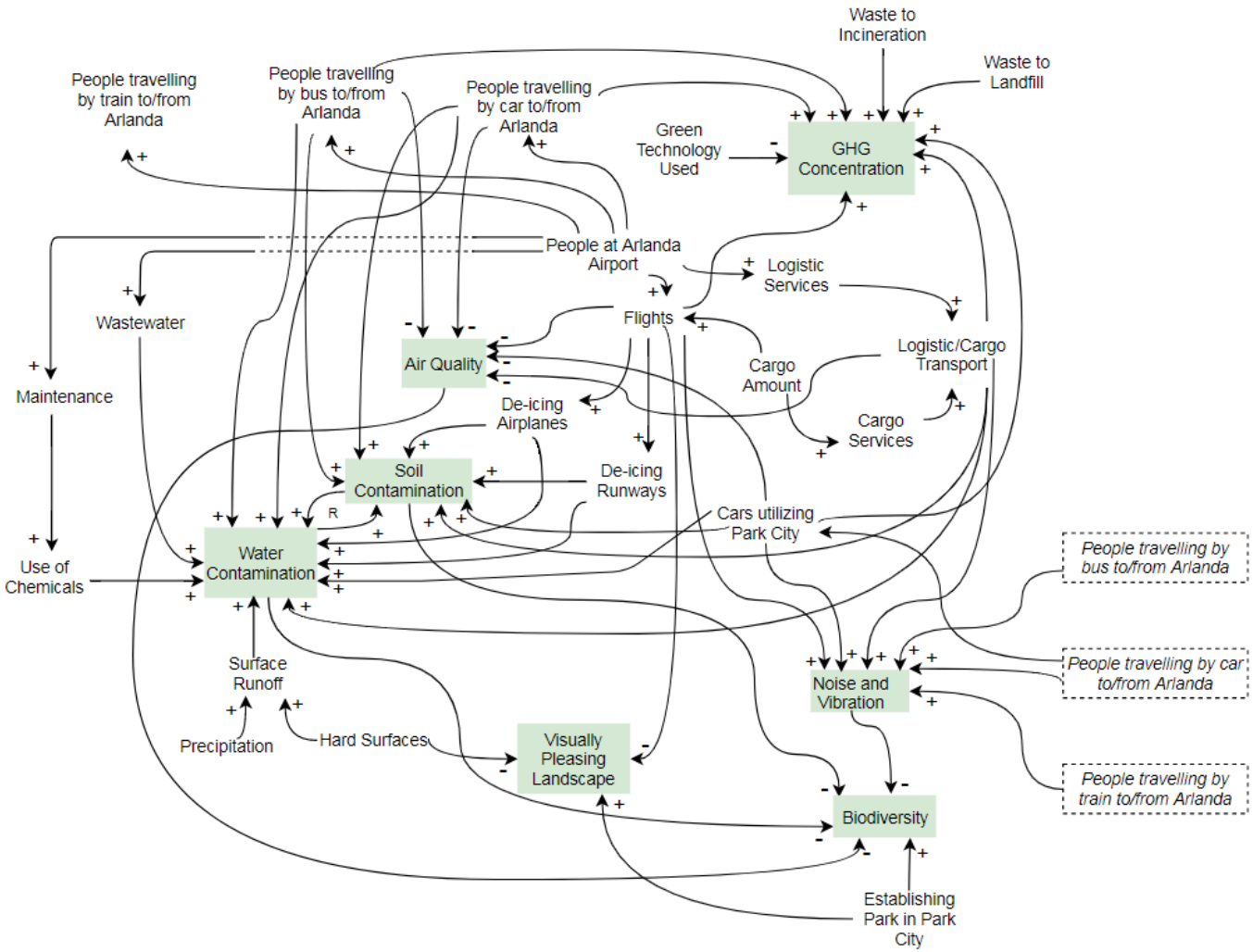


Figure 7.2. Causal loop diagram over operational phase and the cumulative impacts. Environmental aspects are displayed in green.

7.2.1 Biodiversity

Four of the five projects, with the exception of Park City, will have a negative impact on the biodiversity within their operation phase. There are in total ten actions that could lead to these negative impacts.

- Increased *use of chemicals*, indirect impact through water contamination.
- Increased amount of *surface runoff*, indirect impact water contamination.
- Increased amount of *wastewater*, indirect impact water contamination.
- Increase of *people travelling by car to/from Arlanda*, indirect impact through soil contamination, water contamination, air quality and noise and vibration.
- Increase of *people travelling by bus to/from Arlanda*, indirect impact through soil contamination, water contamination, air quality and noise and vibration.
- Increased *de-icing of airplanes*, indirect impact through soil- and water contamination.
- Increased *de-icing of runways*, indirect impact through soil- and water contamination.
- Increase of *cars utilizing Park City*, indirect impact through soil contamination, noise and vibration, water contamination and air quality.
- Increased amount of *logistic/cargo transport*, indirect impact through air quality, water contamination, noise and vibration and soil contamination.
- Increased amount of *flights*, indirect impact through noise and vibration and air quality.
- Increase of *people travelling by train to/from Arlanda*, indirect impact through noise and vibration.

In total there are 26 actions which affect Biodiversity negatively through Water Contamination, Soil Contamination, Air Quality and Noise and Vibration. Together they accumulate and worsen the living conditions for Biodiversity in all of the project areas.

Park City will however increase car traffic locally, but these effects are indistinguishable from the impacts caused by the noise and vibration from the nearby runway. Also, in the Park City project there will be a new park established which creates a positive effect on the local Biodiversity. This positive effect is marked with a green plus sign in table 7.2.

7.2.2 Water Contamination

All of the five projects affect this parameter negatively within their operation phase. There are in total nine actions that could lead to water contamination.

- Increase of *people travelling by bus to/from Arlanda*, direct impact.
- Increase of *people travelling by car to/from Arlanda*, direct impact.
- Increased amount of *wastewater*, direct impact.
- Increased *use of chemicals*, direct impact.
- Increased amount of *surface runoff*, direct impact.
- Increase of *de-icing runways*, direct impact.
- Increase of *de-icing airplanes*, direct impact.
- Increased amount of *logistic/cargo transport*, direct impact.
- Increase of *cars utilizing Park City*, direct impact.

All the actions, separate and combined, can affect both groundwater, local streams and other bodies of water, all of which can transport the

contaminants to other areas. Therefore, they could together accumulate and worsen the level of contaminants in water.

7.2.3 Soil Contamination

All of the five projects affect this parameter negatively within their operation phase. There are in total six actions that could lead to soil contamination.

- Increase of *de-icing runways*, direct impact.
- Increase of *de-icing airplanes*, direct impact.
- Increase of *people travelling by bus to/from Arlanda*, direct impact.
- Increase of *people travelling by car to/from Arlanda*, direct impact.
- Increased amount of *logistic/cargo transport*, direct impact and indirect.
- Increase of *cars utilizing Park City*, direct impact.

The impacts due to the operation phases of the Terminal-, Runway- and Logistics and Cargo City projects will together increase the contamination of the soil at Arlanda airport. The impacts from the Transport project will increase the soil contamination within its project area, but not within the area of Arlanda airport. Therefore, the cumulative impact is between the Terminal-, Runway- and Logistics and Cargo City projects, but not in combination with the Transport project.

7.2.4 GHG Concentration

All of the five projects will increase the GHG concentration in the project areas within their operation phase. However, there is also one external factor affecting the GHG concentration in the project areas. The variable green technology used could decrease the amount of GHG emissions let out from the implementation of each project. For example, if more people choose to travel by public transport instead of using a private car running on non-environmentally friendly fuel, there would be less GHG emissions from the operation phase of the Transport project. In total there are seven actions leading to higher concentrations of GHG.

- Increase of *people travelling by bus to/from Arlanda*, direct impact.
- Increase of *people travelling by car to/from Arlanda*, direct impact.
- Increased amount of *logistic/cargo transport*, direct impact.
- Increased amount of *flights*, direct impact.
- Increase of *cars utilizing Park City*, direct impact.
- Increase of *waste to incineration*, direct impact.
- Increase of *waste to landfill*, direct impact.

The amount of GHG emissions from the five projects will together contribute to a higher concentration of GHGs.

7.2.5 Noise and Vibration

Four of the five projects, with the exception of the Terminal project, will increase noise and vibrations within their operation phase. In total there are six actions leading to increased amount of noise and vibration.

- Increase of *people travelling by bus to/from Arlanda*, direct impact.
- Increase of *people travelling by car to/from Arlanda*, direct impact.
- Increase of *people travelling by train to/from Arlanda*, direct impact.
- Increased amount of *logistic/cargo transport*, direct impact.
- Increased amount of *flights*, direct impact.
- Increase of *cars utilizing Park City*, direct impact.

Impacts due to the Runway- and Logistic and Cargo City projects will together create higher levels of noise and vibration at the airport. Impacts regarding the Transportation project will not influence the noise levels at the airport since the project areas of the Transport group is outside of Arlanda airport. Park City will result in some removal of forest, and a potential concentration of cars in the Park City area which produces noise and vibration.

7.2.6 Air Quality

Four of the five projects, with the exception of the Terminal project, will have a negative impact on the air quality in the project areas. There are in total five actions that could lead to these negative impacts.

- Increase of *flights*, direct impact.
- Increased amount of *logistic/cargo transport*, direct impact.
- Increase of *people travelling by car to/from Arlanda*, direct impact.
- Increase of *people travelling by bus to/from Arlanda*, direct impact.
- Increase of *cars utilizing Park City,* direct impact.

Although not all of the projects are worsening the air quality, the wind might spread it out to all of the project areas. Therefore, the five impacts from four projects could accumulate, together creating a worse air quality.

7.2.7 Visually Pleasing Landscape

Two of the five projects will have a negative impact on the level of visually pleasing landscape; the Runway and the Transport project. Together they have two actions negatively affecting the parameter.

- Increase of *flights*, direct impact.
- Increase of *hard surfaces*, direct impact.

The Transport project would create a lot more hard surfaces, while the Runway project will lead to an increased amount of flights. Together, the increase of hard surfaces and flights will decrease the level of a visually pleasing landscape.

The Park City project does not have a negative impact on the visually pleasing landscape, even if they will have a lot more hard surfaces in the operation phase than the parking areas of Arlanda airport has today. This is because the Park City project also entails the building of a green park in its project area.

Table 7.2. Shows which projects that impacts environmental aspects. When minus is present, the project has one or more negative actions affecting the environmental aspect. The column Number of Actions summarizes the actions in all projects.

Operational Phase	**Projects**					**Number of Actions**
	Runway	Terminal	Park City	Transport	Logistic & Cargo City	
Biodiversity	-	-	+	-	-	26
Water contamination	-	-	-	-	-	9
Soil contamination	-	-	-	-	-	6
GHG concentration	-	-	-	-	-	7
Noise and Vibration	-		-	-	-	6
Air quality	-		-	-	-	5
Visually pleasing landscape	-			-	-	2

7.3 Final Reflections

Using this chapter, it is not possible to determine magnitude or significance, due to lack of quantitative data and expert knowledge. However, according to table 7.1, almost all actions in the construction phase will lead to Water contamination, Soil contamination, increased GHG concentration and Noise and Vibration. On the other hand, during the operation phase (see table 7.2) Biodiversity, Water contamination and GHG emissions are the most affected parameters. Important to note is that the number of actions does not reflect the magnitude or significance. Therefore, further investigation and collection of quantitative data is needed in order to establish which parameters could be most affected due to the implementation of these five projects regarding the Arlanda airport expansion.

Also important to consider is where in time the construction of the different projects will take place. If they are not constructed simultaneously, some impacts may not be cumulative, for example Noise and Vibration. Nevertheless, since not all impacts are time bound, for example soil contamination, cumulative impacts can still emerge even if the projects are constructed at different times.

Different scales are important to consider for the different environmental aspects. For example, air quality and biodiversity can be assessed at different geographical scales. Also, impacts from the construction of different construction action may reinforce each other and lift the impact to a higher geographical, temporal and social scale.

Chapter 8 Result and Discussion

8.1 Effects of the development proposal

Based on an overall assessment of all the projects dealing with expansions in Arlanda airport, the collective development proposal with the least negative impacts we recommended is presented in figure 8.1. The combination of Alternative North for the fourth runway and the Central Alternative for the terminal means that the new runway is quite far from the infrastructure of the rest of the airport (figure 8.1). Better logistically suited to parallel this runway development would be expansion of the North Alternative for terminals. However, that alternative would result in a major negative environmental impact on the exploited area which is not outweighed by the increased proximity to the runway. Internal transport solutions must be developed at the airport so that the new runway is connected in an efficient way with the terminal. A possible solution could be building an Automated People Moreover, a bus or train without a driver, which could connect the runway with the other parts of the airport, which has been suggested by Swedavia (2017b).

Logistic City and Park City are located on opposite sides of a transport corridor made up of Arlandaleden/Road 273 and other smaller roads (figure 8.1). The expansions proposed by the projects would increase both the cargo and ground-based passenger traffic on Arlandaleden. This increase of vehicles on the road could cause problems. There would be risk of both heavy congestion and increased levels of air and noise pollution. It is important to take this into account when planning, so that the capacity of the road would be sufficient.

The people working in and visiting the airport could benefit from being close to planned recreational areas in Park City. Accessibility to these areas may be an issue however, but this could be improved by building tunnels or bridges that would further connect Park City to the rest of the airport. Moreover, Arlandaleden will contribute to giving a Park city a good location.

Regarding future transport to/from Arlanda, the proposed Railway Option would mean an increase in passenger bus traffic along smaller roads from Märsta station. In addition, Cargo City also make use of these roads. There would be a risk of problems with congestion on these roads as well. This could partly be mitigated by two combined measures. One would be to implement the Road Option together with the railway option, which would distribute an increase in passengers over all existing road infrastructure. The second would be to expand Cargo City road, where no passenger traffic is allowed. This strategy could further mitigate the potential capacity overload.

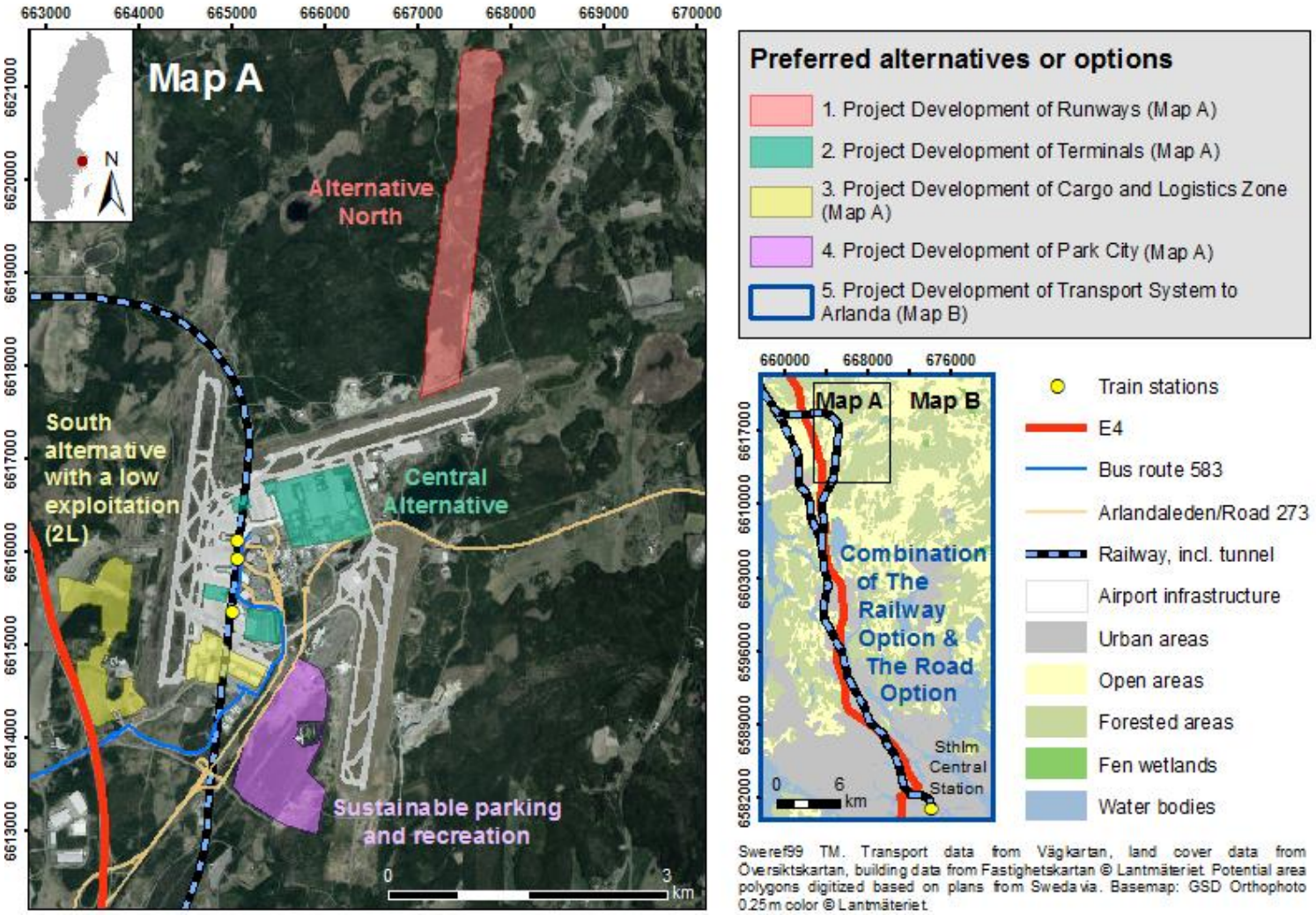


Figure 8.1. Result map of preferred alternatives or options for all areas of expansion. Where red represent the runway 4, green represent the new terminal, yellow represent the logistic zone and purple represent the area for Park city in Map A. Blue represent the area for expanding the railway and E4 in the Stockholm region in Map B.

8.1.2 Swedavia's goals

By implementing the projects *Expansion of Arlanda Terminals* and *Development of Runways* the future vision of 70 million passengers could be achieved. By also implementing the project *Expansion* of *Logistics and cargo zone at Arlanda Airport* and *Development of Park city*, Swedavia can increase its air freight, storage and parking capacity. This could contribute to making Arlanda a metropolitan hub, including facilities such as shopping centres, green spaces and parks, offices, hotels and parking spaces. Moreover, Swedavia wants to be a role model for sustainability by eliminating the emissions of CO_2 produced by its own operations and supporting the use of biofuels at their airports (Swedavia, 2017a; Swedavia, 2017b). The development of Park city strives towards a goal of zero CO_2 emssion, due to the suggested solar panels. Project *Expansion of Transports System* to *Arlanda* would make Arlanda airport more accessible, increasing Arlanda's attractiveness.

8.1.3 Relating to plans

The development of Arlanda airport is in accordance with the regional plan of Stockholm. All five projects considered in this report contribute in one way or another toward a more metropolitan region, which is the main aim of the regional plan. The job opportunities in the region as well as the economy can benefit from the Arlanda expansion. The two projects regarding development of the airport area, *Development of Runways* and *Expansion of Arlanda Terminals*, make it possible for the airport to develop into a hub, which in turn enables good international and domestic communications to and from the Stockholm region. Project *Expansion of the Logistics and Cargo Zone at Arlanda Airport* also contributes to Arlanda's ability to become a hub, by increasing the capacity for air and other cargo transportation. Furthermore, the development of Logistic City together with the expansion of Park City will increase the capacity of the area to incorporate facilities such as offices, shopping centres and more hotels and parking spaces. The hotels and facilities suggested by the project *Development of Park City*, aim to be sustainable both during the construction and operation phases. This is also in accordance with the regional plan of Stockholm which states that resources should be used efficiently and that the amount of GHG emissions should be small (RUFS, 2010). Project *Expansion of Transport System to Arlanda*, concerning and expansion of the transport system is also in line with the regional plan since it enables increased infrastructure in the region.

Sigtuna municipality has eight strategies in their comprehensive plan, with the purpose to develop the municipality in a sustainable way. The five projects in this report are in line with some of these strategies, yet they go against others. This is a result of that the strategies amongst themselves are somewhat contradictory for large projects falling into more than one strategy. For example, the projects *Development of Runways*, *Expansion of Arlanda Terminals* and *Expansion of the Logistics and Cargo Zone at Arlanda Airport*, are incorporated in the strategy to develop the Arlanda-Märsta region, but they go against the strategy of ecological endurance, since implementing the expansions impact the ecology in the area in a negative way. Moreover, the Project *Expansion of Transport System to Arlanda* is in line with the strategies concerning increased infrastructure, but it also goes against the strategy of ecological endurance, since the increase in traffic impacts ecology in a negative way by to increased amounts of contaminants, noise, vibrations and air pollutants. Project *Development of Park City*, suggest recreational green areas, which compiles with the strategy regarding attractive and social sustainable environment. The project also suggests hotels, which are in accordance with the strategy of sustainable construction.

8.1.4 Impacts on the environment

The expansion of Arlanda airport will affect two nature reserves in the surrounding. The construction of the runway in the North will affect the nature reserve Laggatorp due to the construction as well as contaminant transport. An expansion of E4, as proposed in the project *Expansion of*

Transport System to Arlanda, would have a negative impact on the ecosystem functions of Fysingen nature reserve. The expansion of the Arlanda area will also lead to cumulative effects (see chapter 7), which in turn could increase the risk of exceeding the EQS for noise as well as EQS for NO_2, O_3 and particles in the air. Today, the nearby recipient water body *Märstaån* experience an average ecological status and a poor chemical status. The current EQS state that Märstaån should reach a good ecological status by 2027 as well as good chemical status for surface water. An increased contaminants transport, as a result of the Arlanda expansion, would increase the risk of *Märstaån* not reaching a good ecological and chemical status. Thereby, the Arlanda expansion would worsen the ecological status of *Märstaån* which is not an environmentally sustainable development.

According to Swedavia (2017d), sustainability is the basis of its business and strategy. The expansion of the Arlanda airport would have adverse effects on the environment due to construction and operation activities although mitigation measurements will be taken. If Swedavia would realize their vision of 70 million passengers yearly at the airport, the resulting increase in air traffic would constrain the achievement of a number of Environmental Objectives, such as "Reduced climate impact" and "Clean Air". An extensive expansion of air travel, using current technology is not environmentally sustainable due to the large emissions of CO_2, noise and other pollutants from air planes. However, air travel is important for economic and social factors both regionally, nationally and globally. It is not an easy task to balance socio economic benefits against negative environmental impacts which an expansion of the airport and air traffic would result in. It is important to keep the three parts of sustainability in mind when planning such an expansion so that no aspects are favoured at the expense of the other.

A majority of the Swedish environmental objectives would overall be negatively affected by the proposed expansion of Arlanda (Table 8.1.).

The expansion of Arlanda airport will negatively affect the following objectives: “Reduced climate impact", "Clean Air", "Natural acidification", "Zero Eutrophication", "A Non-Toxic Environment", "A Varied Agricultural Landscape", "Good-Quality Groundwater", "A Rich Diversity of Plant and Animals Life". Negative impacts will occur as a result both of the construction phase and of more vehicles moving in the area. The negative impacts are largely due to usage of diesel vehicles, which emit CO_2 NO_2, and particles, negatively affecting air quality and contributing with GHGs. Emitted NO_2, can react and generate tropospheric ozone, increase the acidification and eutrophication in surrounding areas and water bodies. The compounds from vehicles, material, de-icing and other operations can negatively affect the ground water quality and result in more contaminants in the area and nearby water bodies. These consequences as well as more noise and reduced air quality can adversely affect aquatic ecosystems and other ecosystem.

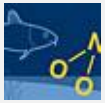
The five projects have no overall net impact on the objectives "A Good Built Environment" and "Thriving wetlands". There would be a negative impact on the "Thriving wetlands" from the implementation of the project *Expansion of Arlanda Terminals*, which would remove wetland area. However, the new wetland areas proposed by project *Development of Park city*, could compensate for the lost wetlands. Thus, the projects are assessed to have no net impact on this objective. Regarding the objective "A Good Built Environment", the development of the airport area would lead to improved aviation infrastructure and accessibility. Also, the planned hotels and facilities in Park city would contribute to the objective since they are meant to be built in a sustainable way. However, a result of the projects would be an increase in the noise levels in the area. This has a negative impact on the objective. The overall assessment is thereby that there would be no net impact from the projects on the objective since the positive and negative impacts balance each other.

Several of the Environmental Objectives are considered to not be relevant to assess in the frame of the projects due to the spatial boundary

of the project and the configuration of the Arlanda expansion. The objectives considered as irrelevant are "A magnificent mountain landscape", "A Balanced Marine Environment", "Flourishing Coastal Areas and Archipelagos", "A Safe Radiation Environment" and "A protective ozone layer".

Table 8.3. The effect of Arlanda's expansion on the Swedish Environmental Objectives. A downward arrow represents a negative impact on the objective and an upward arrow represents a positive impact on the objective. The arrow pointing straight ahead represents no noticeable impact on the objective.

Reduced Climate Impact 	↘
Clean Air 	↘
Natural Acidification Only 	↘
A Non-Toxic Environment 	↘

A Protective Ozone Layer 	**Not relevant**
A Safe Radiation Environment 	**Not relevant**
Zero Eutrophication 	↘
Flourishing Lakes and Streams 	↘

Good-Quality Groundwater 	↘
A Balanced Marine Environ-ment, Flourishing Coastal Areas and Archipelagos 	**Not relevant**
Thriving Wetlands 	→
Sustainable Forests 	↘
A Varied Agricultural Landscape 	↘
A Magnificent Mountain Landscape 	**Not relevant**

A Good Built Environment 	→
A Rich Diversity of Plant and Animal Life 	↘

8.1.5 Conclusions

There is no overlapping conflict between the expansion areas proposed by the different projects. However, there is still a need to solve issues that could arise when implementing the projects in relation to each other.

In general, the large scale proposed development of Arlanda airport is not sustainable from an environmental perspective. An implementation of the plans to expand the airport and connected transport system would have significant negative effects on the majority of the relevant environmental objectives as well as some EQS. However, such a large scale expansion plan could, on the other hand, have significant positive impacts on regional and national economy, which could be beneficial for sustainable socio-economic development.

Furthermore, incorporation of mitigation measures in the planning process, Swedavia's goal to become fossil free and the potential future use of biofuels by airlines might enable a more sustainable development in the environmental perspective as well. On a national level, it is important for Arlanda to increase its capacity since it is the largest airport in Sweden and an important transport hub. This could enable growth in the region and increase Sweden's attractiveness internationally. It would also be in accordance with the aims of the comprehensive plans of Sigtuna and Stockholm municipalities and the regional plan for Stockholm county.

A development as complex as an expansion of the operations at Stockholm-Arlanda Airport calls for a system analysis perspective in order to manage cumulative impacts as well as in incorporating sustainable development at the core of all processes.

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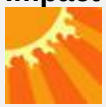
9. Appendix

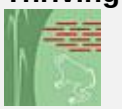
9.1 Appendix Chapter 1

Swedish Environmental Goals

Definitions of the Swedish generation goal and the sixteen environmental objectives and the official illustrations associated with each objective by Tobias Flygar (Naturvårdsverket, 2012).

Reduced Climate Impact 	"In accordance with the UN Framework Convention on Climate Change, concentrations of greenhouse gases in the atmosphere must be stabilized at a level that will prevent dangerous anthropogenic interference with the climate system. This goal must be achieved in such a way and at such a pace that biological diversity is preserved, food production is assured and other goals of sustainable development are not jeopardized. Sweden, together with other countries, must assume responsibility for achieving this global objective."
Clean Air 	"The air must be clean enough not to represent a risk to human health or to animals, plants or cultural assets."
Natural Acidification Only 	"The acidifying effects of deposition and land use must not exceed the limits that can be tolerated by soil and water. In addition, deposition of acidifying substances must not increase the rate of corrosion of technical materials located in the ground, water main systems, archaeological objects and rock carvings."
A Non-Toxic Environment 	"The occurrence of man-made or extracted substances in the environment must not represent a threat to human health or biological diversity. Concentrations of non-naturally occurring substances will be close to zero and their impacts on human health and on ecosystems will be negligible. Concentrations of naturally occurring substances will be close to background levels."
A Protective Ozone Layer 	"The ozone layer must be replenished so as to provide long-term protection against harmful UV radiation."
A Safe Radiation Environment 	"Human health and biological diversity must be protected against the harmful effects of radiation."

Zero Eutrophication 	” Nutrient levels in soil and water must not be such that they adversely affect human health, the conditions for biological diversity or the possibility of varied use of land and water."
Flourishing Lakes and Streams 	"Lakes and watercourses must be ecologically sustainable and their variety of habitats must be preserved. Natural productive capacity, biological diversity, cultural heritage assets and the ecological and water-conserving function of the landscape must be preserved, at the same time as recreational assets are safeguarded."
Good-Quality Groundwater 	"Groundwater must provide a safe and sustainable supply of drinking water and contribute to viable habitats for flora and fauna in lakes and watercourses."
A Balanced Marine Environment, Flourishing Coastal Areas and Archipelagos 	"The North Sea and the Baltic Sea must have a sustainable productive capacity, and biological diversity must be preserved. Coasts and archipelagos must be characterized by a high degree of biological diversity and a wealth of recreational, natural and cultural assets. Industry, recreation and other utilization of the seas, coasts and archipelagos must be compatible with the promotion of sustainable development. Particularly valuable areas must be protected against encroachment and other disturbance."

Thriving Wetlands 	"The ecological and water-conserving function of wetlands in the landscape must be maintained and valuable wetlands preserved for the future."
Sustainable Forests 	"The value of forests and forest land for biological production must be protected, at the same time as biological diversity and cultural heritage and recreational assets are safeguarded."
A Varied Agricultural Landscape 	"The value of the farmed landscape and agricultural land for biological production and food production must be protected, at the same time as biological diversity and cultural heritage assets are preserved and strengthened."
A Magnificent Mountain Landscape 	"The pristine character of the mountain environment must be largely preserved, in terms of biological diversity, recreational value, and natural and cultural assets. Activities in mountain areas must respect these values and assets, with a view to promoting sustainable development. Particularly valuable areas must be protected from encroachment and other disturbance."

A Good Built Environment 	"Cities, towns and other built-up areas must provide a good, healthy living environment and contribute to a good regional and global environment. Natural and cultural assets must be protected and developed. Buildings and amenities must be located and designed in accordance with sound environmental principles and in such a way as to promote sustainable management of land, water and other resources."
A Rich Diversity of Plant and Animal Life 	"Biological diversity must be preserved and used sustainably for the benefit of present and future generations. Species habitats and ecosystems and their functions and processes must be safeguarded. Species must be able to survive in long-term viable populations with sufficient genetic variation. Finally, people must have access to a good natural and cultural environment rich in biological diversity, as a basis for health, quality of life and well-being."

9.2 Appendix Chapter 2

Maps for Hydrology and Geology

Storm water is collected and transported through various ditches seen in figure 2.9 below.

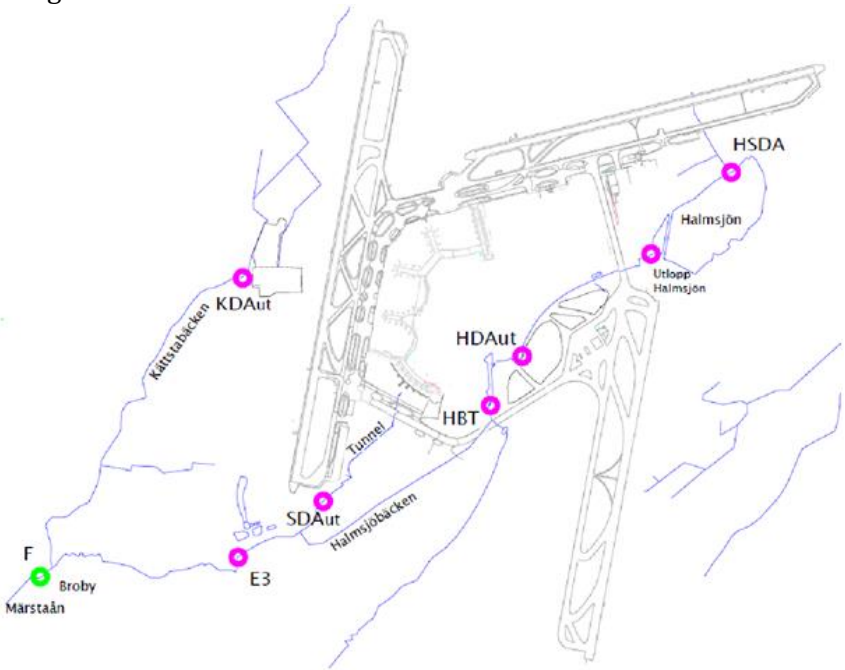


Figure 2.9. Figure showing both the tunnel and all of the surface ditches and treatment plants for storm water (Swedavia, 2017b).

Wastewater is collected and transported by various pipes, see figure 2.10 below.

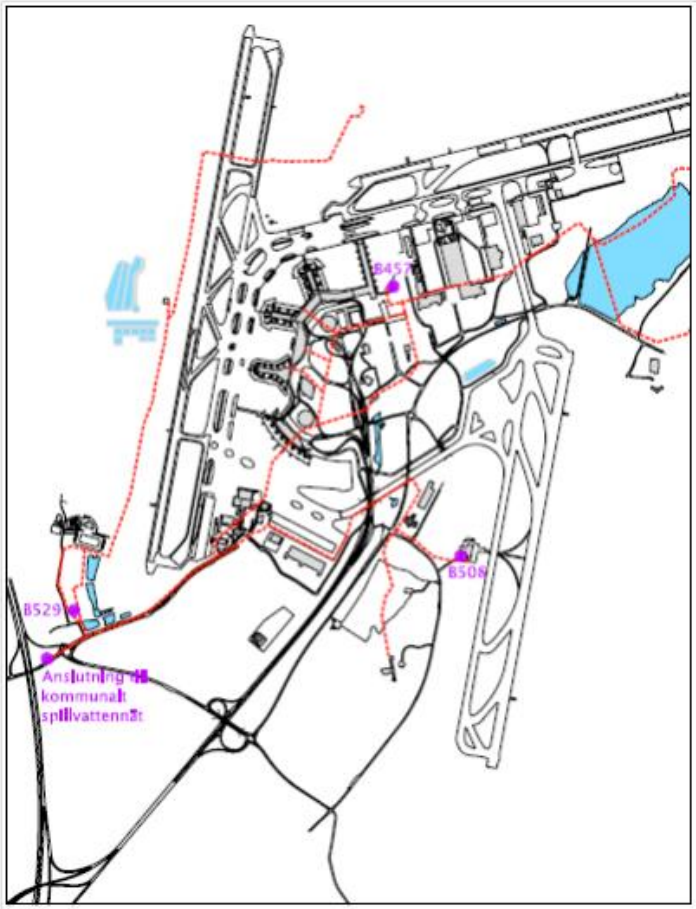


Figure 2.10. Wastewater pipes in red and three internal treatment plants; B457, B508 and B529 (Swedavia AB, 2011).

Surface water movement and the buried tunnel that connects Halmsjön with Halmsjöbäcken and Broby.

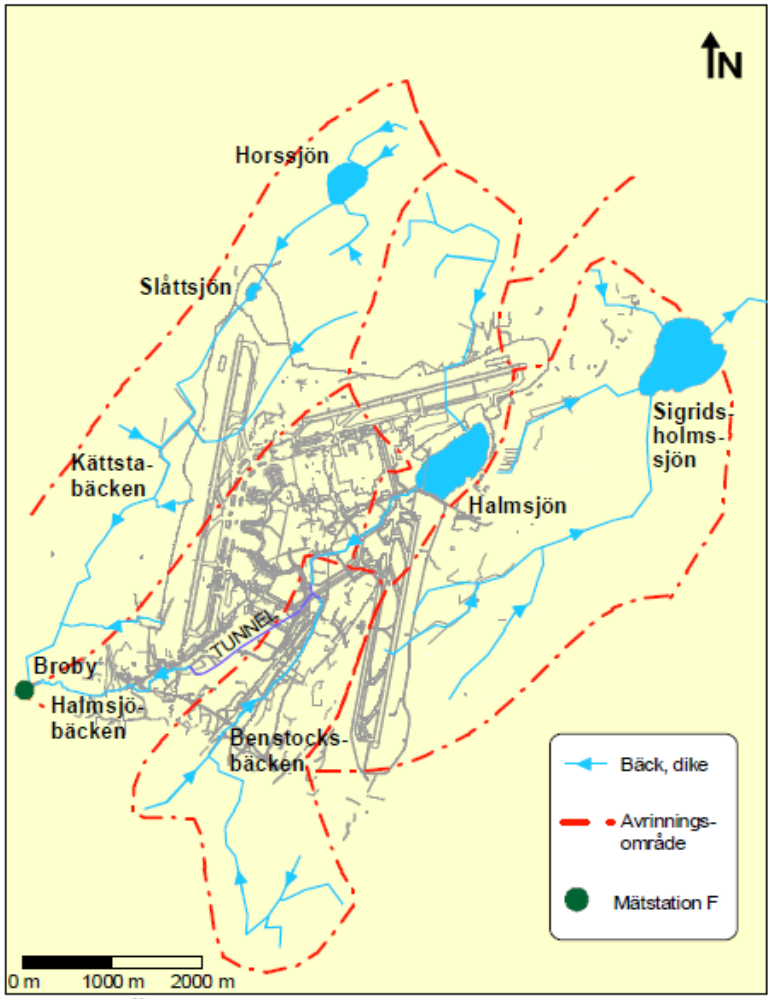


Figure 2.11. It is showing both the tunnel the all of the surface brooks and treatment plants for storm water (SWECO, 2002).

Ground water movement inside the esker are shown in figure 2.12 below.

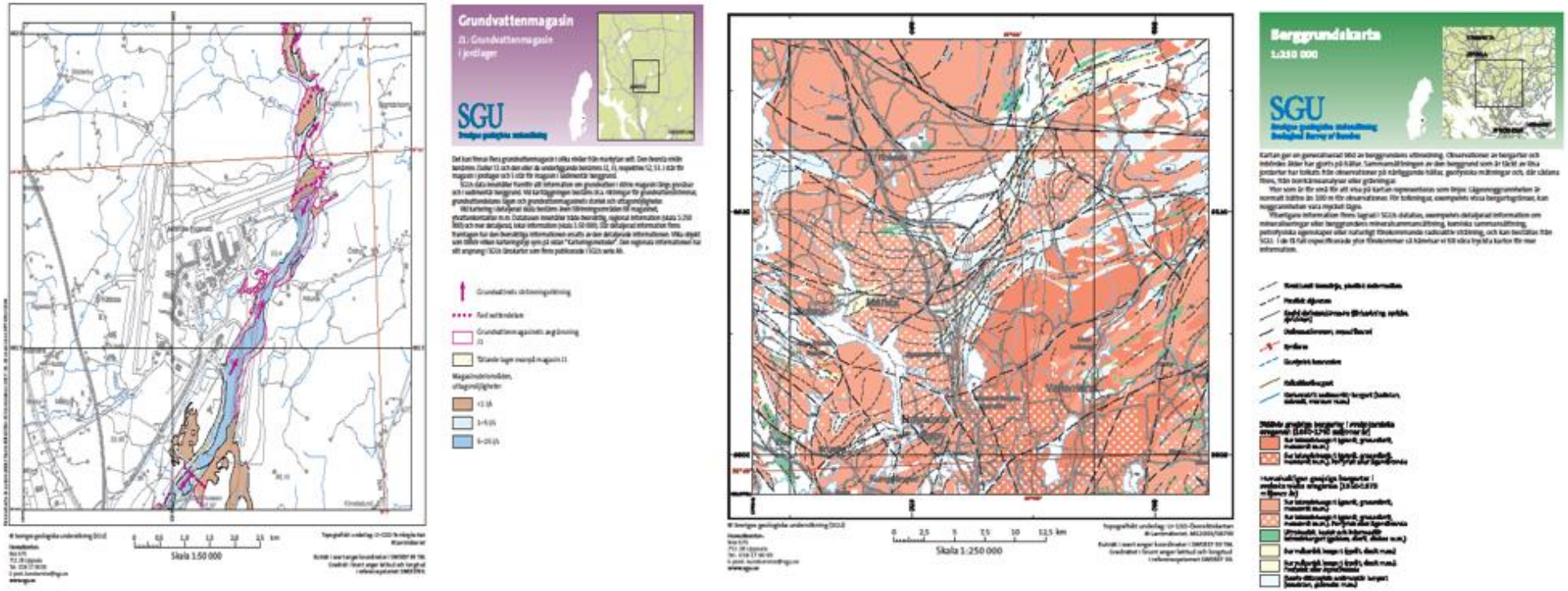


Figure 2.12. Map of bedrock formations (SGU, 2017c).

Rational method

This method is a simple deterministic model to estimate the peak discharge from an area, and could thereby assess the risk of flooding. The peak discharge can be calculated by knowing the rainfall intensity, surface area and land cover, see equation 1 (LMNO engineering, 2015). Different ground cover will affect the infiltration and the runoff from the area, the runoff coefficients for different covers are in table 2.21.

Table 2.20. Size of the area at each location. These data were collected from GIS.

Location of runway four	Before construction			Short runway built		Long runway built	
	Forest (km2)	Meadow (km2)	Cultivated land (km2)	Lawn (km2)	Runway (km2)	Lawn (km2)	Runway (km2)
Proposed	1.33	0.24	0.44	1.90	0.11	1.31	0.15
North	0.97	0.24	0.22	1.35	0.11	1.86	0.15
East	5.07	0.61	0.42	5.99	0.11	5.95	0.15

$Q_{peak} = C \cdot I \cdot A$ [Equation 1]

Where:
Q_{peak} = Peak runoff (m^3/day)
C = Runoff coefficient $(no\ unit)$
I = Rainfall intensity $(mm/year)$
A = Drainage area (km^2)

Table 2.21. Runoff coefficients for different type of ground cover, used to estimate the peak discharge by the rational method (LMNO engineering, 2015).

Runoff coefficient	Forest	Meadow	Cultivated land	Lawns	Asphalt/ Concrete	Parks, cemeteries	Unimproved areas	Pasture	Residential areas	Business areas	Industrial areas	Brick streets	Roofs
min	0.05	0.10	0.08	0.05	0.70	0.1	0.1	0.12	0.3	0.5	0.5	0.7	0.75
max	0.25	0.50	0.41	0.35	0.95	0.25	0.3	0.62	0.75	0.75	0.9	0.85	0.95

During 2016 rainfall intensity was 500 $mm/year$ according to SMHI (2017). Other collected data are from either GIS (Table 20) or from LMNO Engineering, Research, and Software Ltd (Table 21).

This data was used in equation above, which was retrieved from the Urban Drainage and Flood Control District (2016).

Zero alternative runoff were compared to sum of each runway and lawn runoff to exemplify the percentage increase. This can be found in chapter 4.3.1 under Alternative location.

Table 2.22. Peak Surface runoff, calculations are separated by minimum and maximum value of runoff coefficient.

Land use	Proposed location		North location		East location	
	min (m3day)	max (m3day)	min (m3day)	max (m3day)	min (m3day)	max (m3day)
Forest	90.34	452.12	66.29	329.56	344.39	1722.35
Meadow	33.01	163.03	37.08	183.40	83.27	414.36
Cultivated	48.22	245.08	24.31	122.54	46.05	234.34
Zero alternative (sum)	171.17	860.23	126.48	635.50	473.31	2370.25
Lawn	91.53	641.12	91.53	641.12	407.11	2847.39
Short runway	107.39	145.19	107.39	145.19	107.39	145.19
Sum	198.52	786.31	198.52	786.31	514.10	2992.18
Lawn	89.09	623.60	89.09	624.00.00	404.27	2830.28
Long runway	141.22	192.06	141.22	192.06	141.22	192.06
Sum	230.31	815.26	230.31	815.26	545.49	3021.54

Map showing drainage basins shown in a radius

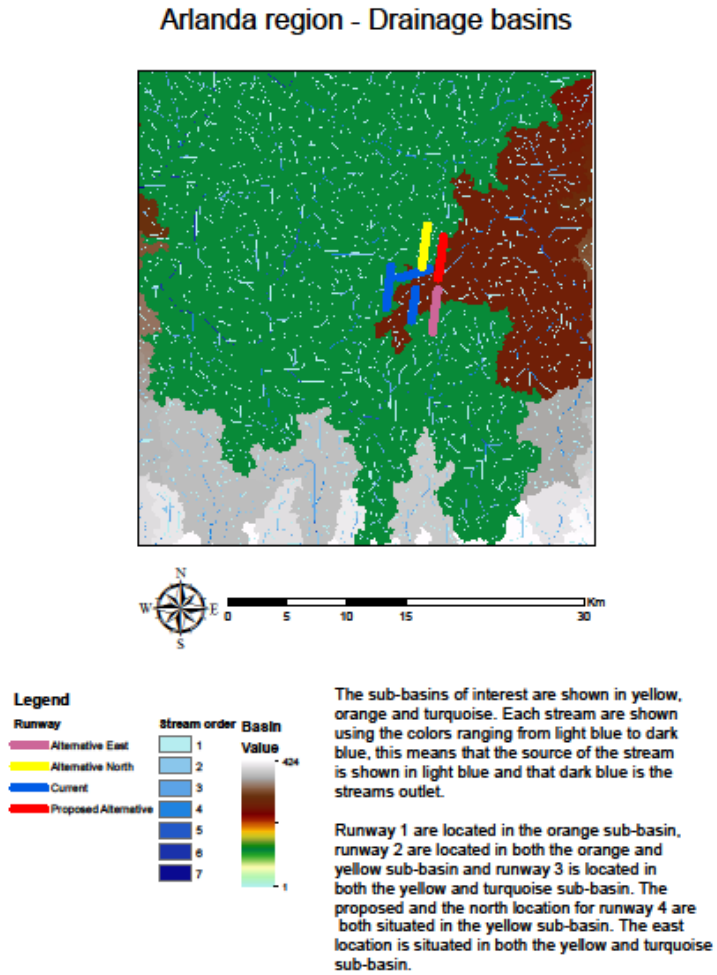


Figure 2.13. A larger map of the surface water flow in sub-basins of the Arlanda region (Created using DEM from SGU).

9.3 Appendix Chapter 3

Table 3.11. Total score for each environmental values or aspects assessed in the literature review.

Environmental values or aspects	Total Score
Air (Quality)	8
Water (Surface)	8
Noise	8
Land Use Changes (important ecosystems)	7
Cultural Heritage	6
Socioeconomic (jobs, trade, investment)	6
Soils	5
Water (Underground)	5
Environmental Hazards	5
Transportation	4
Air (Climate)	4
Vegetation	4
Wildlife	4
Utilities: Water and sewer utilities	4
Vibration	4
Waste	4
Energy and Natural Resources	3
Historic and cultural preservation	3
Land Use Zoning	2
Public Services	2
Light and glare	2
Emergency Services	1
Housing	1
Recreation	1

9.4 Appendix Chapter 4

Questions from Interview with Cargo Manager

Interview with Bas Van Goch, Cargo Operations Manager at Arlanda Airport.

- What would be the use of Logistics City? What do you want the development to include?
- Why this specific area (west of runway 1), and what is the purpose of merging cargo/business with hotels and service areas?
- What is the difference between Cargo City and Logistic City 2?
- What do the current logistics look like for Arlanda? Do they occur at Cargo City now?
- Does Swedavia own the property for the proposed sites? What about the existing buildings, village, and farm areas?
- Is it an alternative to move only parts of Cargo City west of the runway?
- If Cargo City is moved to the west of the runway, will that make cargo transports at the airport problematic?
- Is it an alternative to place parts of this development on the other side (east) of the E4?
-

Maps Showing Alternatives

Large-scale maps of the alternatives studied in the report can be found on the following two pages.

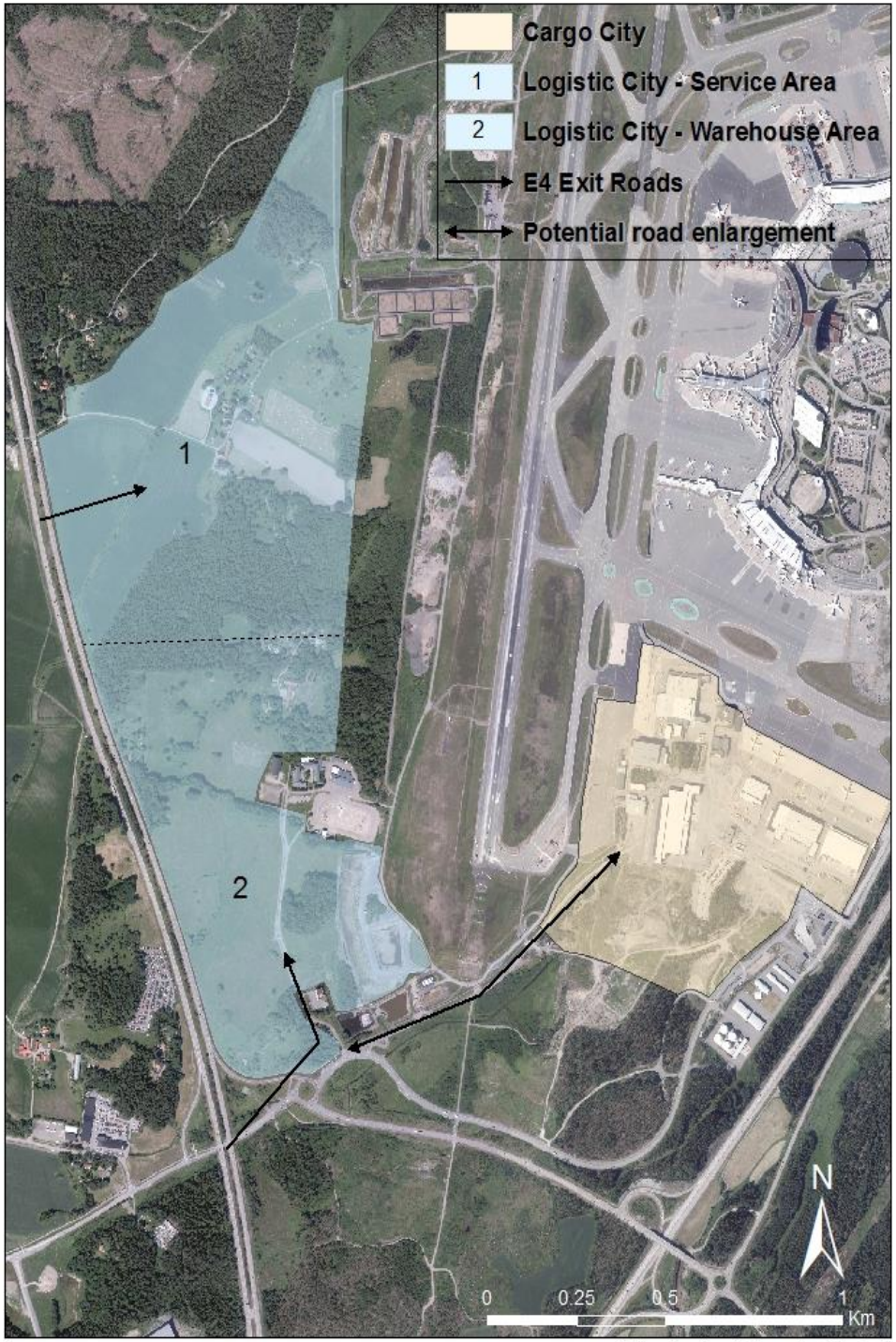
Alternative 1 High

Ortophoto © Lantmäteriet

Alternative 1 Low

Ortophoto © Lantmäteriet

Alternative 2 High



Ortophoto © Lantmäteriet

Alternative 2 Low

Ortophoto © Lantmäteriet

Pictures from field observations

Pictures 1 and 2 shows the current area of Cargo City with warehouses and unloading places for air cargo.

1

5

Pictures 3 and 4 shows the agricultural landscape in the area where the north part of Logistic City is suggested.

3

4

Pictures 5 and 6 shows the forest landscape where the south part of Logistic City is suggested.

5

6

9.5 Appendix Chapter 5

Maps

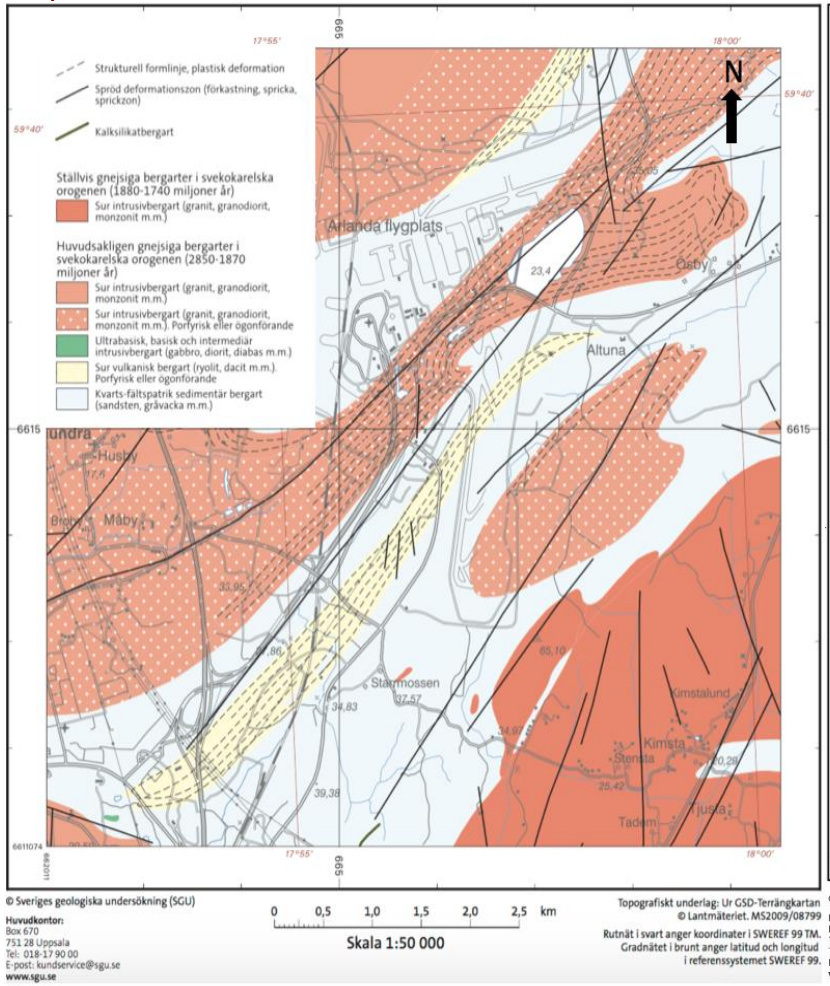


Figure 5.A. Bedrock types in Arlanda region (SGU, 2017).

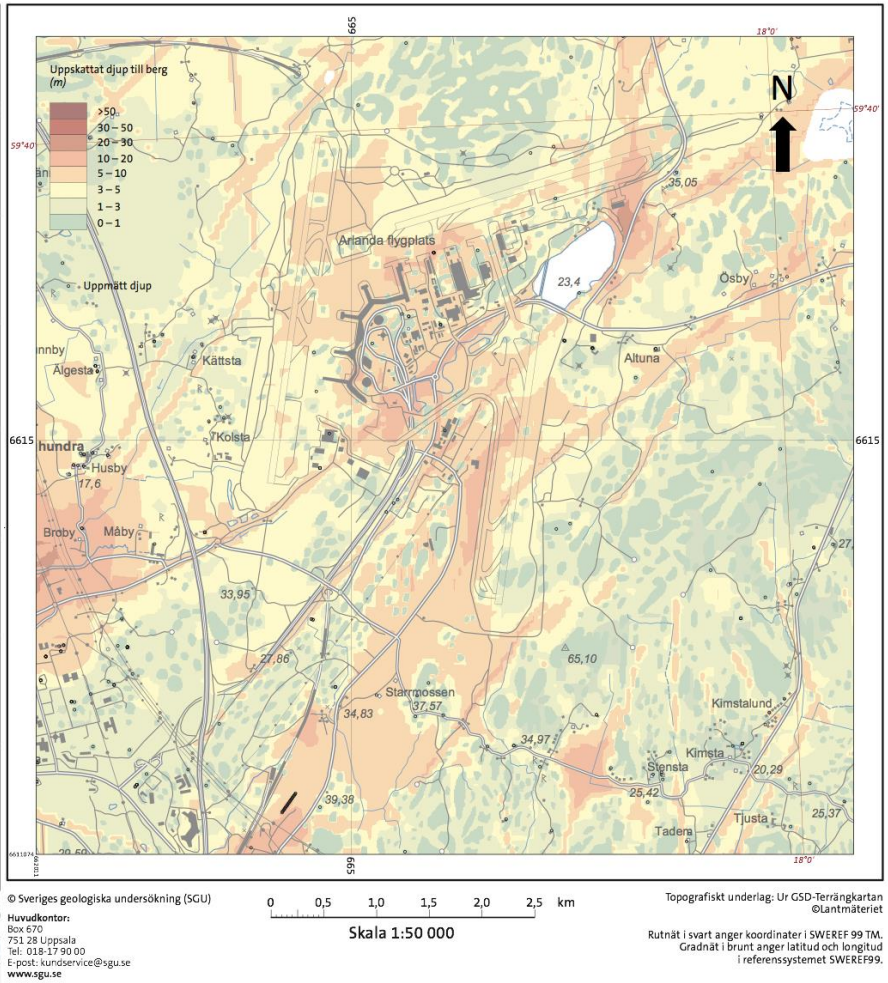


Figure 5.B. Soil depths in Arlanda area (SGU, 2017).

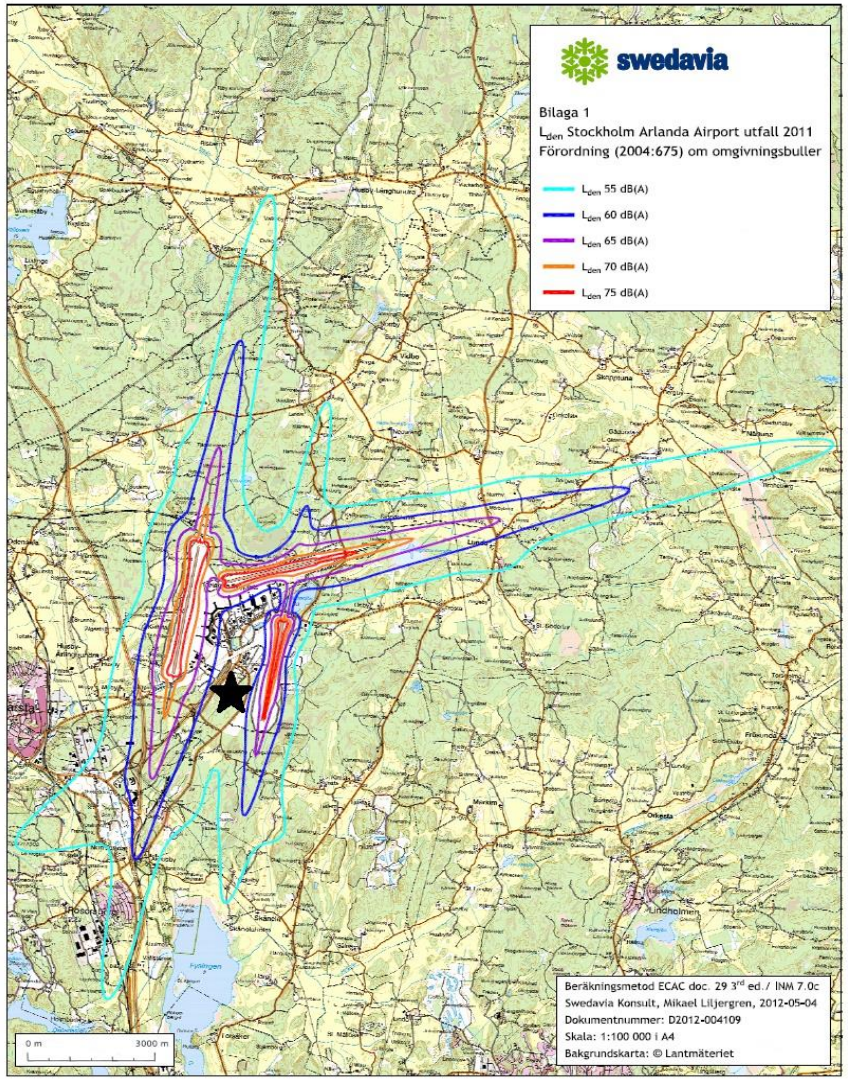


Figure 5.C. Measured daytime noise pollution from Arlanda airport in 2011. The project area (the star) is within the 55 dB and east and west side are on the border to 60 dB. Map made by Mikael Liljegren for Swedavia with background map © Lantmäteriet.

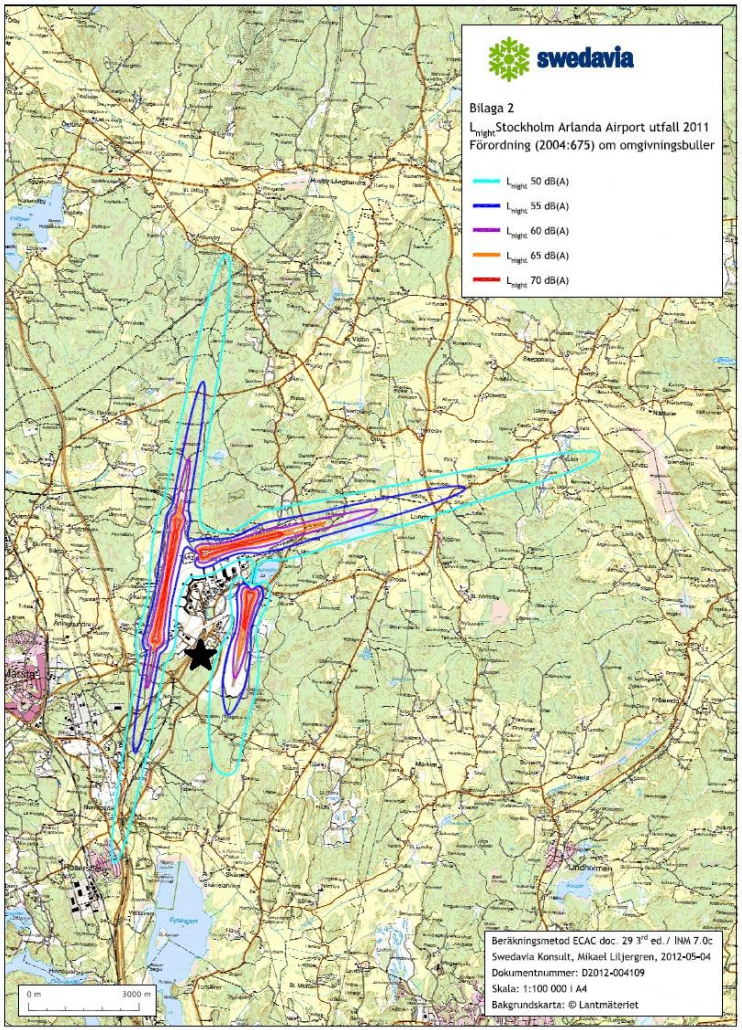


Figure 5.D. Measured night-time noise pollution from Arlanda airport in 2011. Parts of the east side of the project area (the star) is within the 55 dB. Map made by Mikael Liljegren for Swedavia with background map © Lantmäteriet.

Interview with Adam Lunderup at Swedavia

1. **Hur många parkeringsplatser finns det på P2 Beta?**

   Ca 4700 varav 1 200 används för personalparkering och resterande som resenärsparkering.

2. **Ska framtida Park City innehålla samtliga Arlandas parkeringsplatser?**

   När det gäller den parkeringskapacitet som Swedavia tillhandahåller kommer Park City att vara centralt och få ökad betydelse när fastighetsutvecklingen tar markparkeringar i anspråk terminalnära. Parkering i P-hus planeras dock vara kvar terminalnära för lång tid framåt. Långtidsparkering tillhandahålls också av externa parkeringsoperatörer. Vi har inte tillgång till deras strategiska planer men vi kan anta att även de kommer utveckla sin verksamhet stegvis då flygplatsen växer.

9.6 Appendix Chapter 6

Table 6.6. People who have been contacted and who have contributed with information to the SEA (chapter 6).

Contacted Stakeholder	Response
Interview with Phoebe, *Technical support*, SL	Answered one of many questions
Interview with Anonymous employee at Flygbussarna	No answer
Interview with Anders Nyqvist, Arlanda Express	Answered
Interview with Sofia Lindblad, *Strategisk planerare*, Trafikverket	Answered
Interview with Kerstin Gustavsson, *Miljöstrateg*, Trafikverket	Answered
Adam Lunderup, *Utvecklingsingenjör*, Swedavia	Answered
Frida Svensson, *Planarkitekt*, Sigtuna kommun	No relevant answers

CLD Description, Operation Phase

With the expansion of Arlanda airport, the increase of airborne passengers will increase the number of people using ground transportation to reach Stockholm and the airport. There will be more *people travelling by train*, *people travelling by bus* and *people travelling by car*. The public choice will be influenced by *travel time by road, travel time by train*, *punctuality* and *cheaper tickets*.

More *people travelling by car* will lead to more *cars on the road*, more *noise and vibrations*, more *traffic congestion, toxic waste from vehicles* and *chemical leakage from traffic accidents.* It will also, together with *people travelling by bus*, lead to a worsened *air quality,* which leads to negative impacts on *human health* and increases the *damage to cultural heritage*. *People travelling by bus* and *car* will also increase *GHG emissions*, which can be decreased with the use of *green technology*.

More *people travelling by bus* will lead to more *toxic waste from vehicles.* In addition, with more *people travelling by bus* there will be more *overcrowded buses* on the road leading to the increase of the *bus departures* with a delay. More *bus departures* will increase the levels of *noise and vibrations* on the road which together with *overcrowded buses* will lead to a negative impact on *human health*.

Likewise, the more *people travelling by train* will lead to *overcrowded trains* increasing the *train departures* with a delay. With increase of *train departures, noise and vibrations* will also increase. *Human health* will be negatively affected by *overcrowded trains and noise and vibrations*.

The *toxic waste from vehicles* and *chemical leakage from traffic accidents* will increase the *soil contamination* and *water contamination*. In addition, waters will be contaminated due do *road salting* as the necessary measure during snowfalls. The more of the *hard surfaces* that will be exposed to the snow, the more salt will enter the soil leading to *water contamination*. *Hard surfaces* will also lead to an increase of *surface runoff*, which will lead to more *soil contamination*. The *hard surfaces* will also decrease the *biodiversity*. *Hard surfaces* will also lead to a less *visually pleasing landscape* which then will negatively influence *human health*.

The variables connecting operational phase to the construction phase are denoted in bold style in blue boxes: *construction of more lanes on E4* and *construction of railway tracks.*

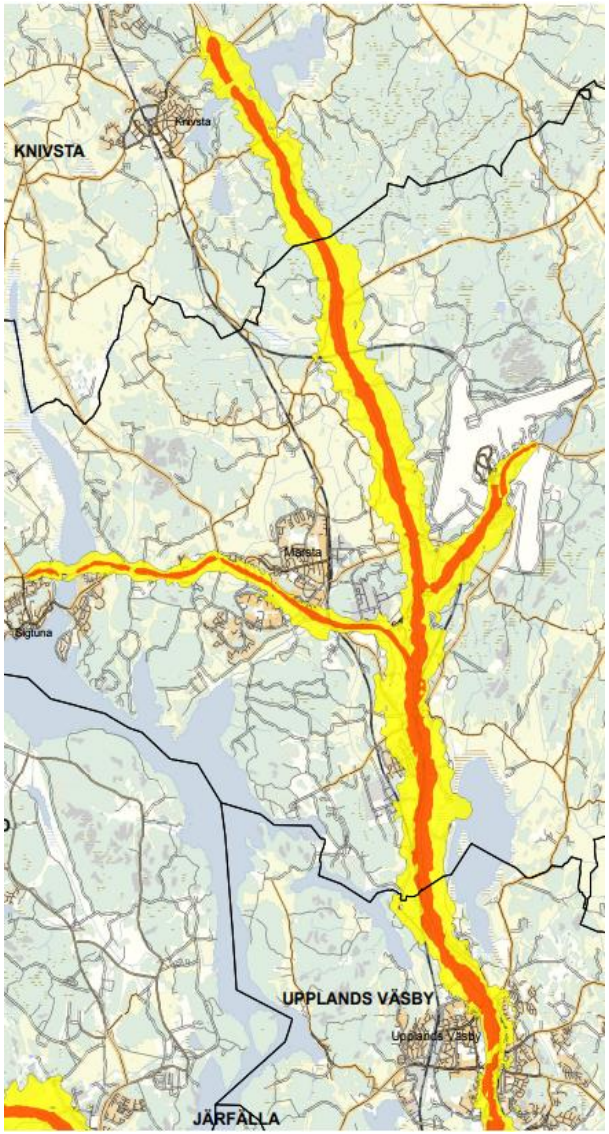


Figure 6.13. Noise map for road traffic at Arlanda Airport (Trafikverket, 2012).

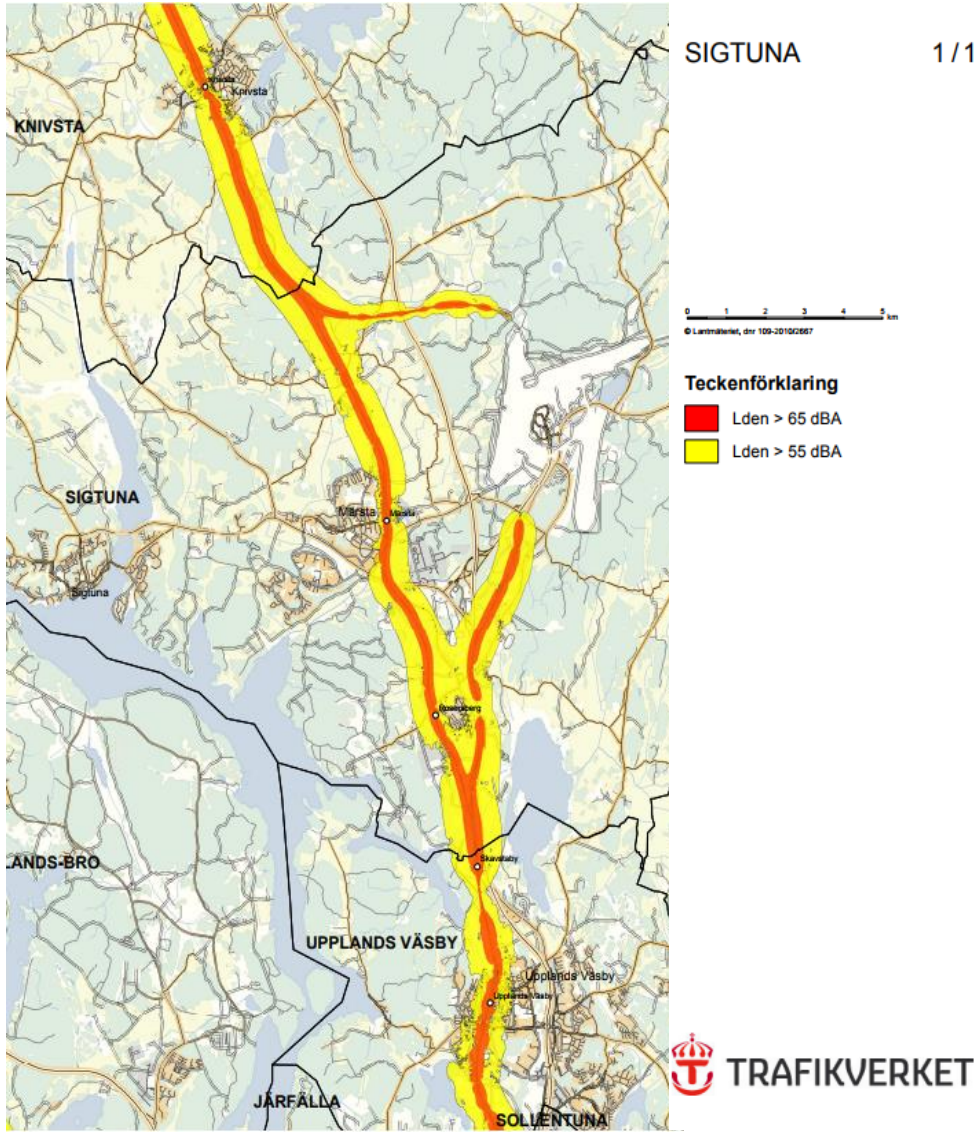


Figure 6.14. Noise map for railway traffic at Arlanda Airport (Trafikverket, 2012).

Table 6.7. Overview over the ecological and chemical status of the surface water in the study area.

Surface water	Ecological Status	Chemical Status	Significant Impacts	Parameter with Need of Improvement
Norrviken	unsatisfying	does not achieve good	● not IED industry ● urban land use ● agriculture ● Polluted soil/ old industrial soil ● Individual sewerage ● atmospheric deposition	● tributyltin ● cadmium/ cadmium compounds ● lead/ lead compounds ● anthracene ● total phosphorus ● total nitrogen ● PFOS ● copper ● zinc
Brunnsviken	unsatisfying	does not achieve good	● IED industry ● not IED industry ● urban land use ● agriculture ● Individual sewerage ● atmospheric deposition	● ammoniac ● nutrients ● PFOS
Märstaån	Moderate	does not achieve good	● IED industry ● not IED industry ● urban land use ● agriculture ● Individual sewerage ● atmospheric deposition	● nutrients ● connectivity of the stream ● morphology ● PFOS
Oxundaån-Verkaån	Moderate	does not achieve good	● not IED industry ● atmospheric deposition	● morphology ● PFOS
Oxundaån-Väsbyån (Väsbyån, Edsån)	Moderate	does not achieve good	● urban land use ● agriculture ● Individual sewerage ● atmospheric deposition	● nutrients ● morphology ● PFOS
Igelbäcken	good	does not achieve good	● atmospheric deposition	● connectivity of the stream

Table 6.8. Overview over the ecological and chemical status of the groundwater in the study area.

Groundwater Area	Quantitative Status	Chemical Status	Source of Impact	Parameter with Need of Improvement
Stockholmsåsen-Norrsunda	good	good	• polluted areas • landfills • transport and infrastructure • polluted soil/ old industrial soil	• sulphate • PFAS 11
Stockholmsåsen-Upplands Väsby	good	unsatisfying	• polluted areas • transport and infrastructure • polluted soil/ old industrial soil	• trichloroethene • tetrachloroethene • chloride • conductivity • PFAS 11
Stockholmsåsen-Sollentuna	good	good	• polluted areas • Transport and infrastructure	• sulphate
Stockholmsåsen-Silverdal	good	good	• polluted areas • transport and infrastructure	-
Stockholmsåsen-Solna	good	good	• polluted areas • transport and infrastructure	-
Stockholmsåsen-Haga	good	good	• polluted areas • transport and infrastructure	-

9.7. Appendix Chapter 7

Operation CLD go-through

More *people at the Arlanda airport* will lead to an increased number of *flights* and more *people that will travel to and from Arlanda by car, bus and train*. It will also lead to more *logistic services* and an increased amount of *cargo*. More *people at the airport* will increase the *use of energy*, the *wastewater* and the *maintenance*. More *maintenance* will lead to an increased *use of chemicals*, which in turn will increase the *water contamination*. More *wastewater* will also increase the *water contamination*. With more *people traveling to and from Arlanda by car and bus*, *GHG emissions* will increase. An increase of *waste to incineration* and *waste to landfill* will also increase the *GHG emissions*. Both *soil and water contamination* will increase while the *air quality* decreases. More *people that will travel to and from Arlanda with help of buses and cars* will increase the *soil and water contamination*. Increased travels by *car, bus and train* will increase the *noise and vibrations*.

A higher amount of *flights* will increase the amount of *cargo*, increase the *logistic services*, emit more *noise and vibrations*, contribute to a *less visually pleasing landscape*, increase the need to *de-ice both the airplanes and the runways*, release more *GHG emissions* and lower the *air quality*. A higher amount of *cargo* will increase the *cargo services*, which together with increased *logistic services* will increase the *logistic/cargo transport*. The *logistic/cargo transport* will raise the *GHG emissions* and lower the *air quality*. The *GHG emissions* will decline with a higher *usage of green technology*.

More *flights* will lead to a decreasing *air quality*, a higher amount of *cargo*, more *logistic services*, a bigger need to *de-ice both airplanes and runways*, more *noise and vibration*, a *less visually pleasing landscape* and more *GHG emissions.* Lower *air quality* will in turn lower the *biodiversity*. Also more *noise and vibration*, *water contamination* and *soil contamination* will lower the *biodiversity*. At the same time, the *establishing a park in Park City* will increase the *biodiversity*. A higher amount of *cargo* will increase the *cargo services* which, together with the *logistic services*, will increase the *logistic/cargo transport*. The *logistic/cargo transport* will increase *noise and vibration* and *GHG emissions*. The *GHG emissions* will decline with increasing *green technology used*.

Increased *precipitation* will lead to increased *surface runoff*. More *hard surfaces* will also lead to more *surface runoff* and a *less visually pleasing landscape*. The increased *de-icing of both airplanes and runways* will increase both *soil* and *water contamination*. In turn, more *water contamination* will lead to more *soil contamination* as well.

More *Cars utilizing Park City* will lead to more *noise and vibration*, a higher *GHG concentration* and more s*oil contamination*. In turn, it will lead to lower *air quality*.

Construction CLD go-through

Diverting transmission lines will lead to more *excavation*. More *excavation* will in turn lead to more *changes in hydrology*, more *soil contamination*, more *use of heavy machinery* and a higher *GHG concentration*. It will also lead to a *less visually pleasing landscape*, lower *air quality*, lower *biodiversity* and a decline in *cultural heritage*.

Rerouting current infrastructure will increase *soil contamination*, increase *noise and vibration*, increase the *changes in hydrology* and implement more *use of heavy machinery*.

Underground construction work will lead to less *biodiversity*. It will also lead to more *soil contamination*, more *noise and vibration*, more *changes in hydrology* and an increased *use of heavy machinery*.

Land clearance will lead to a *less visually pleasing landscape*, lower *biodiversity*, more *changes in hydrology* and an increased *use of heavy machinery*. An increased use of *heavy machinery* will in turn lead to more *noise and vibration*, more *water and soil contamination*, a higher *GHG concentration* and lower *air quality*. An increase in *soil contamination* will in turn decrease the *air quality*.