Strategic
Alliance
for
Integrated
Water
Management
Actions

Flood and risk mapping according to the flood directive

Scenarios in Lidköping and Karlstad

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Abstract

SAWA - Strategic Alliance for Integrated Water Management Actions - is an EU-funded project that aims to reduce the risk of flooding in vulnerable areas, with particular focus on how to consider future climate changes. An intermediate target of the work is to produce flood maps and flood risk maps, in accordance with Council Directive 2007/60/EC (the Floods Directive), for the urban centres of the pilot areas of Karlstad and Lidköping. The aim is to test how to work with parts of the Floods Directive in Sweden, with the given conditions and tools available to us today within Länsstyrelsen (county administration) and the local authorities. It is this target that is addressed by this report.

The choice of hydrological scenarios for the initial survey should be done defensively - that is to say that even water levels with a low probability of occurrence should be chosen, in order to obtain as accurate a picture as possible of the exposed areas. Thereafter, a thorough analysis can be conducted at finer resolution for estimation of flood impacts. In Lidköping's case, SAWA opted to use levels of +46.5 m and +47.4 m (RH 70). Both levels are taken from SOU 2006:94 Översvämningshot risker och åtgärder för Mälaren, Hjälmaren och Vänern (Flood threat risks and measures for lakes Mälaren, Hjalmaren and Vänern). A water level of 46.5 m is considered to have a recurrence interval of 100 years in today's climate, with 60 cm added for the effect of high winds in an unfavourable direction. A water level of +47.4 m is considered a worst case scenario, taking into account climate change by 2100, and an addition for wind effect of 0.5 m. Karlstad has a more complicated situation, in that its urban area is affected by both the Klarälven river and the Vänern lake. Karlstad estimates that "100 year" flows in the Klarälven represent a higher risk than the equivalent event in the Vänern, and has therefore chosen to focus primarily on that. From a spatial planning perspective, Karlstad estimates that a 200-year return event in the Klarälven may be a relevant hydrological starting scenario.

Risk maps, according to the Floods Directive, aim to describe the social, economic and environmental consequences of flooding. An other important knowledge base, that does not clearly fall within any of the categories being described by flood risk maps, is that of the effects on important community infrastructure and services - such as electricity, water and sewage, healthcare and welfare, and impact on important transport routes etc.
Therefore, SAWA has placed these effects under the heading of "other information". In the rules that will be developed to guide the work related to the Floods Directive in Sweden, it is important to include how these vital community systems and services should be defined and described. In order to easily gather all of the information needed for the survey work, it is our view that there should be further development of VISS, the database of water information developed in the context of Swedish water management. Much of the information requested is already found there.

A major limitation to developing a good overview map basis is, currently, the national elevation database, which contains very coarse data. The model used by SAWA for Lidköping municipality is based upon manually entered values. In Karlstad, the local authority has paid for its own laser scanning. Given that the lack of elevation data has been identified as a

problem, Lantmäteriet (national land survey) has been commissioned by the government to create a new national elevation database. Work began in autumn 2009 and expected to be finished in 2015. In order for the survey work under the Floods Directive to contribute new and useful knowledge, new data from Lantmäteriet should be used to the greatest possible extent when the mapping is started on a large scale.

Zusammenfassung

SAWA - Strategic Alliance for Integrated Water Management Maßnahmen - ist ein EU-finanziertes Projekt, um die Gefahren von Überschwemmungen in gefährdeten Gebieten zu verringern, insbesondere mit Einbezug eines zukünftigem Klimawandels. Ein Zwischenziel dieser Arbeit sind die Hochwasserkarten und Hochwasserrisikokarten gemäß der Richtlinie 2007/60/EG über die Hochwasserrisiken (Hochwasser-Richtlinie) der städtischen Pilotgebiete Karlstad und Lidköping. Ziel der Arbeit ist es zu prüfen, wie man mit Teilen der Hochwasser-Richtlinie in Schweden arbeiten kann, mit den gegebenen Rahmenbedingungen und Instrumente die heute im Länsstyrelsen und Gemeinden zur Verfügung stehen. Dieser Bericht behandelt dieses Ziel.

Die Wahl der hydrologischen Szenarien für die erste Identifizierung sollte defensiv gemacht werden, welches auch Wasserstände mit einer geringen Wahrscheinlichkeit, als die gewählte, beinhalten sollte, alles um ein so genau wie mögliches Bild der exponierten Gebieten zu bekommen. Danach werden gründlichere Analyse mit feinerer Auflösung für die Schätzung der Auswirkungen eines Hochwassers durchgeführt. Im Fall von Lidköping hat sich die SAWA Gruppe auf ein Niveau von 46,5 m und 47,4 m (RH 70) bewählt. Beide Niveaus stammen aus dem Bericht ”Überschwemmungsrisiken und massnahmne für Mälaren, Hjälmaren und Vänern”(SOU 2006:94). Der Wasserstand +46,5m ist der geschätzte Ausgangswert der innnerhalb von 100 Jahren wiederkehrt mit einbezug von heutigen Wetter mit einem 60cm Auschlag für kraftige Winde aus ungünstiger Richtung. Der Wasserstand +47,4m ist der geschätzte Wert für das *Worst-Case* Szenario mit Klimawandel bis zum Jahr 2100 und mit einem Aufschlag von 0,5m für Wind. Karlstad hat eine komplizierte Situation, weil das städtische Gebiet sowohl von dem Fluss Klarälven und dem See Vänern betroffen ist. Karlstad schätzt, dass die erhöhten Ströme des Flusses Klarälven mit einer 100 jährigen Wiederholungszeit ein höheres Risiko darstellen als der See Vänern, und Karlstad hat sich entschieden, sich in erster Linie auf den Fluss Klarälven zu konzentrieren. Aus Sicht der Planung ist eine 200-jährigen Wiederholungszeit von erhöhten Strömen im Fluss Klarälven ein geeignetes hydrologisches Ausgangs-szenario.

Gefahrenkarten im Rahmen der Hochwasser-Richtlinie zielen darauf ab und beschreiben die sozialen, wirtschaftlichen und ökologischen Folgen der Überschwemmungen. Eine wichtige Wissensbasis, die nicht eindeutig in eines der Elemente fallen wie die Hochwasserrisikokarten angeben, sind die Einflüsse auf soziale Aktivitäten wie Strom, Wasserversorgung, Kloake, Gesundheits-und Sozialwesen, Auswirkungen auf die wichtigsten Transportwege, etc. In SAWAs Arbeit wurden wichtige Auswirkungen auf gesellschäftliche Aktivitäten unter der Überschrift ”weitere Informationen” gesammelt. Deshalb sind die Beschreibung und Eingränzung von diesen Aktivitäten wichtig für die Arbeit mit der Hochwasser-Richtlinie in Schweden.

Um auf einfache Weise alle Daten zu sammeln, die für die Zuordnung der Arbeit erforderlich sind, ist unsere Auffassung, dass man die Datenbank der Wasser-Informationen im Rahmen der schwedischen Wasserwirtschaft, VISS, weiterentwickeln sollte. Ein Großteil der angeforderten Informationen ist dort vorhanden.

Eine wichtige Beschränkung um einen guten Überblick über Kartendaten zu bekommen, ist nun die nationalen Höhen- Datenbank, die sehr grobe Daten bietet. Das Modell für die Stadt Lidköping in SAWA verwendet manuell eingegebene Daten. Karlstad hat hingegen in eine eigenen Laser-Scanner investiert.
Weil die bristfälligen Höhendaten als Problem identifiert wurden, hat ”Lantmäteriet” den Auftrag von der schwedischen Regierung bekommen eine neue nationelle Höhen-Datenbank zu erstellen. Die Arbeiten begannen im Herbst 2009 und werden voraussichtlich 2015 abgeschlossen sein. Wegen der Arbeit im Rahmen der Richtlinie für den Hochwasserschutz werden neue, nützliche Kenntnisse wie neue Daten aus der ”Lantmäteriet”, so weit wie möglich genutzt werden, wenn im Rahmen der Hochwasser-Richtlinie die Kartierung in großem Umfang gestartet werden soll.

Samenvatting

SAWA – Strategic alliance for integrated water management actions – is een door de EU gefinansieerd projekt over het verminderen van overstromingsrisico's in overstromings-gevoelige gebieden met het focus op hoe te handelen in een veranderend klimaat. Een sub-doelstelling van het projekt is om overstromingsgevaar- en overstromingsrisicokaarten op te stellen volgens Richtlijn 2007/60/EG van het Europees Parlament en de Raad over de beoordeling en beheer van overstromingssrisico's. In Zweden richt het werk zich op de pilootgebieden rond Karlstad en Lidköping aan het meer Vänern.

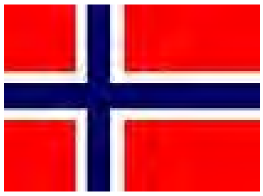
De bedoeling is om in beide pilots te testen hoe men kan werken met delen van de Richtlijn, uitgaande van de randvoorwaarden bij en gebruik makend van de beschikbare werktuigen op Länsstyrelsen en bij de gemeenten. Het is dit deeldoel dat in dit rapport belicht wordt.

De keuze van hydrologische scenario's bij een eerste kartering dient defensief te geschieden, dat wil zeggen dat men ook waterstanden met lage waarschijnlijkheidsgraad kiest om daarmee een zo rechtvaardig mogelijk beeld te krijgen van overstromingsgevoelige gebieden. Daarna kunnen er diepgaande analyses gedaan worden met meer uitgewerkte meetwaarden om in te schatten wat de gevolgen van een overstroming zouden kunnen zijn.
In het geval van Lidköping heeft de SAWA groep ervoor gekozen om de niveaus + 46,5 m en + 47,4 m (RH 70) te gebruiken. Deze niveaus komen uit de overheidspublikatie SOU 2006:94 'Overstromingsgevaar, risico's en maatregelen voor Mälaren, Hjälmaren en Vänern'. Een waterniveau van +46,5 m wordt ingeschat voor te komen eens in de 100 jaar, uitgaande van het huidige klimaat en rekening houdend met een 60 cm extra stijging door ongunstige wind. Het niveau van +47,4 m is berekend vanuit het *worst case* scenario met klimaatwijzigingen zoals voorzien in het jaar 2100 en met een extra stijging van 0,5 m door ongunstige wind.
In Karlstad is de situatie meer gecompliceerd daar de bebouwde kom zowel door de rivier Klaraälven beinvloed wordt als door het meer Vänern. Karlstad gaat ervan uit dat er een groter risico bestaat voor overstromingen met een herhalingsperiode van 100 jaar in de rivier Klaraälven dan dat het geval is voor Vänern en heeft daarom besloten zich vooral daar op te richten. Vanuit het samenlevingsperspektief beoordeelt Karlstad dat een herhalingsperiode van 200 jaar in het stroomgebied van Klaraälven een relevant hydrologisch startscenario is.

Risicokaarten dienen volgens de Richtlijn de sociale,economische en milieu gevolgen van overstromingen te beschrijven. Eén kennisgebied wordt echter niet duidelijk benoemd binnen de aandachtspunten voor deze risicokaarten, namelijk de *impact* van overstromingen op essentiële functies in de samenleving zoals o.a. elektriciteitsvoorziening, waterverzorging en riolering, zorgsector en gevolgen voor het communicatienetwerk. In SAWA is de *impact* op maatschappelijke functies geschaard onder het aandachtspunt 'andere informatie'.
De hoofdvraag is dan hoe deze maatschappelijke velden af te grenzen en te beschrijven in de te ontwikkelen Zweedse aanwijzingen in het werk met de Richtlijn Overstromingsrisico's.

Onze beoordeling is dat men op een eenvoudige wijze de stroom van informatie voor de kartering kan hanteren door de informatiebank VISS uit te bouwen. VISS is ontwikkeld als een water database als deel van de nieuwe zweedse overheidsdienst voor waterbeheer. Veel belangrijke gegevens zijn daar al in opgeslagen.

Een grote belemmering in het opstellen van goed en overzichtelijk kaartmateriaal is dat de nationale hoogte databank geen fijnschalige gegevens aan kan bieden. Het model dat SAWA gebruikt in Lidköping is gebaseerd op met de hand ingevoerde waarden. In Karlstad heeft de gemeente een eigen laserscanning bekostigd. Lantmäteriet (Kadaster) heeft van de Zweedse regering als opdracht gekregen om een nieuwe informatiebank voor hoogtegegevens op te zetten en is daar in 2009 mee begonnen en wordt geacht daarmee klaar zijn in 2015.
Als nu de inventarisatie volgens de Richtlijn dient bij te dragen met nieuwe en bruikbare kennis dan zullen de nieuwe gegevens van Lantmäteriet hopelijk gebruikt kunnen worden wanneer de inventarisatie en kartering op grote schaal in gang gezet worden.



Oppsummering

SAWA – *Strategic alliance for integrated water management actions* – er et EU-finansieret projekt hvis målsetning er å minske risikoene for flom i utsatte områder, med et fokus på å ta hensyn til klimaforandringer i fremtiden. Et delmål i projektet er å ta frem risikokart og flomkart ifølge *Rådets direktiv 2007//60/EF om flomrisikoer* (heretter referert som flomdirektivet) over pilotområdene Karlstad og Lidköpings tettsteder. Hensikten er å teste hvordan man kan arbeide med deler av flomdirektivet i Sverige under gitte forutsetninger og med de verktøy vi har tilgang til idag i Fylkeskommuner og kommuner.

Valget av hydrologiske scenarioer knyttet til den første kartleggingen bør utføres defensivt, det vil si at de høyeste vannivåene som med liten sannsynlighet vil oppstå bør velges. Dette for å få et så rimelig bilde som mulig av utsatte områder. Deretter kan fordypninger i analysen utføres i finere oppløsning for å beregne hvilke konsekvenser en flom kan få.
For Lidköping har SAWA-gruppen valgt å bruke vannnivåene +46,5 m og +47,4 m (RH 70). Begge vannivåene er hentet fra den svenske etterforskningen SOU 2006:94 (”Översvämningshot risker och åtgärder för Mälaren, Hjälmaren och Vänern”). Vannivået +46,5 m vurderes til å være et vannivå med tilbakekomst hvert 100:e år i dagens klima, med et påslag på 60 cm for kraftig vind i uheldig vindretning. Vannivået +47,4 m vurderes til å være det verste tenkelige scenarioet der hensyn er tatt til beregnede klimaforandringer frem til år 2100, og et påslag for vind på 0,5 m.

Karlstad har en mere komplisert situation da vannivået rundt tettstedet blir påvirket av både Klarälven og Vänern. Karlstad vurderer at det største fløde som forekommer i Klarälven med 100 års mellomrom er en større risiko en et tilsvarende vannivå i Vänern, og har valgt og fokusere på det. Utifra et samfunnsperspektiv vurderer Karlstad at en tilbakekomst hvert 200:e år i Klarelva kan være et relevant hydrologisk scenario.

Risikokart ifølge flomdirektivet har til hensikt å beskrive sosiale, økonomiske og miljømessige konsekvenser av flom. Et annet viktig område den beskriver er påvirkningen på samfunnsviktig virksomhet som el, vann og kloakk, helse og omsorg, samt påvirkninger på viktige vei- og transportårer. Innen SAWAs arbeid håndteres disse påvirkningene under punktet ”annen informasjon”. Hvordan samfunnsviktig virksomhet skall definieres og beskrives er viktig å få med i de veiledende foreskriftene for arbeidet med flomdirektivet i Sverige.

For å enkelt samle all informasjon som trengs for kartleggingsarbeidet er vår vurdering at den databasen for vanninformasjon som den svenske vannforvaltningen har tatt frem (VISS) må videreutvikles. Mye av den ettersporte informasjonen finnes der allerede.

En stor begrensning for å ta frem et oversiktlig kartmateriale er idag den nationelle høydedatabasen som tilbyr veldig grove data. Den modellen som er brukt for Lidköpings kommune innen SAWA er basert på manuellt målte verdier. I Karlstad har kommunen bekostet en egen laserscanning. Da den mangelfulle høydedataen er blitt identifisert som et problem så har svenske Lantmäteriet fått i oppdrag av regjeringen å skape en ny national høydedatabase. Arbeidet startet høsten 2009 og beregnes å være ferdig 2015. For at kartleggingsarbeidet ifølge flomdirektivet skall kunne bidra med ny, brukbar kunnskap bør ny data fra Lantmäteriet brukes, så langt det er mulig.

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1 Aims & Objectives

The overall objective of this report is to test how to work with elements of Council Directive 2007/60/EC on flood risks in Sweden. Flooding and risk maps have been developed for urban locations within the pilot areas of Karlstad and Lidköping. During this process, the conditions and tools available to Länsstyrelsen (county administration) and the local authorities, were evaluated. The aim is to clarify the possibilities and limits of the work and to understand the different effects on important issues.

2 Flood maps under the Floods Directive

Article 4, paragraph 1[1] *of the Floods Directive (FD) states: "Member States shall, for each river basin district, or unit of management referred to in Article 3(2)(b), or the portion of an international river basin district lying within their territory, undertake a preliminary flood risk assessment in accordance with paragraph 2 of this Article."*

The assessment will be made on the basis of past experience and presented on an appropriate scale. This first stage in the Floods Directive has not been addressed by SAWA, as the two pilot areas of Karlstad and Lidköping were selected precisely on the basis of their exposed location on the Vänern lake. Both towns also have major river estuaries, which can create problems during the autumn and spring floods. In Lidköping, detailed studies have demonstrated that the Lidan river does not pose any threat to the city centre - something that has been suspected for a long time (Erdahl, 2009). In Karlstad, the opposite has been shown, where the river (the Klarälven) is the major threat to the city, rather than the Vänern lake.

3 Maps of Flood Hazard Areas

Article 6[2] *states:*
"1. Member States shall, at the level of the river basin district, or unit of management referred to in Article 3(2)(b), prepare flood hazard maps and flood risk maps, at the most appropriate scale for the areas identified under Article 5(1).
2. The preparation of flood hazard maps and flood risk maps for areas identified under Article 5 which are shared with other Member States shall be subject to prior exchange of information between the Member States concerned.
3. Flood hazard maps shall cover the geographical areas which could be flooded according to the following scenarios:
(a) floods with a low probability, or extreme event scenarios;
(b) floods with a medium probability (likely return period ≥ 100 years);
(c) floods with a high probability, where appropriate.
4. For each scenario referred to in paragraph 3 the following elements shall be shown:
(a) the flood extent;
(b) water depths or water level, as appropriate;
(c) where appropriate, the flow velocity or the relevant water flow."

3.1 Purpose of the flood maps

The flood maps purpose is to provide a rough picture of which areas will be covered by water under different hydrological conditions. From these different analyses of flood impacts can be implemented.

3.2 Choice of hydrological scenarios

[1] Taken from Directive 2007/60/EC on the assessment and management of flood risks
[2] Taken from Directive 2007/60/EC on the assessment and management of flood risks

Point 3(b) of the FD text, quoted above, refers to a flood with an approximate recurrence interval of 100 years - however, there is no detailed guidance as to what “low” and “high” probability means in this context. In regulation (2009:956) on flood risk, no return period is indicated, even for floods with a medium probability. The MSB (Swedish civil contingencies agency) has been given the right to issue detailed regulations on how the mapping work will be carried out. Work is ongoing at the time of this study, but no detailed rules have been published.

Hydrological scenarios can be selected partly from the type of water system to be mapped (river, lake or sea) and partly from expected impacts of the flood based on the duration and course of events elsewhere.

Flooding by the sea, especially arising from prolonged low pressure, can often be a very fast process. Extreme high tide usually only lasts a number of hours. Floods in river systems are also often relatively short events, lasting days or, at most, a few weeks. To date, the highest flows have most often occurred during the spring thaw. The rapid events mean that there is little room for manoeuvre in the implementation of damage prevention measures. In Karlstad, the local authority has identified the residential settlements of Skåre, Stodene and Grava as being most exposed and, in the event of a 100-year flow of the Klarälven, there will probably not be time to establish the defences required to prevent a major flood. An evacuation of the area can then be envisaged. Strongly flowing water can also cause erosion problems and is very damaging to structures including temporary barriers and dykes. Lake floods are a considerably slower process, especially when talking about the larger lakes. The Vänern is extreme in this context because it is a large lake with a very large storage capacity, which means that floods will occur relatively infrequently. Once they occur, however, the floods last a long time - since water loss from the lake is very limited and an extremely large amount must be lost for it to impact on the level of the lake. The slower process is a positive aspect, in that it provides plenty of time to implement damage prevention measures but, as flooding could be for a very long time (up to a year is not unlikely), it would also impose other requirements. For example, it is likely that buildings and other structures which are under water would be subjected to ice loads.

3.2.1 Design flows for dams

Within the power industry's work with dam safety, there is a tradition of assuming various hydrological scenarios for, amongst other things, design of various facilities. Work on dam safety has given rise to the concept of "risk class 1" and "risk class 2 flows". These result from calculated hydrological prognoses for different water systems, based on a series of unfavourable hydrological conditions such as high snow build up, high precipitation, saturated water table etc. (See guidelines for the determination of design flows for dam installations). Depending on the impact, a dam failure is assessed as being measured on the basis of a Class 1 or Class 2 flow. When the consequences of an event are so large, there is a major focus on minimizing the probability of such an event happening. This will minimise the overall risk of the event (risk = probability * impact). Class 1 and Class 2 flows have subsequently been selected as having a low probability for other types of survey of the water system - partly, perhaps, because estimates already exist for several major regulated water courses in Sweden.

3.2.2 Worst-case scenario

One way to cover ourselves can be to look at the worst possible scenario, in other words, how high the maximum water level can be in a given system. By using this line of reasoning, it is possible to guard against unpleasant surprises, not least because it is difficult to predict how changes in climate may affect the hydrology of the water system. A drawback to using a worst case scenario is precisely the low probability that such a flood would occur. In Sweden we often equate a worst case scenario has having a return period beyond 10,000 years.

3.2.3 Comparisons between different countries

A third way to think/work may be by looking at how other countries in Europe have chosen their scenarios. When compared with other countries participating in the SAWA project, it has come to light that Germany and Norway have opted for a return period of 200 years for low probability river floods, with Holland designing its sea defences for the worst case scenario (recurrence interval of greater than

10,000 years), but using a recurrence interval of between 25 and 1000 years for local and regional waterways in the country.

An additional difficulty is to respond to evolving knowledge about how the climate will change in the future. In 100 years time, it may be that a flood which now statistically occurs once every 100 years, will re-occur every 25th year. The climate and vulnerability assessment suggests that this can happen in the Vänern lake.

3.2.4 Conditions in Lidköping and Karlstad

In Lidköping, SAWA opted to use levels of +46.5m and +47.4m (RH 70). Both levels are taken from SOU 2006:94, Översvämningshot, risker och åtgärder för Mälaren, Hjälmaren och Vänern (Flood threat, risks and measures for lakes Mälaren, Hjälmaren and Vänern). A level of +46.5m is considered to have a 100-year recurrence interval in today's climate, with a 60cm premium for high winds in an unfavourable direction. A water level of +47.4m is considered a worst case scenario which takes into account climate change by 2100, and a wind effect of 0.5m. The Lidan river is not considered to constitute a threat to Lidköping town centre under any circumstances (Erdahl, 2009). See Annex 1 and 2.

In Karlstad, the maximum design flow of the Klarälven river may have far more serious consequences than the maximum design level of the Vänern lake (see also Chapter 4.2). The same also applies when comparing the 100-year flow and 100-year level. Based on hydrodynamic modelling and subsequent GIS analysis, three scenarios were examined for the Klarälven: 25-year flow (1211 m^3/s), 100-year flow (1490 m^3/s) and the maximum design flow (2299 m^3/s). In all three scenarios the Vänern was assumed to be at a normal level.

Figure 1: The picture shows the water distribution in Karlstad during flooding from the Klarälven river under different scenarios (25-year, 100-year, and maximum flow), with the Vänern at normal levels

Flooded areas with the Vänern at normal levels
25-year flow of the Klarälven (very high probability)
100-year flow of the Klarälven (medium probability)
Class 1-flow of the Klarälven (low probability)

3.3 What is meant by an acceptable risk?

Who decides what is an acceptable risk of flooding, and how should such an assessment be made? That which is considered an acceptable risk in a community is, fundamentally, a political question. That which is considered an acceptable risk also changes over time.

The floods directive requires the mapping of areas that flood more or less regularly. In these areas, the impact of a flood on the population, economy and environment shall be clarified. Then, the community should take action at various levels to minimise the impact until the after-effects of a flood are down to an acceptable level. There are serious difficulties in obtaining a complete picture of what happens in a community during a severe flood. Karlstad has, over the last 5 years, prioritised work on flooding and spent large sums of money on investigation and in-depth analysis. Despite this, there is no clear picture of what might happen in the city in the event of a serious flood.

The conclusion must therefore be that the choice of hydrological scenarios must be viewed as an iterative process in which an initial survey is a rough estimate followed, thereafter, by a thorough analysis of the problematic areas in finer resolution. The choice of hydrological scenarios for the initial survey should be done defensively, that is to say that even water levels with a low probability of occurrence should be chosen, so as to get as good a picture as possible of the vulnerable areas and the consequences of a flood.

3.4 Elevation Data

At the moment, a major limitation to developing a good overview map base is the national elevation database, GSD-elevation data, which contains very coarse data. The resolution currently amounts to an elevation value every fifty metres, with a mean height error of 2.5 metres. Height values are specified to one decimal place. Given that the inadequate elevation data have been identified as a problem, Lantmäteriet (Swedish national land survey) has been commissioned by the government to create a new national elevation database. Work began in autumn 2009 and is expected to be finished in 2015. The total cost is estimated at 25 million Kronor. The project is beginning in southern Sweden in the area around the Vänern. Data supplied will be on a 2.5m grid. The point cloud should provide approx 1-2 elevation values per square metre. The elevation accuracy will be 0.5m or better. The planar reference system is SWEREF 99, and the elevation system is RH2000. Two products will be generated from the elevation data - a land model containing "cleaned" data, i.e. with houses and bridges removed, and a surface model that includes infrastructure. In order to make full use of the information, in the new database, local authorities need to transfer their local measurement systems to the RH2000 elevation reference.

The coarse data of the national elevation database led to the SAWA Group having to find another way to build a reliable model of Lidköping town centre. After comparing data from different commercial systems, the group decided that the best solution was to use the municipality's own manually input elevation values. These data are neither comprehensive, nor in digital format, but can be looked up in the municipal archives and digitised manually. Data points are then converted, with help from the ArcGIS 3D Analyst software, to a model that can be used for different types of analyses. This work has been done by Daniel Erdahl in connection with his thesis (Erdahl, 2009). The model as currently developed for Lidköping town centre is thus correct, but the working method is resource intensive, and therefore not ideal for mapping large geographic areas.

Karlstad chose to perform their own laser scan of the flood prone areas in the Klarälven delta, and have acquired data with an accuracy, in elevation, of about 0.1m on hard surfaces.

3.5 Height System

Most communities around the Vänern lake have local versions of RH00. This was based on the first precision levelling of Sweden which took place between 1886 and 1905. No account of land uplift was used in the calculation of RH00 and the elevation system has, over time, come to the end of its usefulness as a national height system, but lives on in the local systems around the country. Today, the official national height system is RH70, which was developed after the second precision levelling, which took place between 1951 and 1967. The difference between RH00 and RH70 is minus 4cm, in southern Sweden, and plus 83cm in northern Sweden. However, few local users are choosing to switch over to RH70. The levels mentioned in the climate and vulnerability assessment are with reference to RH70.

RH2000 is the third precision levelling and will replace RH70 as the national height system. The land uplift has brought about a disparity between RH70 and RH2000 of +7cm in southern Sweden and +32cm in northern Sweden.

Karlstad has, so far, used the RH00 system but recently decided to move to RH2000, which is expected to take several years.

The use of GPS in geodetic measurements has created a need for a height system that can be related to GPS height measurements. Measuring with GPS and then converting to a local elevation system gives a significantly poor result. Therefore, there is great deal of interest in moving over to the new national height system (RH2000). The move, however, is voluntary and it is an economic issue. However, there are economic benefits of a move, both nationally and regionally. By 19th October 2009, only 5 of the 13 local authorities bordering the Vänern had begun work on a transition to RH2000. For the transition to SWEREF 99 (horizontal position reference), there were only two local authorities yet to change. To facilitate work, both in mapping and in emergencies, it is very important that all location information is the same in order to reduce the risk of misunderstanding. It is also important to recognise from which elevation system height values are extracted from.

3.6 Presentation

3.6.1 Proposed layout and presentation of maps

The presentation of maps covering flood hazard areas is important. The map needs to be sufficiently detailed such that various parts of the city and its features are easily identifiable but, at the same time, not be so detailed that the viewer forms a false impression of how much is actually known. At the moment, the level of knowledge that we have at the property, or even district level, is not so detailed as to say with certainty which areas are likely to hit hard, at the high water level, and which ones are safe. Exceptions to this may apply in particularly well surveyed areas of Sweden, such as the Klarälven delta in Karlstad. One should also bear in mind that a flood causes problems long before you see water on the ground. Many vulnerable installations are in basements. In areas consisting of sand (e.g. Karlstad), ground water rises quickly at high water levels, and causes damage at a great distance from open water surfaces. Another difficulty is that water can pour in "through the back door" of the sewage system. Depressions in roads can also cause water flows into the low-lying areas that "should" be safe behind the higher lying parts in the populated area. In the attached maps for Lidköping, we have chosen to present the flood-affected areas at a scale of 1:15,000 and to place the urban map at the bottom for a good overview.

In order to rationalise work at the district level, we should try to use the mapping tools that have been developed in recent years within Swedish water management - primarily VISS and Vattenkartan (Water Map). VISS stands for “Water Information System Sweden” and is a database with information on monitoring and objectives relating to water management. Vattenkartan is a digital map, which is partially connected to VISS so that its information can be displayed geographically. For presentation, as part of a consultation or overview, and detailed planning work, in which extracts from the above information systems are used, we need to consider the appropriate level of detail presented. It is important to make clear the limitations and uncertainty inherent in the map information so that the results will not be used incorrectly.

3.6.2 Reporting of water depth and velocity

In the flood-affected areas, water depth or water velocity should be made clear. Different starting points can be chosen for the subdivision of depth intervals. In the case of Lidköping, SAWA has chosen to describe the depth in half-meter intervals, see Appendix 1 and 2. In Karlstad, a different depth interval has been chosen, based on effects-oriented thinking. What depth interval is appropriate to show, greatly depends on how good the available input data is.

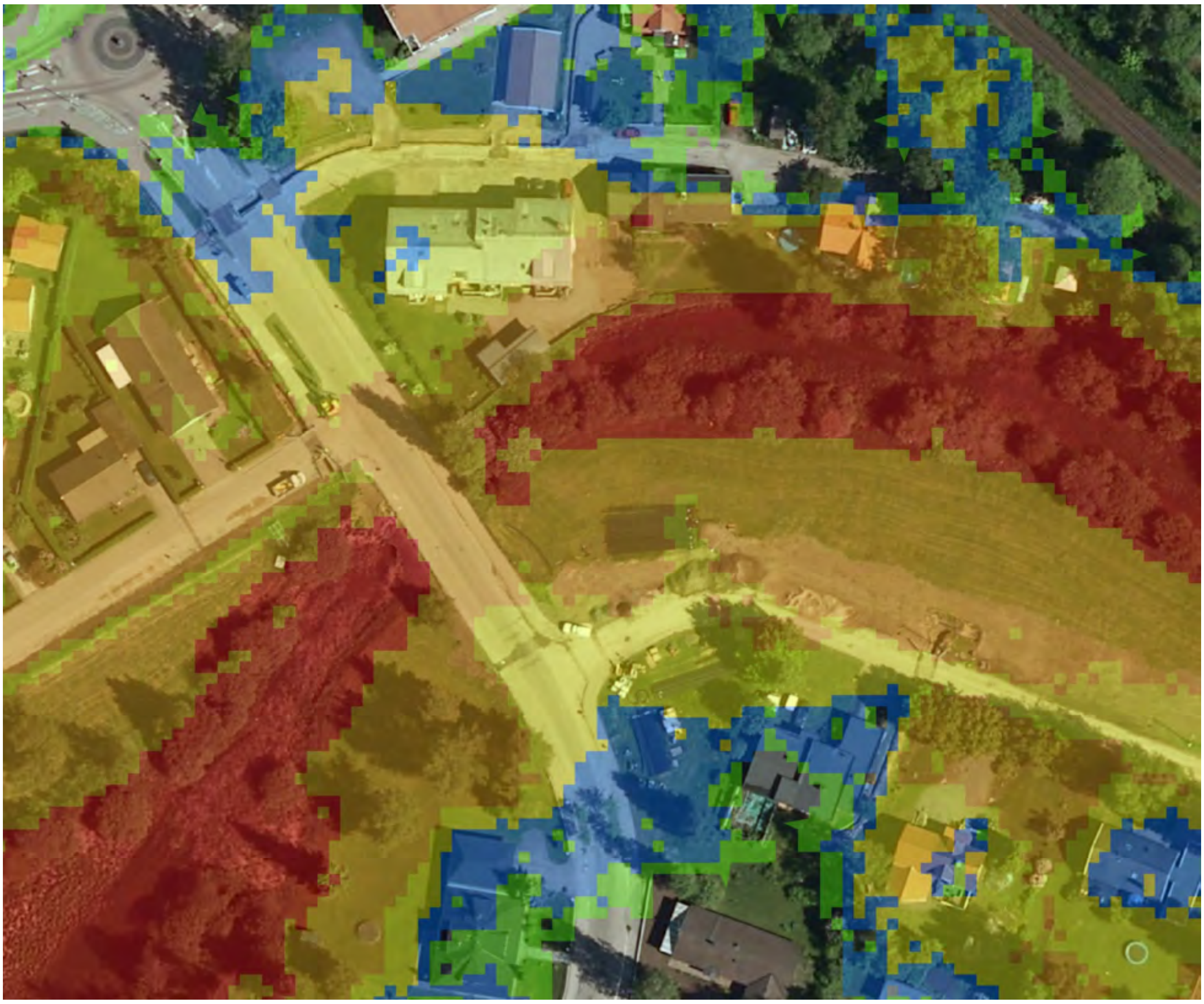


Figure 2: The picture shows the depth interval of a flood in Skåre in the event of a 100-year flow of the Klarälven river. Depth ranges in metres (m) can be read as follows:

Green	**(0-0.2)**	**Possible to get through with boots and car**
Blue	**(0.2-0.5)**	**Possible to get through by wading and by truck, easy to barricade**
Yellow	**(0.5 -1)**	**Better embankments needed, few vehicles get through.**
Orange	**(1-2)**	**Can be a danger to people, substantial barriers needed for containment**
Red	**(> 2)**	**Very difficult to contain**

4 Flood Risk Maps

Article 6, paragraph 5 of the Floods Directive[3]:
Flood risk maps shall show the potential adverse consequences associated with flood scenarios referred to in paragraph 3 and expressed in terms of the following:
(a) the indicative number of inhabitants potentially affected;
(b) type of economic activity of the area potentially affected;
(c) installations as referred to in Annex I to Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control [9] which might cause accidental pollution in case of flooding and potentially affected protected areas identified in Annex IV(1)(i), (iii) and (v) to Directive 2000/60/EC;

[3] Taken from Directive 2007/60/EC on the assessment and management of flood risks

(d) other information which the Member State considers useful such as the indication of areas where floods with a high content of transported sediments and debris floods can occur and information on other significant sources of pollution.

4.1 Purpose of the Risk Maps

The aim of risk maps is to provide a rough picture of the social, economic and environmental impacts that can be foreseen as a result of flooding within an area. There is also no question of risk maps without impact maps, if you stick to the definition of risk being the product of likelihood and consequence of an event. The maps should be able to identify problematic areas where in-depth analysis needs to be implemented and where action may be needed. The work is most easily done, primarily, through GIS analysis but complementary investigation of local business records, for example, is needed in order to obtain a reasonably accurate picture of which economic activities could be affected within an area. Presentation of the information should be primarily digital, using existing digital systems.

4.2 Population

As regards the population, it can be concluded that, at the moment, Länsstyrelsen (county administration) has access to relatively old data. In the case of Lidköping, Länsstyrelsen has access to data from 2000, whilst the local authority gets data annually. The information, that Länsstyrelsen has access to, is registered persons/property.

The purpose of the risk map should be to get a rough estimate of how many people will be directly affected in the different flood scenarios. The risk map presented in this report has therefore estimated the number of people (rounded to even hundreds) whose homes would be affected by different flood scenarios. Holiday homes that are not used for permanent housing are therefore not included. Neither are people that could be affected indirectly through flooded work places, etc. The result, however, gives some indication of how many people will need alternative housing in the event of flooding in the Lidköping locality. See Annex 3 and 4.

To give a feel for how many people live in flood prone areas in Karlstad, population data from the register of local residents was matched against property register address locations and then re-run with different flood scenarios. During a 25-year flow of the Klarälven (Vänern normal) about 500 residents are at risk, with a 100-year flow of the Klarälven (Vänern normal) about 3 600 residents are at risk and at the maximum design flow of Klarälven (Vänern normal) about 18 700 inhabitants are at risk. The statistics for a flood of the Vänern lake are shown in Figure 3. If you compare 100-year events in the Klarälven and the Vänern, nearly 70 times more people at risk from a 100-year flow of the Klarälven compared with a 100-year level in the Vänern. If one also takes into account changes to the Vänern's filling strategy, a 100-year level in the Vänern has no effect on housing in Karlstad.

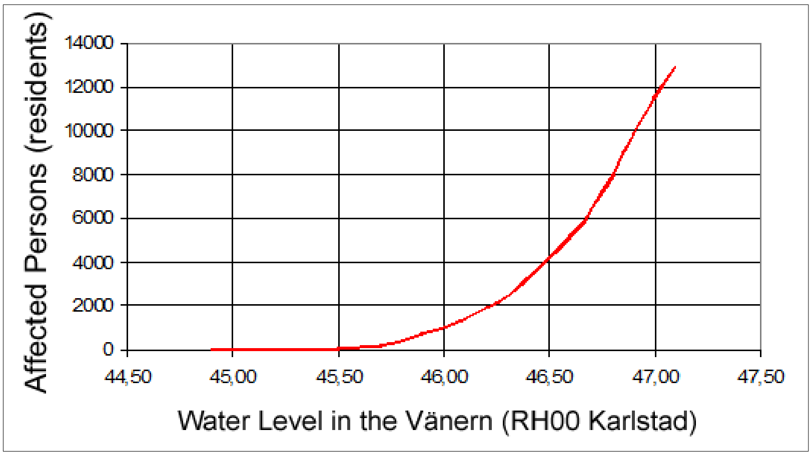


Figure 3: Approximate number of residents who are in the danger zone for flooding from the Vänern (does not include combination effects with the Klarälven river)

The results are presented in a map with a different type of layout to that done by Karlstad. As the local authority has access to better demographics than Länsstyrelsen (county administration), a more detailed breakdown can be done, grouped by age - which may be worthwhile, to some extent. See Annexes 5-10. For example, one can assume that a district with a large number of elderly people has a greater need for public services such as home-help. Irrespective of how you choose to present the impact on the population, at a later stage, when a risk management plan is worked out, the local authority needs to map out in detail how many people in the flood zone have special needs (such as home based health care, home help, or other special requirements) and may require special accommodation in an evacuation.

4.3 Economic Activity

What constitutes economic activity is not clearly defined in the draft or in the text of the directive itself. SAWA interpreted this as meaning various different companies. Länsstyrelsen has no records of companies in different areas. In SAWA's case, by cross-referencing addresses and company records in the flood affected areas, the local authority in Lidköping has produced data on how many companies could be affected by a water level of 47.4m in the Vänern. The conclusion, in Lidköping's case, is that almost 550 companies are located in the flood-affected areas. This includes major industries to small service companies, in various sectors.

One can also consider studying land use in an area to get an idea of the consequences of a flood. This can be done through GIS analysis, where Länsstyrelsen has the data needed for the job.

In Lidköping, it can be established that much of the area, that could flood, consists of industrial land - although the figure is probably not entirely true because there is a general trend in the district to convert waterfront industrial sites into housing. It should be noted that at a water level of 46.5m above sea level, the Vänern would flood 28% of Lidköping's urban industrial area. At a water level of 47.4m, 46% of the urban industrial area would be affected. See Annexes 11 and 12.

4.4 Environmentally hazardous activities

An updated register of category A and B environmentally hazardous activities is held by both the local authority and Länsstyrelsen (county administration), as well as in the water authorities' VISS database and Vattenkartan (Water Map). However, according to the Floods Directive, the environmentally hazardous activities which should be identified are only the so-called IPPC operations (Council Directive 96/61/EC of the 24th September 1996 concerning integrated pollution prevention and control) and these are relatively few in number. It should be stressed that this is a minimum requirement and that it may be appropriate to look at environmentally hazardous activities more generally. All of the major, environmentally hazardous, category A and B activities, which are registered within the flood-affected areas, have been identified by SAWA.

With the Vänern at a level of 46.5m, 15 major environmentally hazardous activities in Lidköping are affected. Two of the installations included are the waste water treatment plant and the district heating plant that serves a large part of Lidköping's urban population. The district heating plant is also a waste incineration facility which is of central importance for waste management throughout the whole region. At a level of 47.4m, further large, environmentally hazardous, activity will be affected. The consequences of flooding of these industries should be carefully identified. See Annexes 13 and 14.

4.5 Protected Nature

Protected nature according to the Floods Directive, has the same definition as in the Water Framework Directive (WFD). According to Regulation (2004:660) on the management of the quality of the aquatic environment, water authorities shall establish a register in the respective catchment areas that have been designated, under specific Community legislation, as requiring special protection for the district's surface or groundwater, or for the conservation of habitats and species directly dependent on the water (draft management plan for North Sea water district). The register shall list both, bodies of water affected by the type of protection, and the protected areas. The geographical boundary, area name, type of perimeter protection, Swedish law that protects the area and the purpose of protection should be made clear. All protected areas can be seen in Vattenkartan (water map) and, in VISS (Water Information System Sweden), you can see which water bodies have certain protection.

The areas around Karlstad and Lidköping urban centres have the following protection orders under Community law for the safety of water:

- Nitrate Sensitive Area: Nitrate Sensitive areas are designated under the Nitrates Directive which aims to protect waters from pollution by nitrates from agriculture. The areas are listed in the Regulation (1998:915) on environmental concerns in agriculture.
- Waste water sensitive catchment area with respect to both nitrogen and phosphorus: According to the Waste Water Directive (91/271/EEC), this shall apply to areas that are sensitive to the discharge of nutrients from urban conglomerations, in order that specific requirements for treatment will apply. Sweden has decided that all towns need to remove the phosphorus from their waste water. In the case of nitrogen, the provisions affect urban conurbations over 10,000 people that contribute to pollution of coastal waters from the Norwegian border to Norrtälje.
- Fishing Waters: Areas identified for protection of economically significant aquatic animal or plant species subject to Fish Water Directive (78/659/EEC). Fishing areas in Sweden are given in the annex to Naturvårdsverket (Swedish nature conservation agency) regulation NFS 2002:6. These areas are protected under the regulation (2001:554) on environmental quality standards for fish and shell fish waters.

Also applicable to Karlstad is that parts of the Klarälven delta are identified as a Natura 2000 site, both in terms of habitat and the Birds Directive.
Note that protection orders under Swedish environmental legislation are not addressed here.

4.6 Other information of interest

Risk maps should contain any other information which the member state deems useful, such as an indication of the areas where floods with a high content of transported sediments and debris may occur and information about other significant sources of contamination.

4.6.1 Potentially contaminated sites

In SAWA's view, it is valuable to have information on potentially contaminated sites located in flood hazard areas. Compilation of an inventory of potentially contaminated areas, is ongoing amongst Länsstyrelsen's environmental protection activities. Information about the identified objects is published in the MIFO database (methodology for inventory and risk classification of contaminated areas), together with the position coordinates. The following figure, of Lidköping's town centre, shows a total list of suspected contaminated objects. The objects, which, in practice, could pose a risk of contamination spreading to the water, have not yet been analysed.

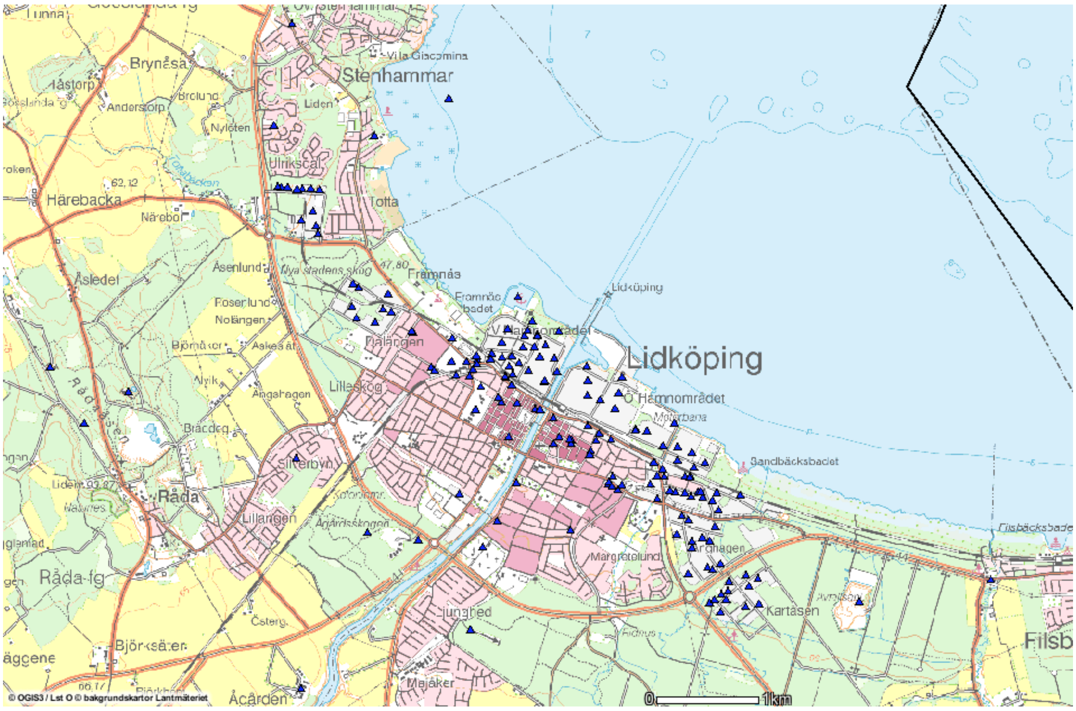


Figure 4 shows an excerpt from EMIR, the database where the information from the ongoing inventory of suspected contaminated land will be saved.

4.6.2 Sites of Historic Interest

Other information, that can also be useful, includes, for example, historically interesting areas of irreplaceable value. See the figure below.

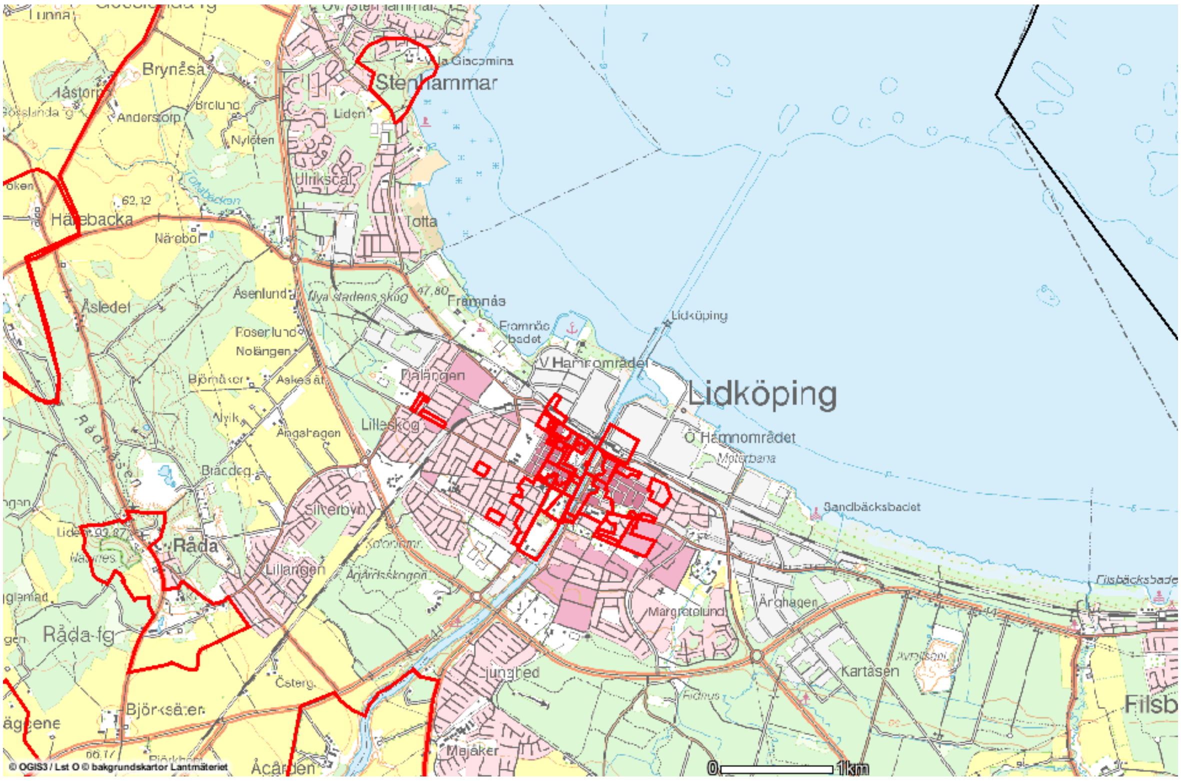


Figure 5: Shown above are municipal conservation areas of cultural interest in urban Lidköping.

4.6.3 Key community infrastructure

Information deemed to be of particular interest, but which does not naturally fall within any of the previous headings in the risk maps, is the identification of socio-critical facilities and functions whose exclusion may result in a significantly larger number of people affected by flooding than just those who have their homes within the flood-affected area. Examples of important community activities that need to be identified are:

- Health care facilities (clinics, nursing homes, etc.)
- Water utilities (sewage and water works, including related installations necessary for their operation)
- Power stations and heating plants (that supply much of the urban area with district heating)
- Major transport routes such as roads and railways

Identification of these facilities must be done in consultation with the county council, local authorities, the highways agency and the rail network administration who, in most cases, are responsible for their operation.

4.6.3.1 Impact on key infrastructure in Lidköping

Lidköping local authority has, within the SAWA framework, compiled location information on important community facilities and service activities in the flood-affected areas - see detailed overview in Annex 15 and 16. In Lidköping's case, district heating and sewage treatment plants have been identified as being highly vulnerable.

4.6.3.2 Impact on key infrastructure in Karlstad

Security of the electricity supply is considered the most critical factor during a flood. A secure supply of drinking water, ensuring as good sewage treatment and storm water management as possible, and good accessibility are all high-priority items, for the municipality, during flooding. All of these functions are affected or at risk of being knocked out, to a greater or lesser degree, during a serious flood in Karlstad. The most serious risk in Karlstad is considered to be the flooding of homes in Skåre/Stodene/Grava, the Central Hospital, sewage treatment plants in Sjöstad and Skåre, extensive overflows of sewage, and E18 and national route 61/62.

Health and social care

Of the municipality's eight health centres, two lie within the river delta - Skåre and Gripen. The health centre in Skåre will be affected by water during a 100-year flow of the Klarälven river. The effect on the water and sewage systems will, however, be earlier. During maximum design flow of the Klarälven, the health centre will not be able to function. The health centre in Gripen is calculated not to get water contact during a 100-year flow. Gripen would have water contact during maximum design flow of the Klarälven, but it is considered that it will generally cope much better than the health centre in Skåre. Access to the two health centres in the delta, as well as the others, has not been studied. Neither has the function of technical systems.

No medical centre is directly exposed to the Vänern lake. The health centre in Gripen is likely to be affected by exceptionally high water levels in the lake.

Of the 92 municipal health care facilities that have been studied, about 35 are at risk during a maximum design flow of the Klarälven river. Functioning of technical systems, and mobility, has not been studied. The following facilities are expected to have water contact during a 100-year flow of the Klarälven:

- Källan nursing home and local home care, Centrumvägen 8
- Hagaborg nursing home, Hagaborg Street 15
- Rehab, Låglandsgatan 8
- Special accommodation, Fagerängsgatan 23

Ten municipal health facilities are likely to be affected at a water level of 46.20m in the Vänern lake. At a level of 46.70m, 24 are affected.

Central Hospital in Karlstad

The Central Hospital in Karlstad (CSK) is located on the western branch of the Klarälven river. A problem associated with flooding is partly that CSK's machine centre and a pumping station (CKS42

Lasarettet) are low-lying, and both can cause problems with accessibility to the hospital. The machine centre is the hospital's "heart" and, if knocked out, could have incalculable consequences for the hospital's operation. It supplies the hospital with heating, cooling, steam, electricity, back-up power and medical gases. CSK is also dependent on the municipal water and sewage system, which may suffer problems in a flood. In 2010, the CSK will have access to their own water reserve. A 100-year flow of the Klarälven river (with the Vänern at normal levels) is expected to give a water level of about 46.7m at CSK. Maximum design flow of the Klarälven would give a level of about 47.5m at CSK. The machine centre is located at an elevation of 46.2m. The part of Älvgatan lying between the Klarälven and the machine center is 46.4m at its lowest point.

The actual hospital is relatively high and not in the high risk zone. On the other hand, accessibility to the hospital would be affected. The accessibility situation will look different depending on whether there is a high level in the Vänern lake, or a high flow in the Klarälven river.

Other important community services
The fire service, SOS Alarm, police and ambulance, etc are located at Sandbäcken. The area is expected to remain clear of a 100-year flow of the Klarälven, but with the possibility that access could be limited. The area at Sandbäcken would be totally knocked out by a maximum design flow of the river.

5 Difficulties and limitations

It is difficult to choose and describe hydrological scenarios, and how to take into consideration the government of water systems. It is also difficult to account for future climate change because the calculations are affected by large uncertainties.

The main limitation in making large-scale flood surveys is, at the moment, the national elevation database. Using it gives such large errors that the mapping does not add any new knowledge and is therefore not useful, either in the planning context or in relief work. After the Lantmäteriet has carried out its new scans it will be possible to generate much more reliable map data. Therefore, wherever possible, one should make use of the new elevation data, in parallel with surveys under the Floods Directive.

It is important to try to achieve a rapid transition to a common height system to minimise the risk of misunderstandings and re-calculation errors in the use of location-linked data.

Some of the information that will form the basis of risk maps is scattered between the various authorities such as county councils, road management, rail management, affected communities and, not least, among private parties. In order to give an accurate picture of the impact on economic activity, it is important that different participants are involved in the work.

6 Conclusions and recommendations

The choice of hydrological scenarios should take into account both how the results of the survey will be used and the type of flooding that will be mapped (sea, river, lake). The choice of hydrologic scenarios should not be confused with the discussion on what can be considered an acceptable risk of flooding in an area; this discussion should be in association with the development of a risk management plan. However, it is important that there is comprehensive support material so that all the consequences of a flood can be analysed at an early stage, which suggests that even low probability hydrological scenarios should be identified.

In order that all the information needed for the survey work may be easily collated, VISS, the database of water information developed in the context of Swedish water management efforts, should evolve. A major limitation to developing a good overview map basis, at the moment, is the national elevation database, GSD-elevation data, which contains very coarse data. The large mean error makes it impossible to make accurate surveys, especially in flat areas such as Lidköping. After Lantmäteriet has implemented its new scans, it will be possible for much more reliable map data to be generated. Therefore, wherever possible, the new elevation data should be used in surveys under the Floods Directive.

To get an accurate picture, especially of how key infrastructure and business may be affected by floods, it is important that risk maps be developed in collaboration with local authorities.

The presentation of maps is important. The material should be sufficiently detailed so that different parts of the city and its features are easily identifiable, but, at the same time, not so detailed as to misrepresent the state of knowledge to the viewer. Our current knowledge, at property or even district level, is not so detailed such that we can state with certainty which areas are likely to be hit hard at the high water level, and which ones are safe. In order to rationalise work at district level, there are advantages in using the digital surveying tools developed in recent years within Swedish water management, primarily VISS and Vattenkartan (Water Map). For presentation, as part of a consultation or overview, and in detailed planning work, in which extracts from the above information system are used, we need to consider the appropriate level of detail presented. It is important to make clear the limitations and uncertainty inherent in the map information so that the results will not be used incorrectly.

7 References

Erdahl, Daniel (2009); Översvämningsrisker för Lidköping – betydelsen av upplösningen hos Höjddata (Flood Risks to Lidköping - the importance of the resolution of Elevation data); thesis 20p

Sverige inför klimatförändringarna - hot och möjligheter (Sweden facing climate change - threats and opportunities), SOU 2007:60

Översvämningshot, risker och åtgärder för Mälaren, Hjälmaren och Vänern (Flood threat, risks and measures for lakes Mälaren, Hjalmaren and Vänern), SOU 2006:94

Statens vattenfallsverk, Svenska kraftverksföreningen and SMHI; Riktlinjer för bestämning av dimensionerande flöden för dammanläggningar, Slutrapport från Flödeskommittén (Guidelines for the determination of design flows for dams, Final Report of the Flow Committee)

Förvaltningsplan för Västerhavets vattendistrikt, samrådsmaterial för perioden 1 mars – 1 september 2009 (Management plan for North Sea water district, consulting materials for the period 1 March - September 1, 2009)

Legislation covered in the text

Council Directive 2007/60/EC on flood risk

Council Directive 96/61/EC of September 24, 1996 concerning integrated pollution prevention and control pollution

Water Framework Directive (2000/60/EC)

Waste Water Directive (91/271/EEC)

Fish Water Directive (78/659/EEC)

Regulation (2009:956) on flood risk

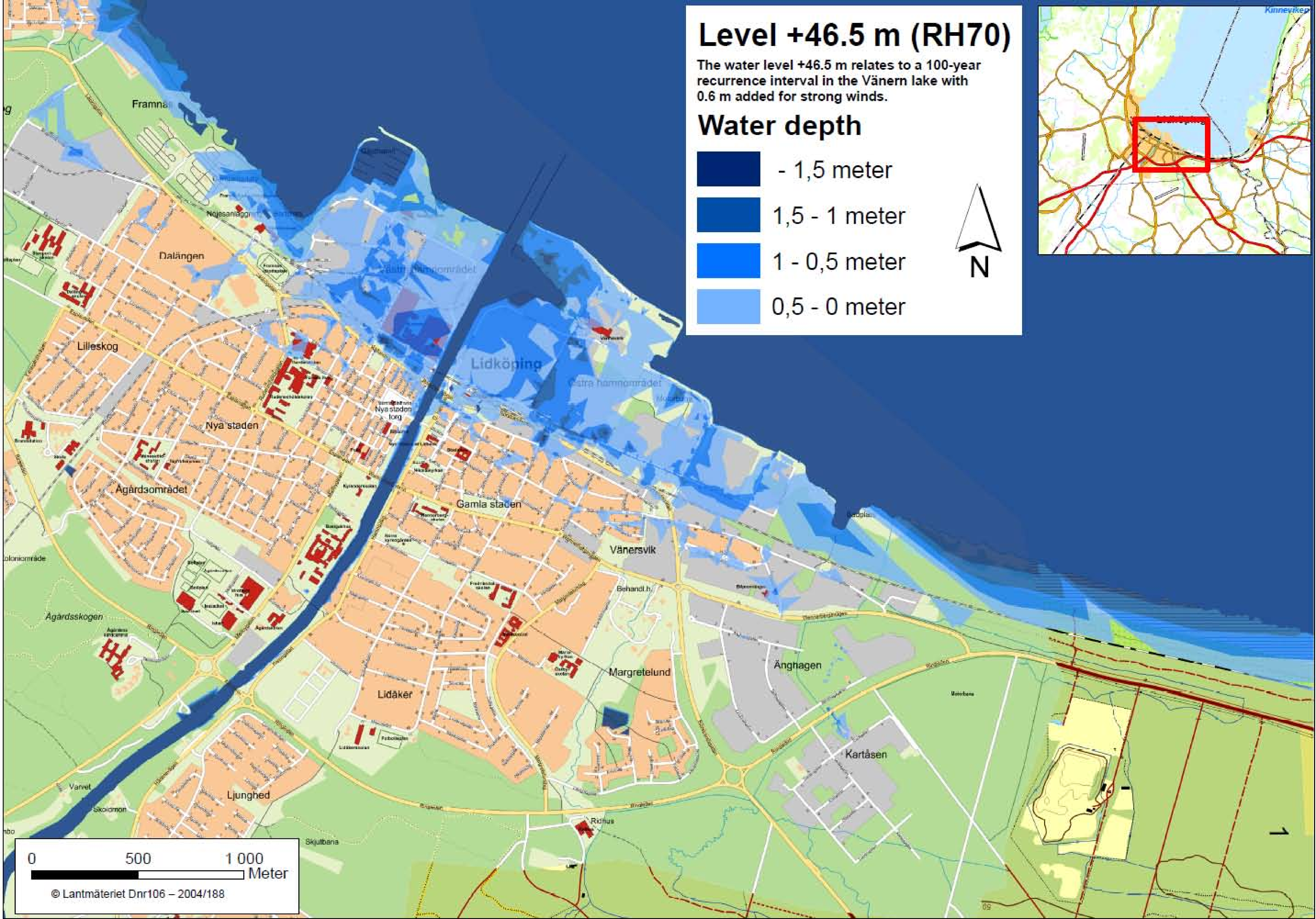
Regulation (2004:660) on management of the quality of the aquatic environment

Regulation (2001:554) on environmental quality standards for fish and shell fish waters.

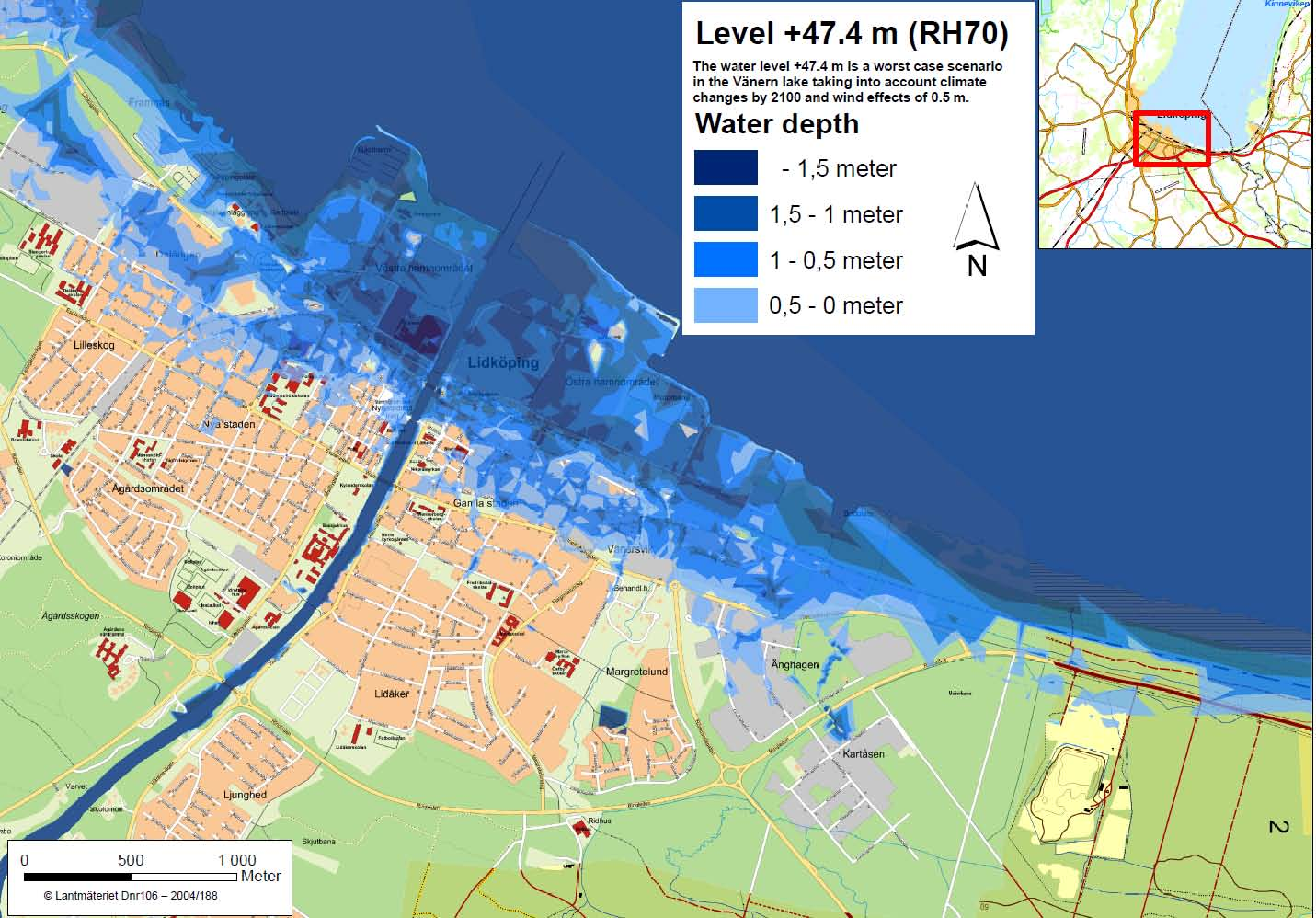
Naturvårdsverket's (Nature Conservation Agency) list (NFS 2002:6) of fishing waters to be protected under the Regulation (2001:554) on environmental quality standards for fish and shell fish waters.

Attachments

1. Flood Map of Lidköping's urban area with a level +46.5 m in the Vänern lake
2. Flood Map of Lidköping's urban area with a level +47.4 m in the Vänern lake
3. Effect on the population of Lidköping's urban area with a level of +46.5 m
4. Effect on the population of Lidköping's urban area with a level of +47.4 m
5. Effect on the population of Grava/Stodene/Skåre during a 25-year flow of the Klarälven river
6. Effect on the population of Karlstad's urban area during a 25-year flow of the Klarälven river
7. Effect on the population of Grava/Stodene/Skåre during a 100-year flow of the Klarälven river
8. Effect on the population of Karlstad's urban area during a 100-year flow of the Klarälven river
9. Effect on the population of Grava/Stodene/Skåre during a Class 1 flow of the Klarälven river
10. Effect on the population of Karlstad's urban area during a Class 1 flow of the Klarälven river
11. Effect on land use in Lidköping's urban area with a level of +46.5 m
12. Effect on land use in Lidköping's urban area with a level of +47.4 m
13. Effect on environmentally hazardous activities in Lidköping's urban area with a level of +46.5 m
14. Effect on environmentally hazardous activities in Lidköping's urban area with a level of +47.4 m
15. Effect on key infrastructure in Lidköping's urban area with a level of +46.5 m
16. Effect on key infrastructure in Lidköping's urban area with a level of +47.4 m



Level +46.5 m (RH70)
The water level +46.5 m relates to a 100-year recurrence interval in the Vänern lake with 0.6 m added for strong winds.
Water depth
- 1,5 meter
1,5 - 1 meter
1 - 0,5 meter
0,5 - 0 meter
N
0
500
1 000
Meter
© Lantmäteriet Dnr106 – 2004/188
Framnäs
Dalängen
Lilleskog
Nya staden
Ågårdsområdet
Ågårdsskogen
Lidköping
Gamla staden
Vänersvik
Behandl.h.
Margretelund
Änghagen
Kartåsen
Lidåker
Ljunghed
Varvet
Ridhus
Nya staden torg


Level +47.4 m (RH70)
The water level +47.4 m is a worst case scenario in the Vänern lake taking into account climate changes by 2100 and wind effects of 0.5 m.
Water depth
- 1,5 meter
1,5 - 1 meter
1 - 0,5 meter
0,5 - 0 meter
N
Lidköping
Lilleskog
Nya staden
Ågårdsområdet
Gamla staden
Vänersvik
Ågårdsskogen
Margretelund
Änghagen
Lidåker
Kartåsen
Ljunghed
Varvet
Ridhus
0
500
1 000
Meter
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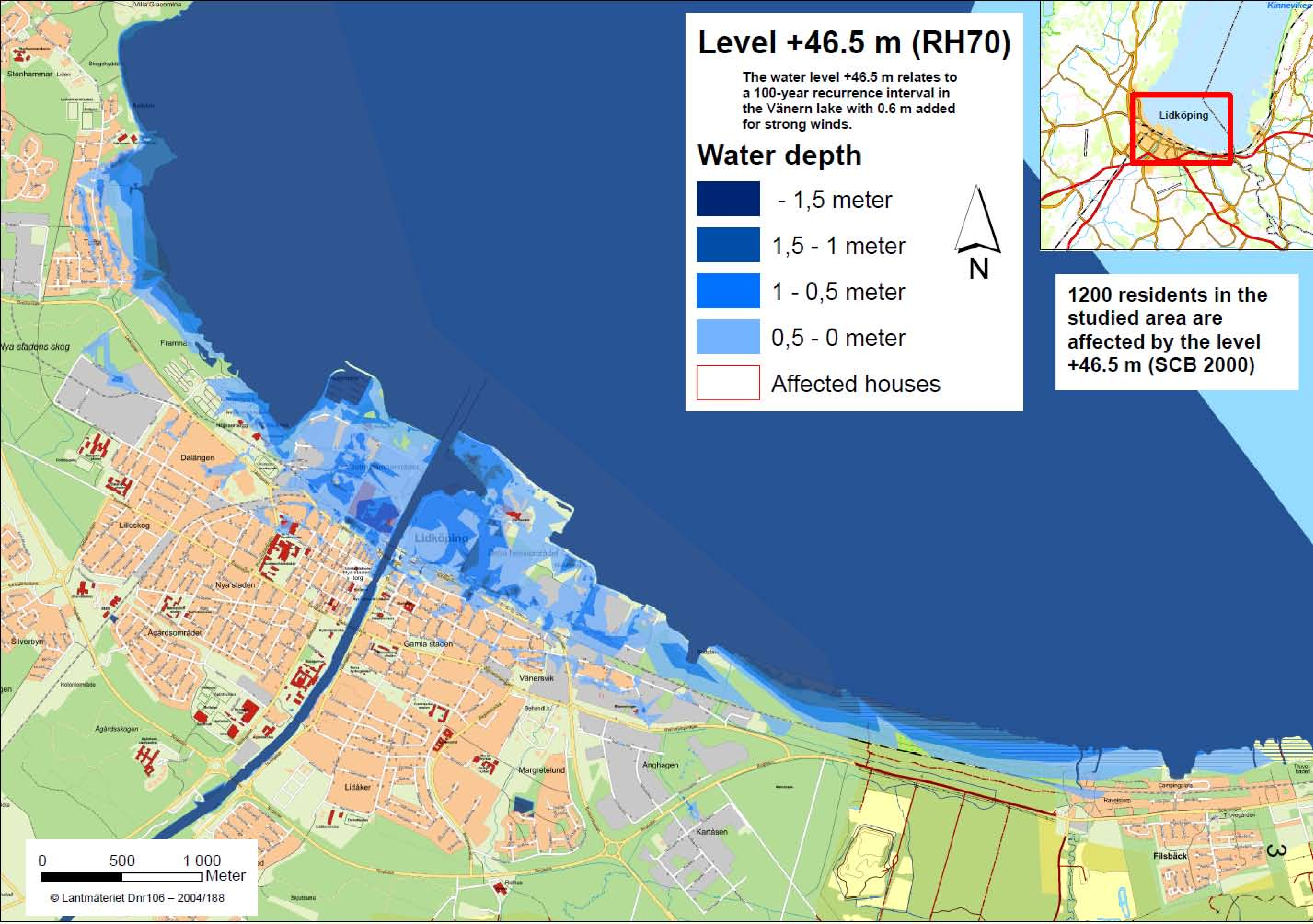
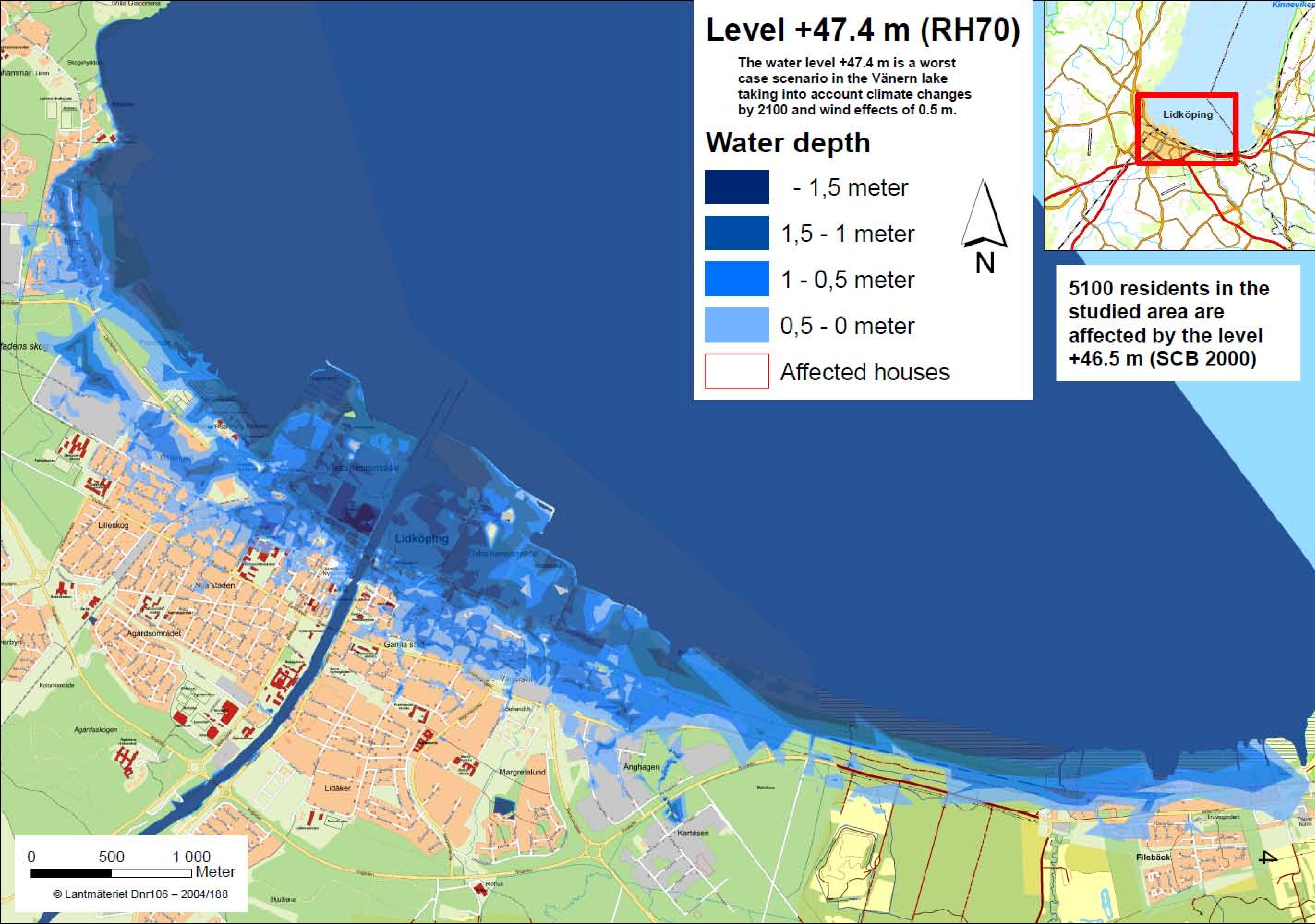


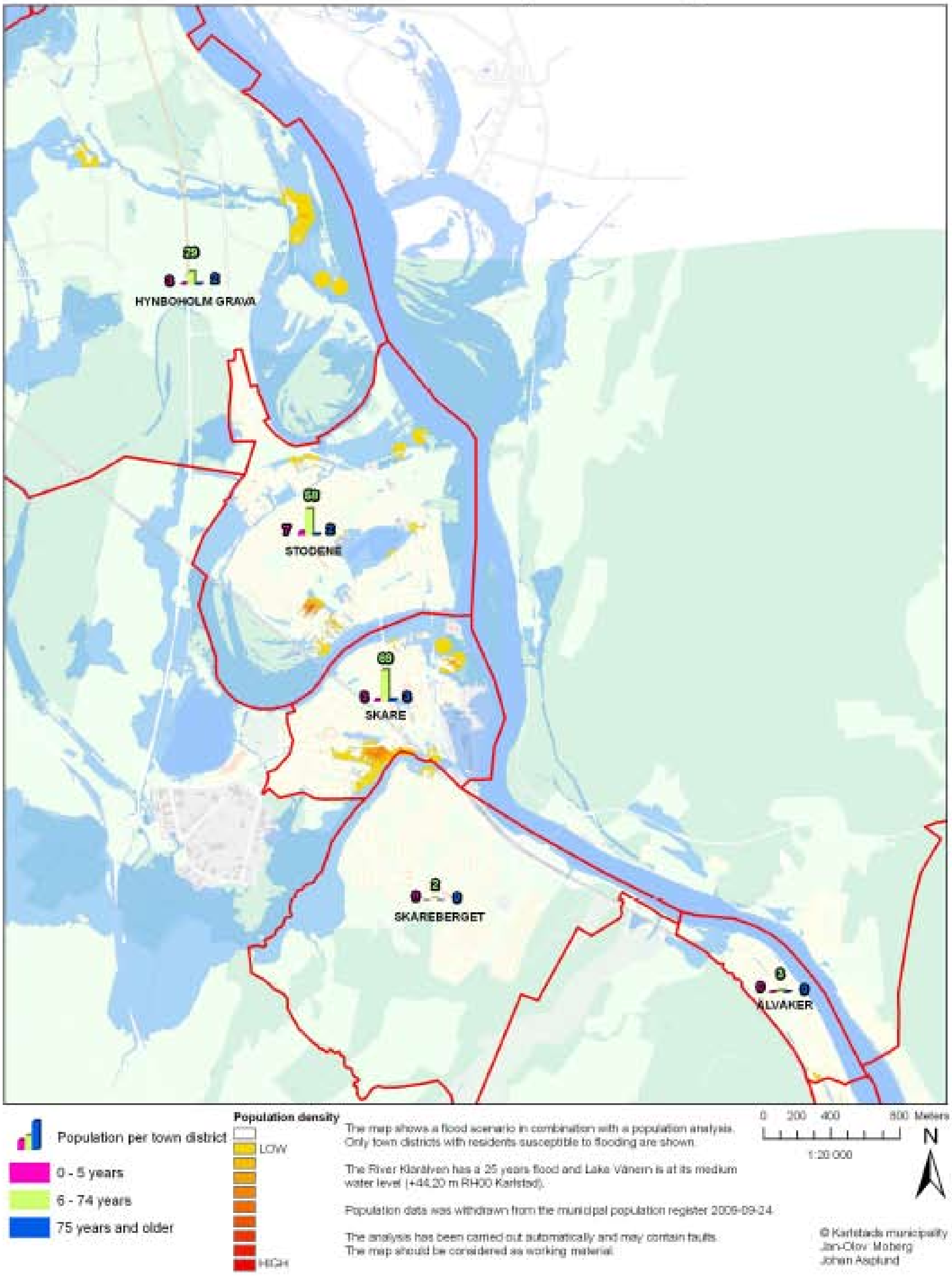
Level +46.5 m (RH70)
The water level +46.5 m relates to a 100-year recurrence interval in the Vänern lake with 0.6 m added for strong winds.
Water depth
- 1,5 meter
1,5 - 1 meter
1 - 0,5 meter
0,5 - 0 meter
Affected houses
N
Lidköping
1200 residents in the studied area are affected by the level +46.5 m (SCB 2000)
Stenhammar
Nya stadens skog
Framnäs
Dalängen
Lilleskog
Nya staden
Silverbyn
Ågårdsområdet
Gamla staden
Vänersvik
Ågårdsskogen
Margretelund
Anghagen
Lidåker
Kartåsen
Filsbäck
0
500
1 000
Meter
© Lantmäteriet Dnr106 – 2004/188



Level +47.4 m (RH70)
The water level +47.4 m is a worst case scenario in the Vänern lake taking into account climate changes by 2100 and wind effects of 0.5 m.
Water depth
- 1,5 meter
1,5 - 1 meter
1 - 0,5 meter
0,5 - 0 meter
Affected houses
N
Lidköping
5100 residents in the studied area are affected by the level +46.5 m (SCB 2000)
Lidköping
Lilleskog
Nya staden
Agårdsområdet
Gamla staden
Margretelund
Änghagen
Lidåker
Kartåsen
Filsbäck
0
500
1 000
Meter
© Lantmäteriet Dnr106 – 2004/188

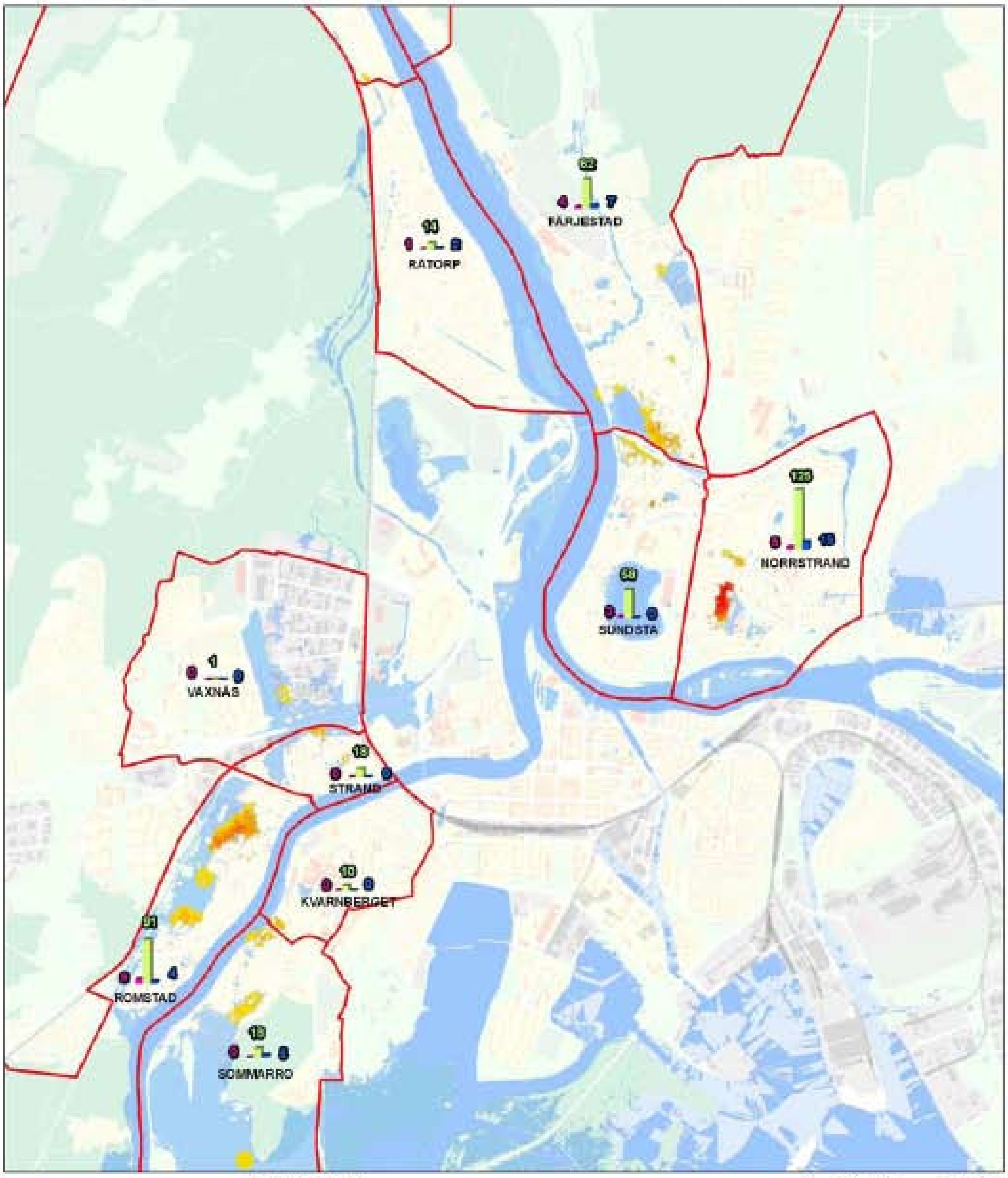
Combination of a 25 years flood in the River Klarälven and a medium water level in Lake Vänern

- number of residents susceptible to flooding -



Combination of a 25 years flood in the River Klarälven and a medium water level in Lake Vänern

- number of residents susceptible to flooding -



Population per town district

0 - 5 years

6 - 74 years

75 years and older

Population density

LOW

HIGH

The map shows a flood scenario in combination with a population analysis. Only town districts with residents susceptible to flooding are shown.

The River Klarälven has a 25 years flood and Lake Vänern is at its medium water level (+44.20 m RH00 Karlstad).

Population data was withdrawn from the municipal population register 2009-09-24.

The analysis has been carried out automatically and may contain faults. The map should be considered as working material.

0 200 400 800 Meters

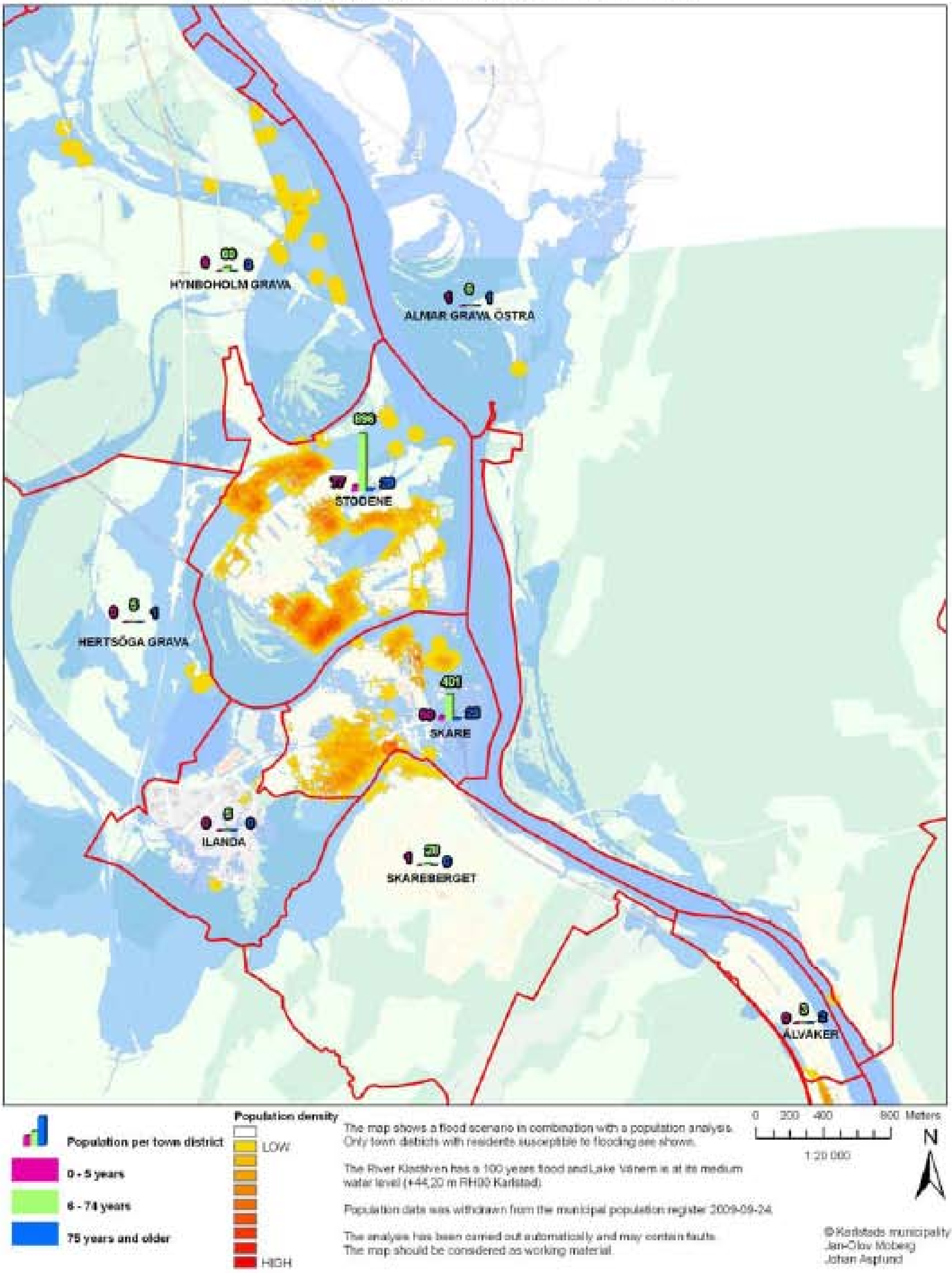
1:20 000

N

© Karlstads municipality
Jan-Olov Moberg
Johan Asplund

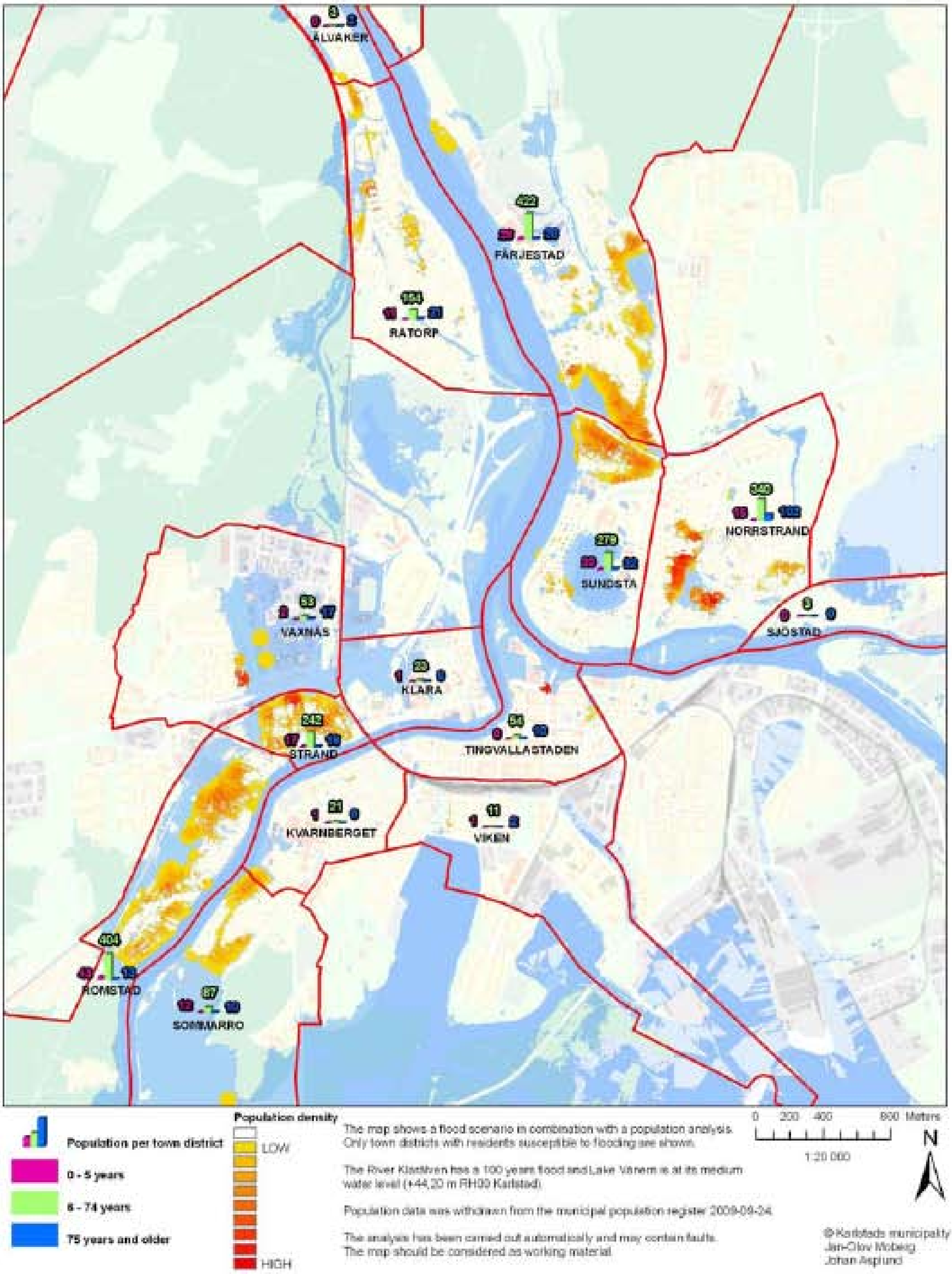
Combination of a 100 years flood in the River Klarälven and the medium water level in Lake Vänern

- number of residents susceptible to flooding -



Combination of a 100 years flood in the River Klarälven and the medium water level in Lake Vänern

- number of residents susceptible to flooding -



The map shows a flood scenario in combination with a population analysis. Only town districts with residents susceptible to flooding are shown.

The River Klarälven has a 100 years flood and Lake Vänern is at its medium water level (+44,20 m RH00 Karlstad).

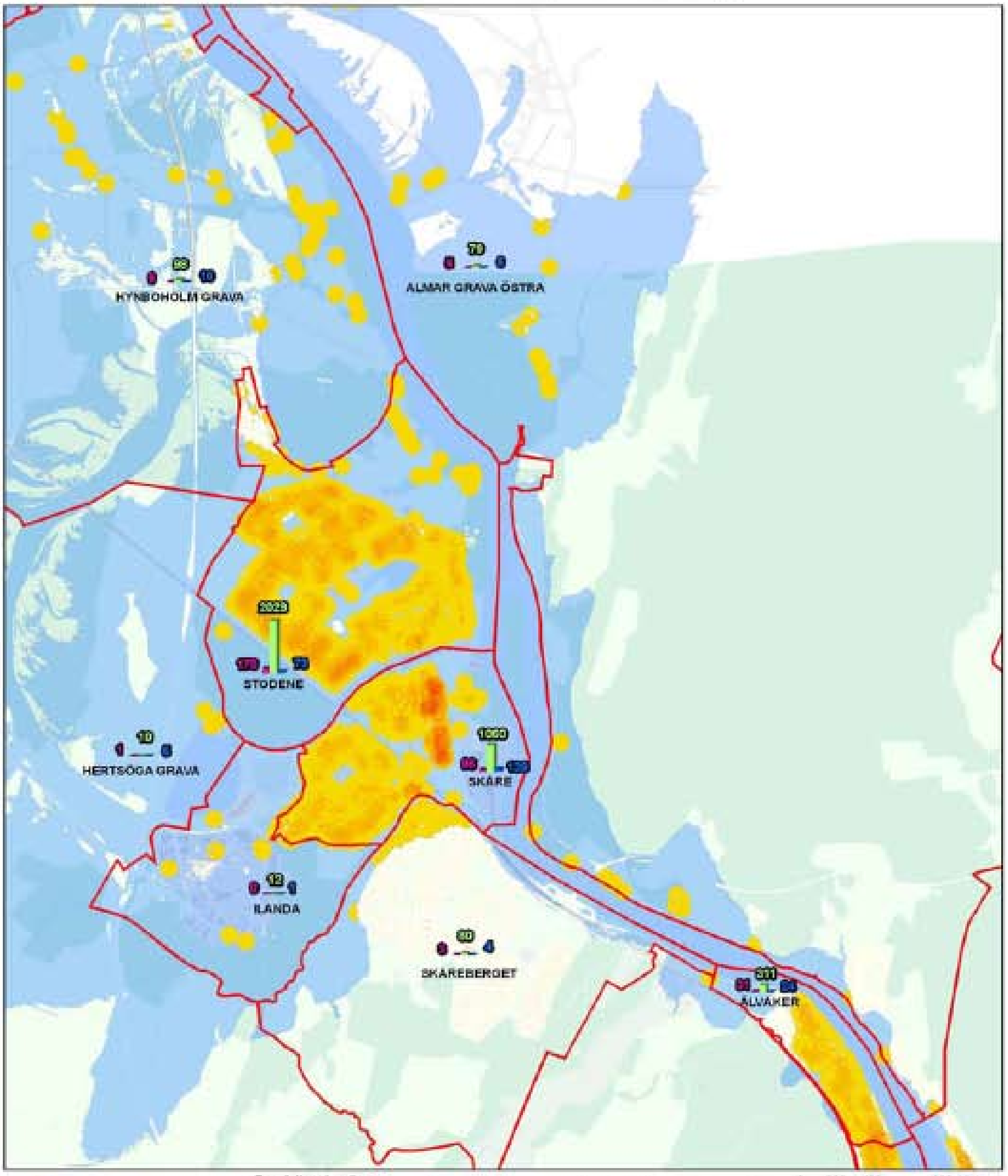
Population data was withdrawn from the municipal population register 2009-09-24.

The analysis has been carried out automatically and may contain faults. The map should be considered as working material.

Jan-Olov Moberg
Johan Asplund

Combination of a flood with very low probability (approx. a 10.000 years flood) in the River Klarälven and a Medium Water Level in Lake Vänern

- number of residents susceptible to flooding -



Population per town district

0 - 5 years

6 - 74 years

75 years and older

Population density

LOW

HIGH

The map shows a flood scenario in combination with a population analysis. Only town districts with residents susceptible to flooding are shown.

The River Klarälven has a flood with very low probability (approx. a 10.000 years flood) and Lake Vänern is at its medium water level (+44.20 m RH00 Karlstad)

Population data was withdrawn from the municipal population register 2009-09-24

The analysis has been carried out automatically and may contain faults. The map should be considered as working material.

0 200 400 800 Meters

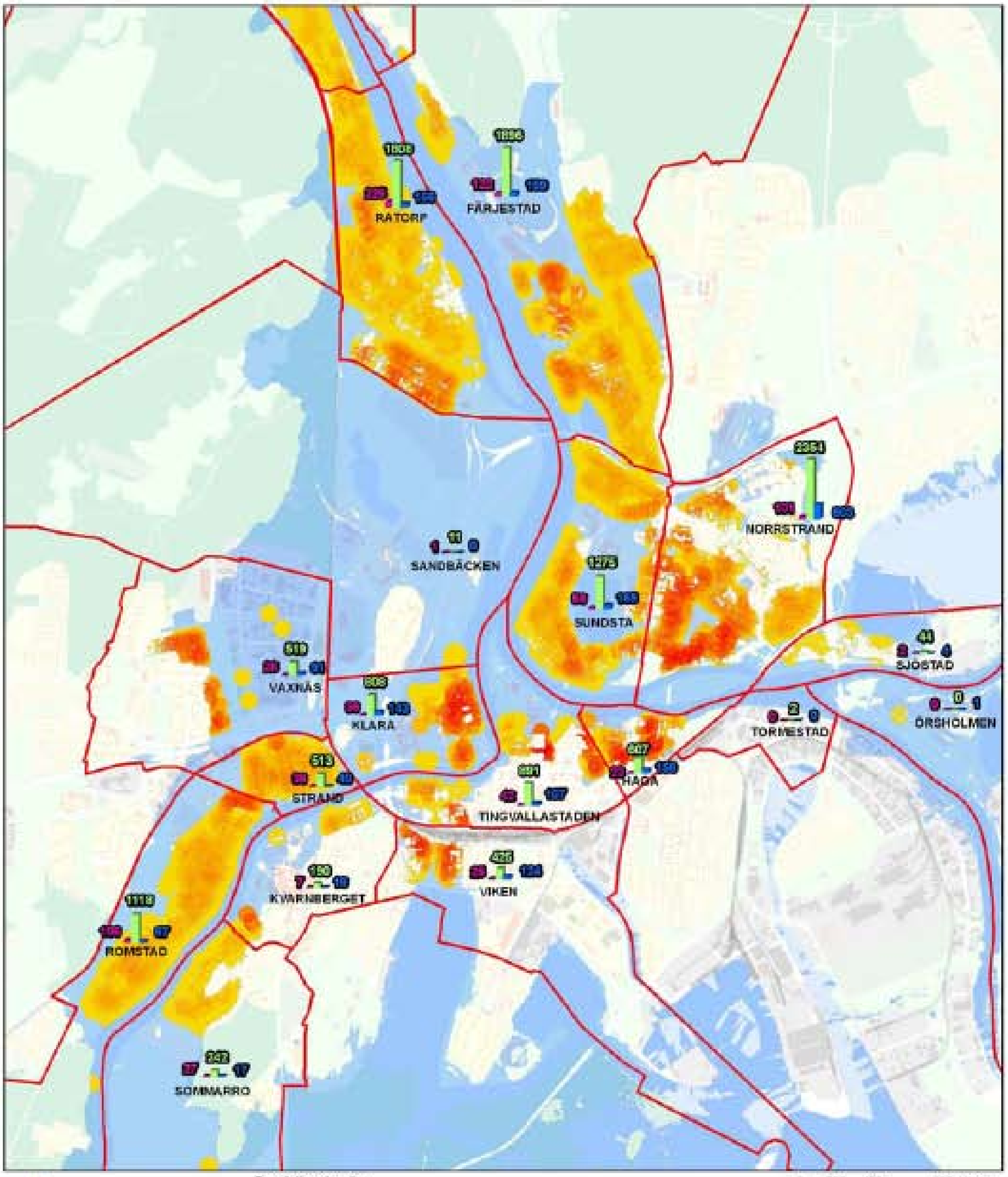
1:20 000

N

Jan-Olov Moberg
Johan Asplund

Combination of a flood with very low probability (approx. a 10.000 years flood) in the River Klarälven and a Medium Water Level in Lake Vänern

- number of residents susceptible to flooding -



Population per town district
0 - 5 years
6 - 74 years
75 years and older

Population density
LOW
HIGH

The map shows a flood scenario in combination with a population analysis. Only town districts with residents susceptible to flooding are shown.

The River Klarälven has a flood with very low probability (approx. a 10.000 years flood) and Lake Vänern is at its medium water level (+44.20 m RH00 Karlstad).

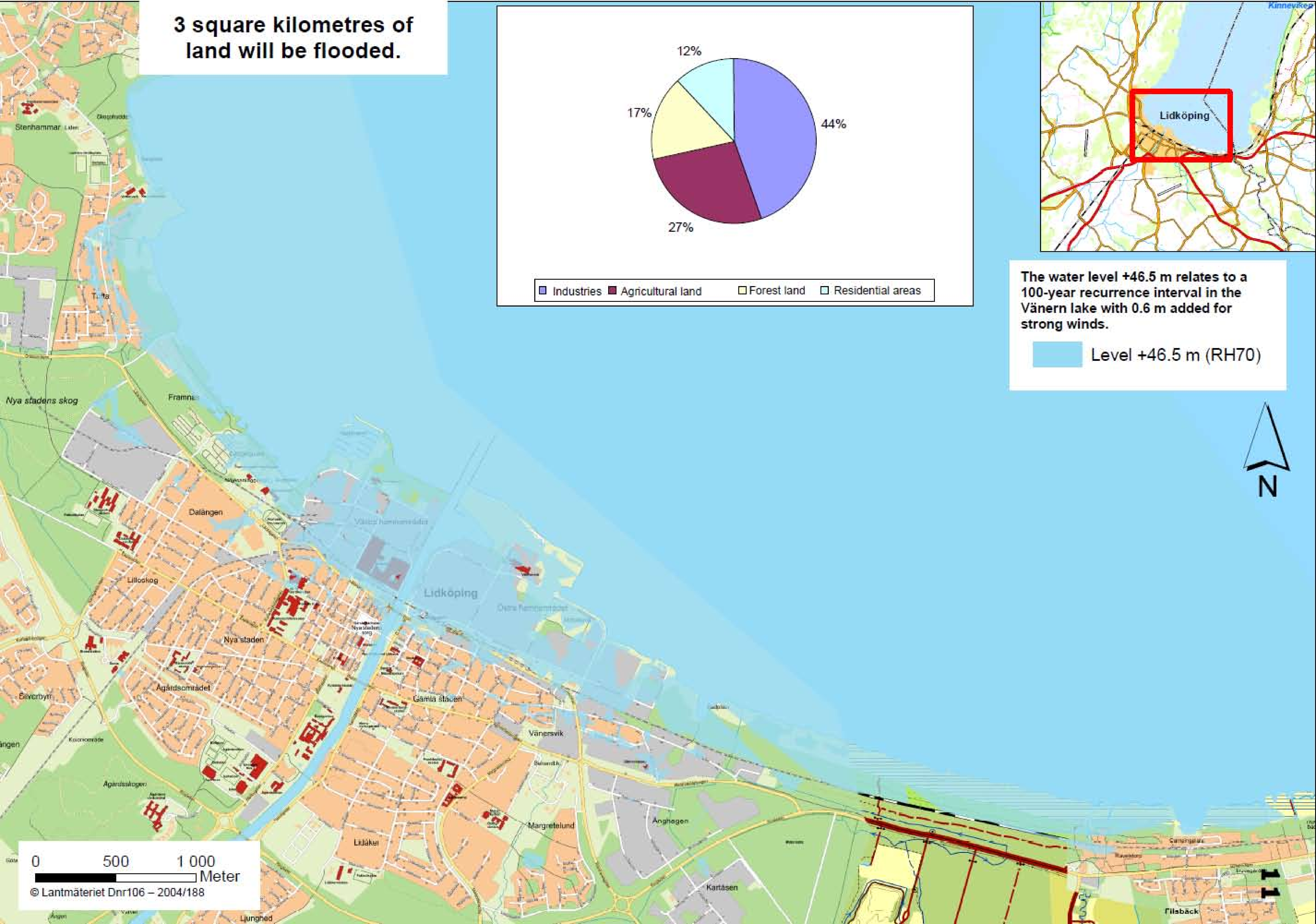
Population data was withdrawn from the municipal population register 2009-09-24.

The analysis has been carried out automatically and may contain faults. The map should be considered as working material.

0 200 400 800 Meters
1:20 000
N

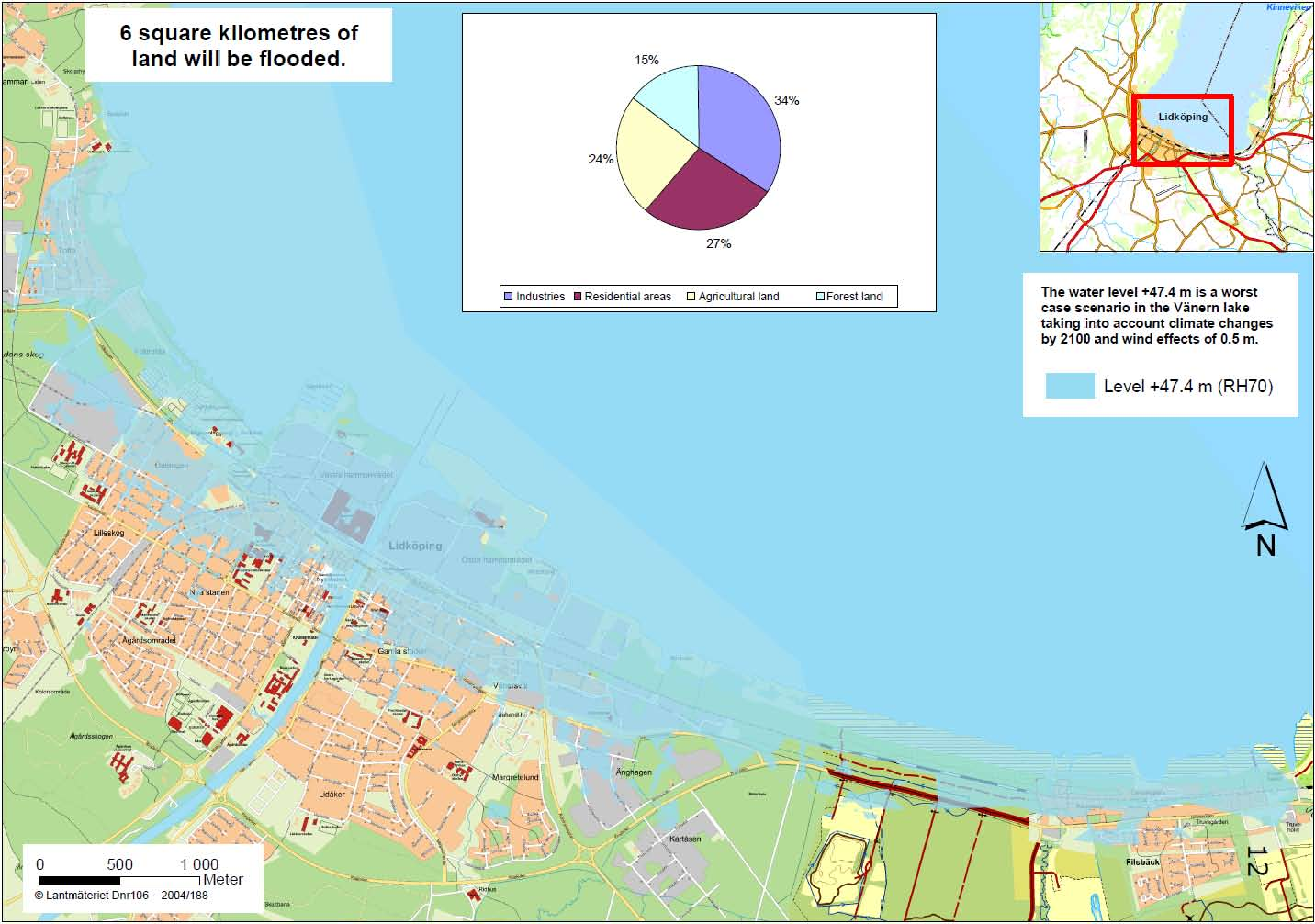
Jan-Olov Moberg
Johan Asplund

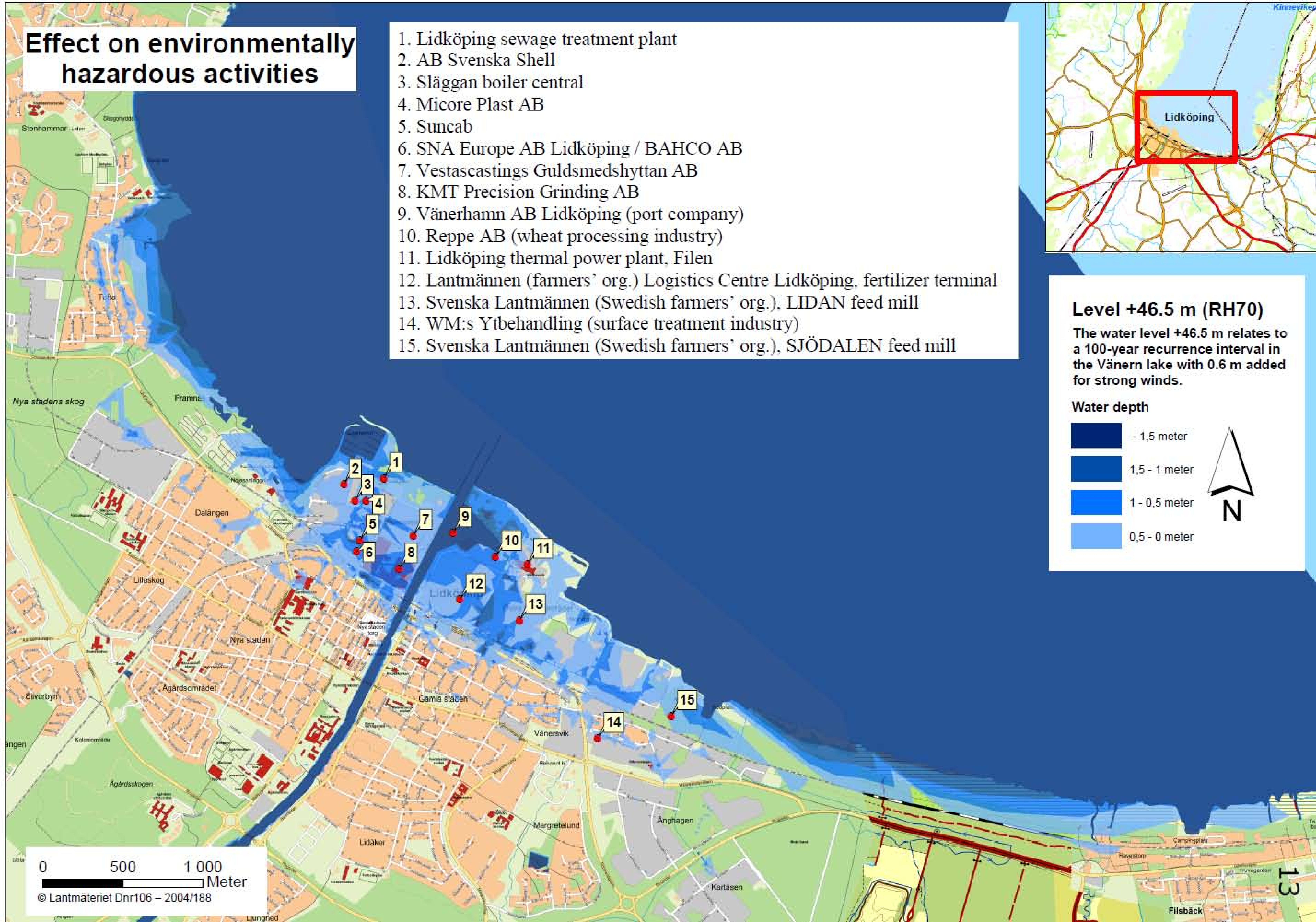
3 square kilometres of land will be flooded.

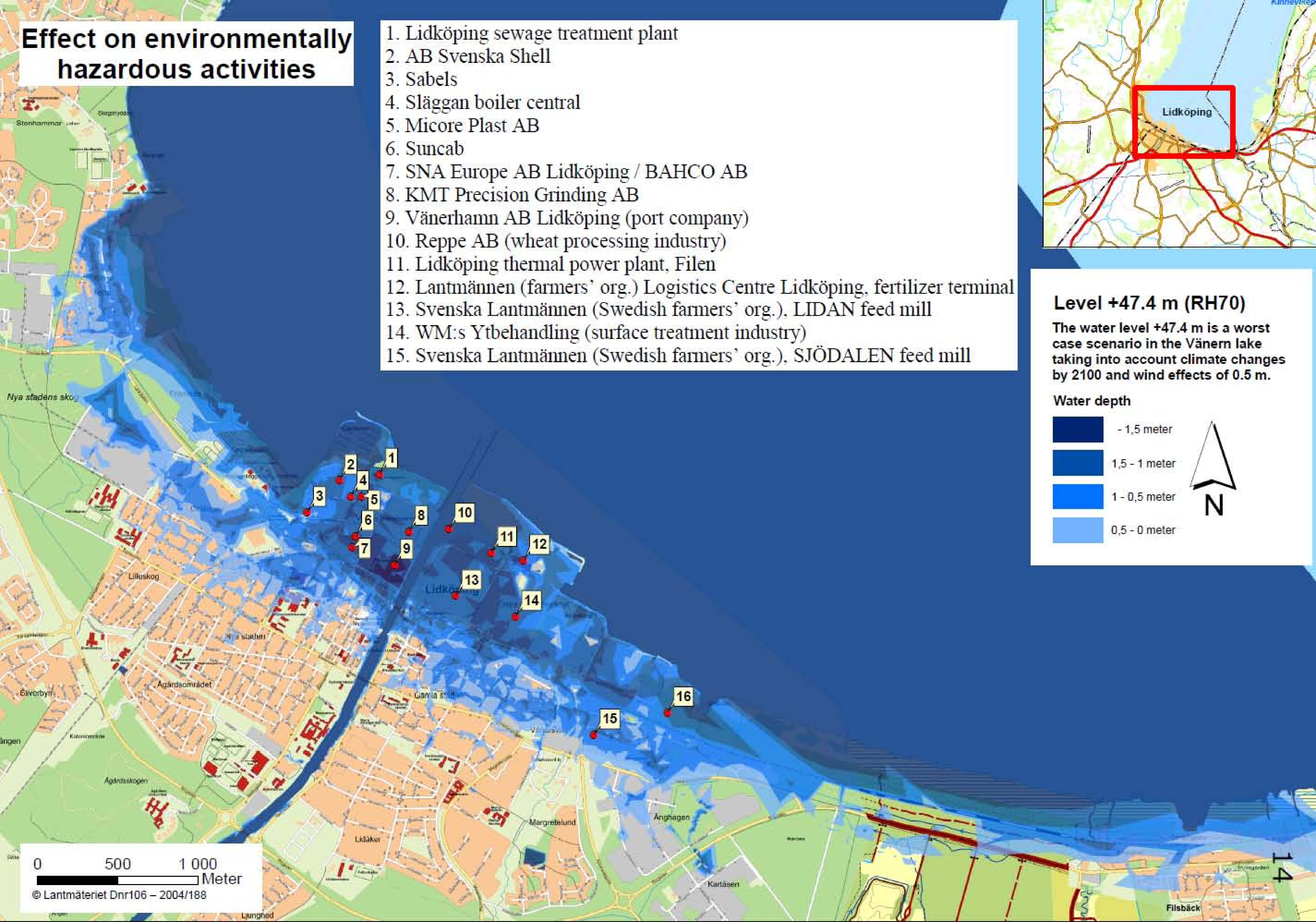


The water level +46.5 m relates to a 100-year recurrence interval in the Vänern lake with 0.6 m added for strong winds.

Level +46.5 m (RH70)


6 square kilometres of land will be flooded.
15%
34%
24%
27%
Industries
Residential areas
Agricultural land
Forest land
Lidköping
The water level +47.4 m is a worst case scenario in the Vänern lake taking into account climate changes by 2100 and wind effects of 0.5 m.
Level +47.4 m (RH70)
N
Lidköping
Lilleskog
Ågårdsområdet
Gamla staden
Ågårdsskogen
Margretelund
Ånghagen
Lidåker
Kartåsen
Filsbäck
12
0
500
1 000
Meter
© Lantmäteriet Dnr106 – 2004/188


Effect on environmentally hazardous activities
1. Lidköping sewage treatment plant
2. AB Svenska Shell
3. Släggan boiler central
4. Micore Plast AB
5. Suncab
6. SNA Europe AB Lidköping / BAHCO AB
7. Vestascastings Guldsmedshyttan AB
8. KMT Precision Grinding AB
9. Vänerhamn AB Lidköping (port company)
10. Reppe AB (wheat processing industry)
11. Lidköping thermal power plant, Filen
12. Lantmännen (farmers' org.) Logistics Centre Lidköping, fertilizer terminal
13. Svenska Lantmännen (Swedish farmers' org.), LIDAN feed mill
14. WM:s Ytbehandling (surface treatment industry)
15. Svenska Lantmännen (Swedish farmers' org.), SJÖDALEN feed mill
Lidköping
Level +46.5 m (RH70)
The water level +46.5 m relates to a 100-year recurrence interval in the Vänern lake with 0.6 m added for strong winds.
Water depth
- 1,5 meter
1,5 - 1 meter
1 - 0,5 meter
0,5 - 0 meter
N
Nya stadens skog
Framnäs
Dalängen
Lilleskog
Nya staden
Ågårdsområdet
Gamla staden
Vänersvik
Ågårdsskogen
Margretelund
Ånghagen
Lidåker
Kartåsen
Filsbäck
0 500 1 000
Meter
© Lantmäteriet Dnr106 – 2004/188



Effect on environmentally hazardous activities
1. Lidköping sewage treatment plant
2. AB Svenska Shell
3. Sabels
4. Släggan boiler central
5. Micore Plast AB
6. Suncab
7. SNA Europe AB Lidköping / BAHCO AB
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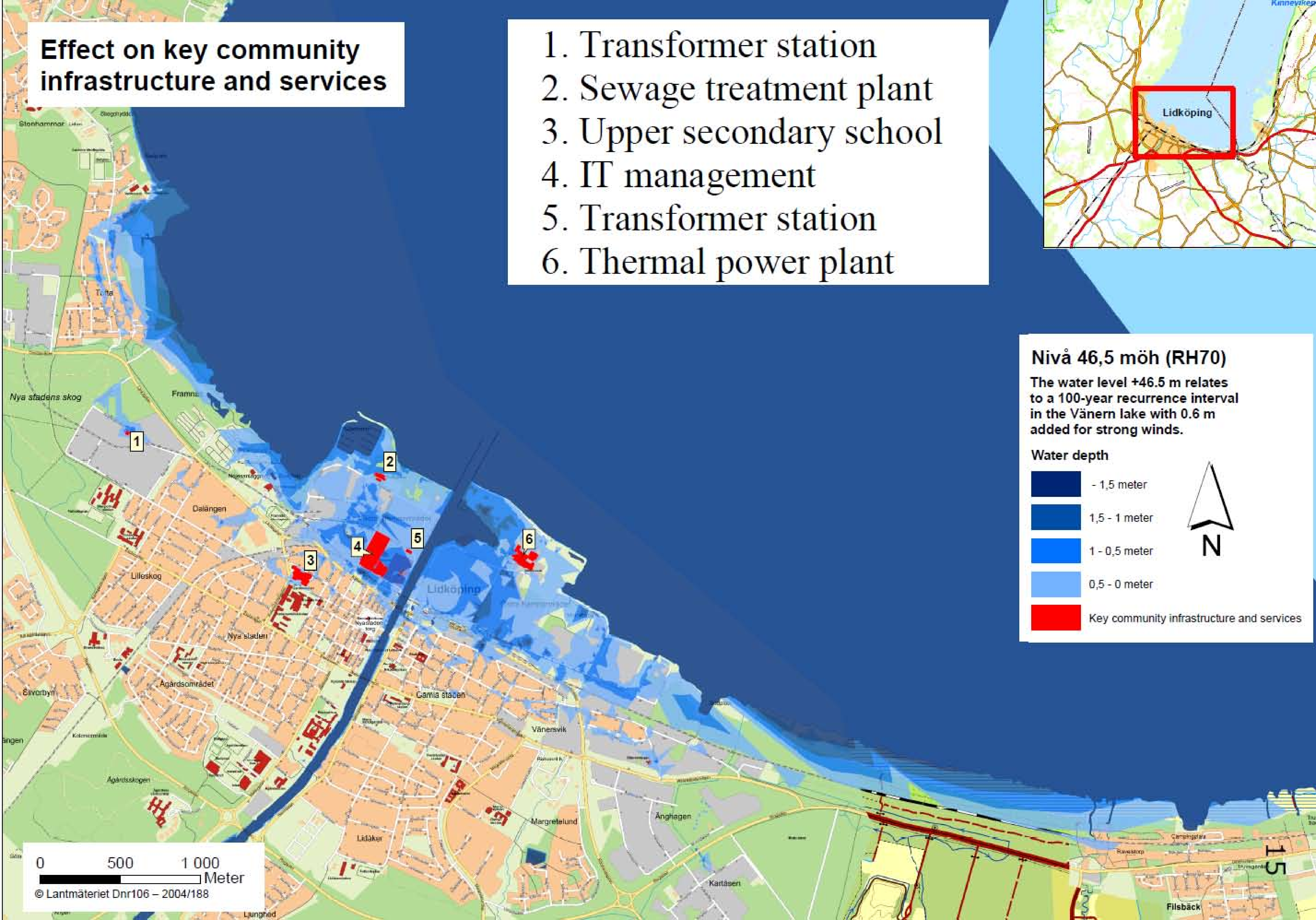
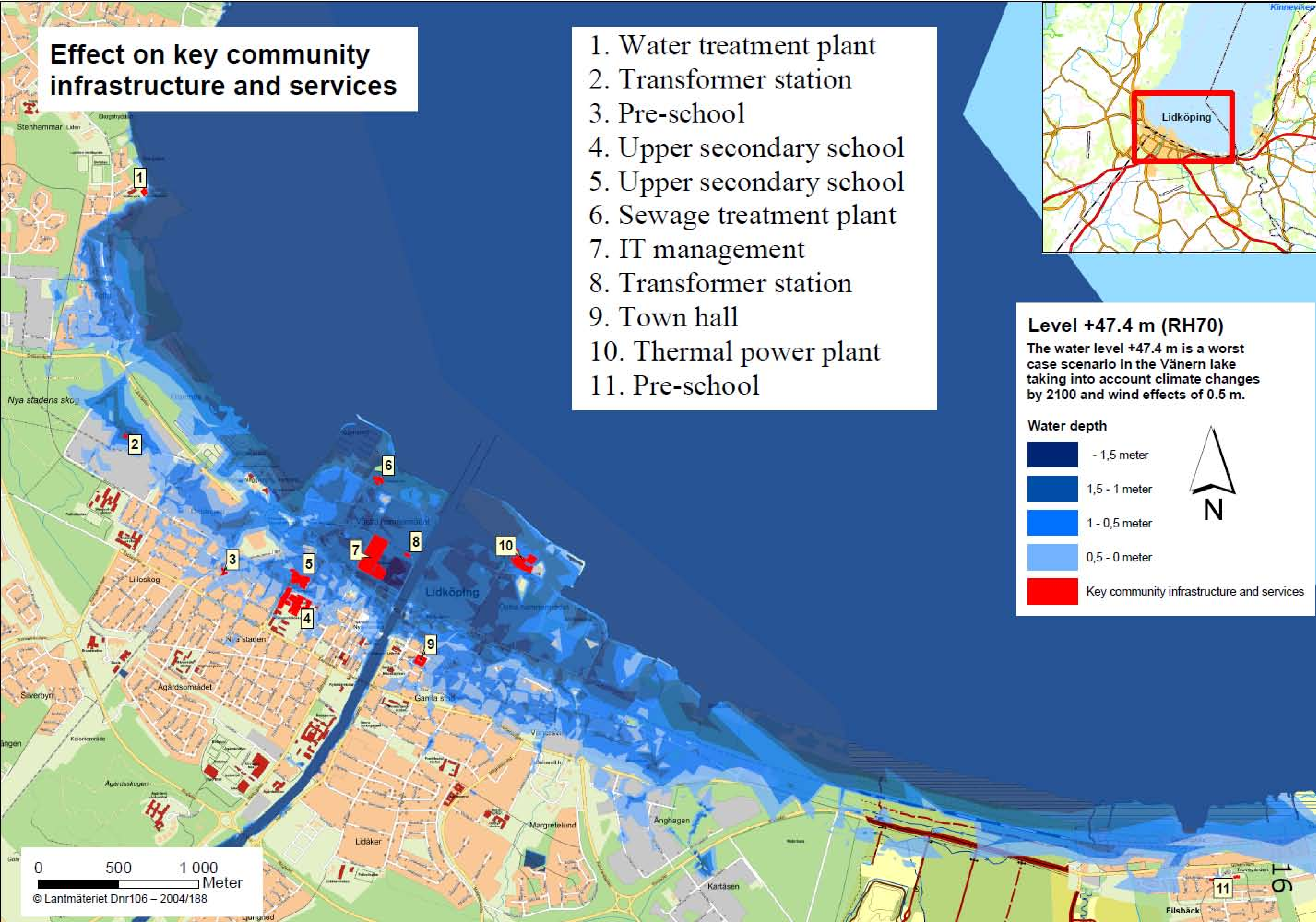
13. Svenska Lantmännen (Swedish farmers' org.), LIDAN feed mill
14. WM:s Ytbehandling (surface treatment industry)
15. Svenska Lantmännen (Swedish farmers' org.), SJÖDALEN feed mill
Lidköping
Level +47.4 m (RH70)
The water level +47.4 m is a worst case scenario in the Vänern lake taking into account climate changes by 2100 and wind effects of 0.5 m.
Water depth
- 1,5 meter
1,5 - 1 meter
1 - 0,5 meter
0,5 - 0 meter
N
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Stenhammar
Nya stadens skog
Lilleskog
Ågårdsområdet
Ågårdsskogen
Margretelund
Änghagen
Lidåker
Kartåsen
Filsbäck
Ljunghed
0
500
1 000
Meter
© Lantmäteriet Dnr106 – 2004/188


Effect on key community infrastructure and services
1. Transformer station
2. Sewage treatment plant
3. Upper secondary school
4. IT management
5. Transformer station
6. Thermal power plant
Lidköping
Nivå 46,5 möh (RH70)
The water level +46.5 m relates to a 100-year recurrence interval in the Vänern lake with 0.6 m added for strong winds.
Water depth
- 1,5 meter
1,5 - 1 meter
1 - 0,5 meter
0,5 - 0 meter
Key community infrastructure and services
N
0
500
1 000
Meter
© Lantmäteriet Dnr106 – 2004/188
Nya stadens skog
Framnäs
Dalängen
Lilleskog
Nya staden
Gamla staden
Ågårdsområdet
Silvorbyn
Ågårdsskogen
Vänersvik
Margretelund
Änghagen
Lidåker
Kartåsen
Filsbäck


Effect on key community infrastructure and services
1. Water treatment plant
2. Transformer station
3. Pre-school
4. Upper secondary school
5. Upper secondary school
6. Sewage treatment plant
7. IT management
8. Transformer station
9. Town hall
10. Thermal power plant
11. Pre-school
Lidköping
Level +47.4 m (RH70)
The water level +47.4 m is a worst case scenario in the Vänern lake taking into account climate changes by 2100 and wind effects of 0.5 m.
Water depth
- 1,5 meter
1,5 - 1 meter
1 - 0,5 meter
0,5 - 0 meter
Key community infrastructure and services
N
Stenhammar
Nya stadens skog
Lilloskog
Lidköping
Gamla stan
Margretelund
Anghagen
Lidåker
Kartåsen
Filsbäck
0 500 1 000
Meter
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