Chapter 5 Reconstruction of Homes and Cities

Section 4 Measures to Prevent the Sliding Collapse of Residential Land and Related Topics

1. Measures to Prevent the Sliding Collapse of Residential Land

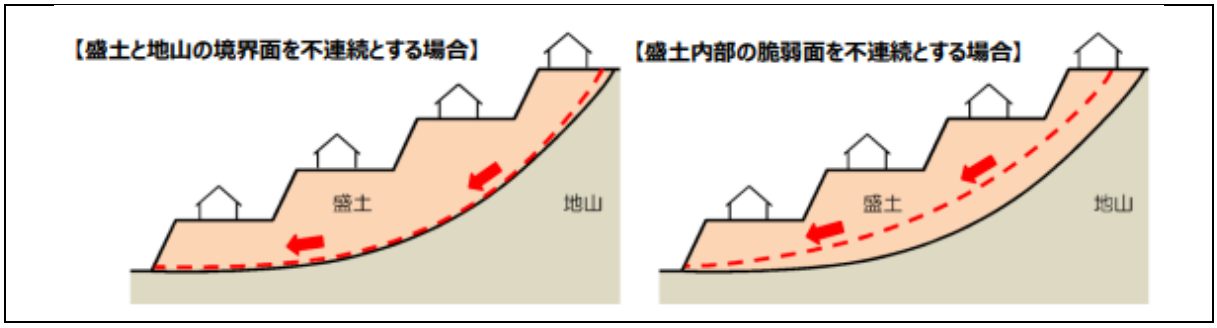
(1) Emergency measures to prevent the sliding collapse of developed residential land

The Great East Japan Earthquake caused unprecedented damage across an extensive area of the Tohoku and Kanto regions, including the collapse of residential embankments and damage to retaining walls. In Sendai City, Miyagi Prefecture, it was reported that up to around 5,800 lots of residential land sustained damage, 160 of which were damaged as a result of sliding collapse. Landslide deformation was the most common type of damage resulting from sliding collapse. Depending on the location of the deformation, landslide deformation damage was classified into one of three categories: deformation of entire embankments, deformation of terraced areas, and combined deformation of entire embankments and terraced areas.

1) Deformation of entire embankments

Landslide deformation of entire embankments, disrupting planes such as the boundary between the embankment and the natural ground, and weak layers within the embankment

Figure 5-4-1 Schematic Diagram Illustrating the Deformation of Entire Embankments



Source: Ministry of Land, Infrastructure, Transport and Tourism, "Measures to Prevent the Sliding Collapse of Large-Scale Embankment Development Sites, 3. Past Cases of Damage, (4) Cases from the 2011 Earthquake off the Pacific Coast of Tohoku (Valley-Filled Large-Scale Embankment Development Sites)"
https://www.mlit.go.jp/toshi/content/001466161.pdf (browsed July 31, 2023)

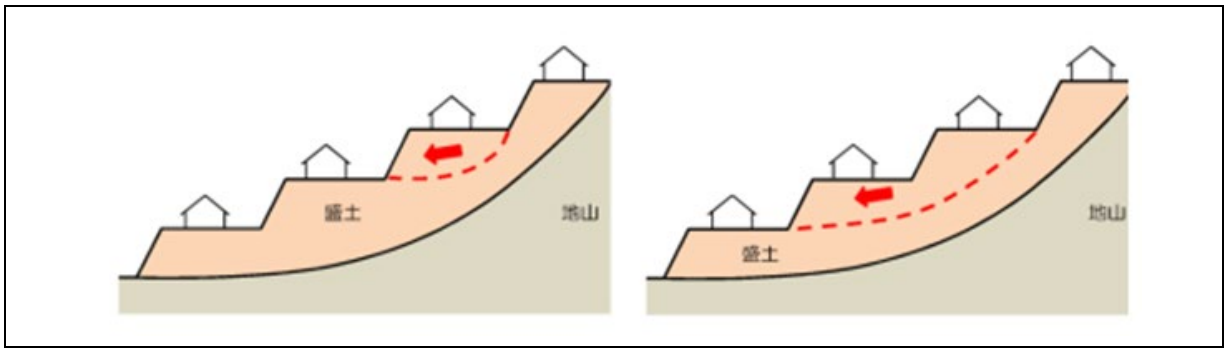
Figure 5-4-2 Photographs of Areas Where Entire Embankments Sustained Deformation Damage

Source: Ministry of Land, Infrastructure, Transport and Tourism, "Measures to Prevent the Sliding Collapse of Large-Scale Embankment Development Sites, 3. Past Cases of Damage, (4) Cases from the 2011 Earthquake off the Pacific Coast of Tohoku (Valley-Filled Large-Scale Embankment Development Sites)"
https://www.mlit.go.jp/toshi/content/001466161.pdf (browsed July 31, 2023)

2) Deformation of Terraced Areas

Landslide deformation of one or more tiers of a terraced embankment, with weak layers within the embankment acting as discontinuity planes

Figure 5-4-3 Schematic Diagram Illustrating Deformation of Terraced Areas



Source: Ministry of Land, Infrastructure, Transport and Tourism, "Measures to Prevent the Sliding Collapse of Large-Scale Embankment Development Sites, 3. Past Cases of Damage, (4) Cases from the 2011 Earthquake off the Pacific Coast of Tohoku (Valley-Filled Large-Scale Embankment Development Sites)"
https://www.mlit.go.jp/toshi/content/001466161.pdf (browsed July 31, 2023)

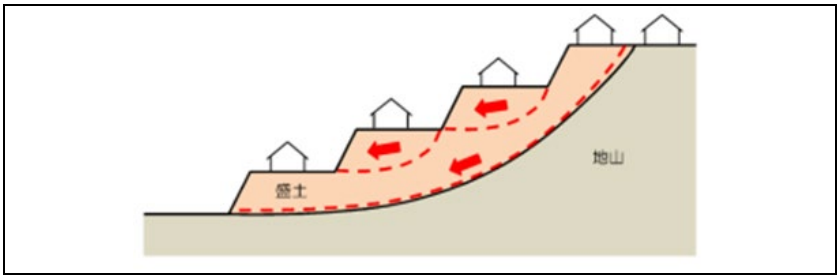
Figure 5-4-4 Photograph of an Area Where Terraced Areas Sustained Deformation Damage

Source: Ministry of Land, Infrastructure, Transport and Tourism, "Measures to Prevent the Sliding Collapse of Large-Scale Embankment Development Sites, 3. Past Cases of Damage, (4) Cases from the 2011 Earthquake off the Pacific Coast of Tohoku (Valley-Filled Large-Scale Embankment Development Sites)"
https://www.mlit.go.jp/toshi/content/001466161.pdf (browsed July 31, 2023)

3) Composite Deformation of Entire Embankments and Terraced Areas

Landslide Deformation Involving Combined Deformation of Entire Embankments and Terraced Areas

Figure 5-4-5 Schematic Diagram Illustrating Composite Deformation of Entire Embankments and Terraced Areas



Source: Ministry of Land, Infrastructure, Transport and Tourism, "Measures to Prevent the Sliding Collapse of Large-Scale Embankment Development Sites, 3. Past Cases of Damage, (4) Cases from the 2011 Earthquake off the Pacific Coast of Tohoku (Valley-Filled Large-Scale Embankment Development Sites)"
https://www.mlit.go.jp/toshi/content/001466161.pdf (browsed July 31, 2023)

Figure 5-4-6 Photographs of Areas Where Combined Deformation of Entire Embankments and Terraced Areas Occurred

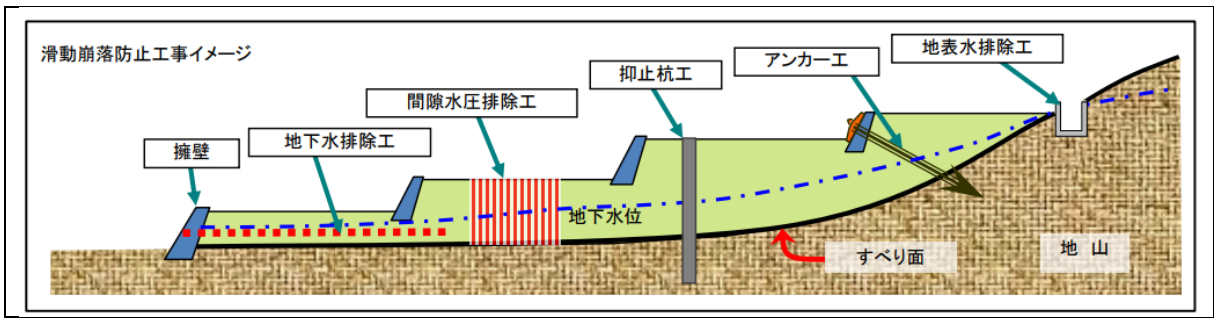
Source: Ministry of Land, Infrastructure, Transport and Tourism, "Measures to Prevent the Sliding Collapse of Large-Scale Embankment Development Sites, 3. Past Cases of Damage, (4) Cases from the 2011 Earthquake off the Pacific Coast of Tohoku (Valley-Filled Large-Scale Embankment Development Sites)"
https://www.mlit.go.jp/toshi/content/001466161.pdf (browsed July 31, 2023)

In response to damage caused by the sliding collapse of foundations on developed residential land, the Ministry of Land, Infrastructure, Transport and Tourism decided to provide support to local governments for emergency construction projects. These emergency measures to prevent the sliding collapse of developed residential land were carried out from FY 2011 to FY 2020 and funded by Reconstruction Grants under the Land Restructuring Plan.

In view of the severity and widespread nature of the damage caused by the Great East Japan Earthquake, Reconstruction Grants were established to ease the financial burden on disaster-affected municipalities for their reconstruction efforts. These grants provide regular national funding for 40 projects, including emergency measures to prevent the sliding collapse of developed residential land, along with additional national funding to cover half of the local governments' share of costs. In addition, the other half the local governments' share was covered by local reconstruction grant taxes, ensuring that local governments incur no financial burden when carrying out the core projects. Moreover, the local governments (prefectures and municipalities) were responsible for the formulation of plans for emergency measures to prevent the sliding collapse of developed residential land. Plans were able to be created for individual districts, or multiple districts across the entire area under the local government's jurisdiction could be covered in a single plan.

The emergency measures to prevent the sliding collapse of developed residential land provide support for emergency construction projects to prevent future disasters on developed residential land affected by the sliding collapse of foundations. Of the areas where such damage was sustained due to the Great East Japan Earthquake, districts where construction would begin by the end of FY 2012 (excluding Fukushima nuclear power station accident evacuation zones) were made eligible for subsidized construction for the prevention of sliding collapse.

Figure 5-4-7 Conceptual Image of Construction to Prevent Sliding Collapse



Source: Ministry of Land, Infrastructure, Transport and Tourism, "Overview of Emergency Measures to Prevent the Sliding Collapse of Developed Residential Land"
https://www.mlit.go.jp/toshi/content/001465917.pdf (browsed July 31, 2023)

Projects were implemented in Iwate Prefecture (1 district), Miyagi Prefecture (167 districts), Fukushima Prefecture (17 districts), Ibaraki Prefecture (7 districts), and Tochigi Prefecture (3 districts). Construction for these measures was completed in all planned districts by the end of 2020.

In Sendai City, Miyagi Prefecture, the following ordinance was enacted in 2013, titled the "Sendai City Ordinance on the Maintenance of Facilities to Prevent Sliding Collapse on Developed Residential Land."

Figure 5-4-8 Sendai City Ordinance on the Maintenance of Facilities to Prevent Sliding Collapse on Developed Residential Land

仙台市造成宅地滑動崩落防止施設の保全に関する条例
（平成二十五年仙台市条例第二十八号）

（趣旨）
第一条　この条例は、造成宅地滑動崩落防止施設（平成二十三年東北地方太平洋沖地震により被害を受けた造成宅地（宅地造成及び特定盛土等規制法（昭和三十六年法律第百九十一号）第二条第九号に規定する造成宅地をいう。）について再度災害を防止するために本市が国の補助を受けて施行する事業により設置する施設で規則で定めるもののうち、地盤の滑動又はこれによる崩落を防止するために設置するものをいう。以下同じ。）の保全に関し、必要な事項を定めるものとする。

（公表等）
第二条　市長は、造成宅地滑動崩落防止施設を設置したときは、速やかに、その旨を公表するとともに、造成宅地滑動崩落防止施設の位置、種類、構造その他のその保全のために必要な事項を記載した書類を一般の閲覧に供するものとする。

（届出）
第三条　造成宅地滑動崩落防止施設の保全に支障を及ぼすおそれがある行為として規則で定めるものをしようとする者は、当該行為に着手する日の三十日前までに、規則で定めるところにより、その旨を市長に届け出なければならない。

（指導及び助言）
第四条　市長は、造成宅地滑動崩落防止施設（設置の工事中のものを含む。）を保全するために必要があると認めるときは、前条の行為をしようとする者又はした者に対し、必要な指導及び助言をすることができる。

（委任）
第五条　この条例の施行に関し必要な事項は、市長が定める。

附　則
この条例は、公布の日から施行する。
附　則
この条例は、令和五年五月二十六日から施行する。

Source: Sendai City, "Pamphlet on the 'Sendai City Ordinance on the Maintenance of Facilities to Prevent Sliding Collapse on Developed Residential Land'" https://www.city.sendai.jp/takuchihozen/shise/daishinsai/fukko/takuchihigai/documents/r050526.pdf (browsed August 17, 2023)

The "Iwaki City Reconstruction Grant Project Plan: Individual Record for the Reconstruction Grant Project" is shown below, followed by the construction site plan and cross-sectional diagram for a construction project in Iwaki City, Fukushima Prefecture.

Figure 5-4-9 Iwaki City Reconstruction Grant Project Plan: Individual Record for a Reconstruction Grant Project

（様式１－３）

いわき市復興交付金事業計画　復興交付金事業等（いわき市（町村）交付分）個票

平成 24 年 6 月時点

※本様式は１－２に記載した事業ごとに記載してください。

NO.	27	事業名	造成宅地滑動崩落緊急対策事業（西郷町忠多）	事業番号	D-14-1
交付団体			いわき市	事業実施主体（直接/間接）	いわき市（直接）
総交付対象事業費			403,884（千円）	全体事業費	403,884（千円）

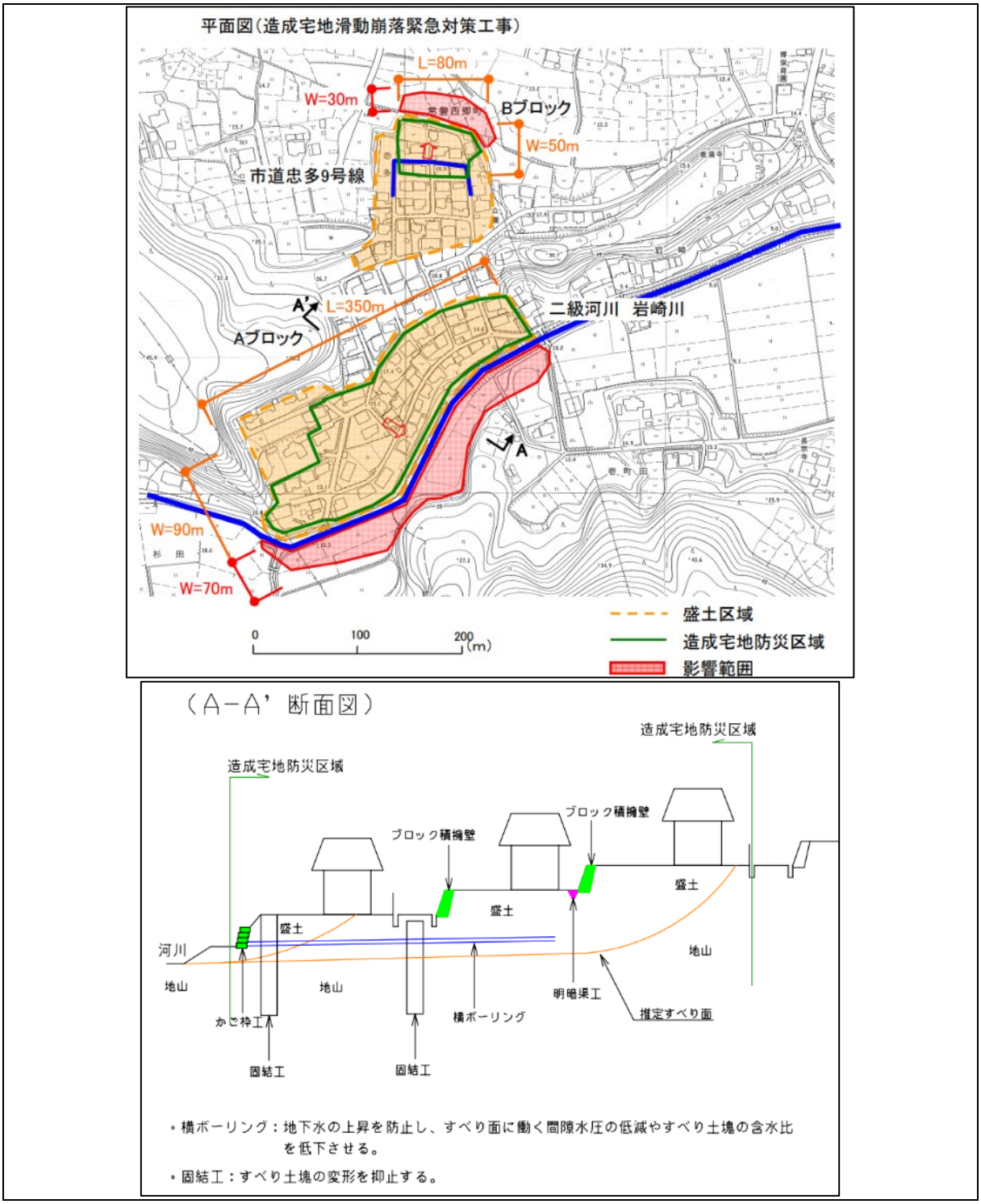
事業概要
地盤の滑動崩落等により被害を受けた造成宅地の復旧及び二次災害を防止するための滑動崩落防止の対策工事を緊急に行うものです。 [事業内容] 対象地区　いわき市常磐西郷町忠多地区 対象面積　全体 A=2.6ha（盛土上に存在する家屋数　50 戸） A ﾌﾞﾛｯｸ　A=2.2ha（盛土上に存在する家屋数　40 戸） B ﾌﾞﾛｯｸ　A=0.4ha（盛土上に存在する家屋数　10 戸） 対策工　滑動崩落防止工事（抑止工、抑制工、排水工、擁壁工等） ※当該事業を復興ビジョン、復興計画、復興プラン等に位置付けている場合は、該当箇所及び概要も記載してください 『市復興事業計画』 取組名：　宅地・団地被害に対する支援 取組内容：造成地盛土の滑動崩落による被害を受けた住宅団地の復旧について、整備を図る。
当面の事業概要
<平成 24 年度> 工事 <平成 25 年度> 工事
東日本大震災の被害との関係
平成２３年３月１１日発生の東北地方太平洋沖地震により、これまで安定していた盛土造成宅地が滑動崩落したものです。 ※区域の被害状況も記載して下さい。
関連する災害復旧事業の概要
無し

※効果促進事業等である場合には以下の欄を記載。

関連する基幹事業	
事業番号	
事業名	
交付団体	
基幹事業との関連性	

Source: Iwaki City, "Iwaki City Reconstruction Grant Project Plan (Emergency Measures to Prevent the Sliding Collapse of Developed Residential Land) (Nishigomachi Chuda)"
https://www.city.iwaki.lg.jp/www/contents/1001000004024/simple/D-14-1.pdf (browsed August 17, 2023)

Figure 5-4-10 Construction Site Plan and Cross-Sectional Diagram of Emergency Measures to Prevent the Sliding Collapse of Developed Residential Land (Nishigomachi Chuda, Iwaki City)



Source: Iwaki City, "Iwaki City Reconstruction Grant Project Plan (Emergency Measures to Prevent the Sliding Collapse of Developed Residential Land) (Nishigomachi Chuda)" https://www.city.iwaki.lg.jp/www/contents/1001000004024/simple/D-14-1.pdf (browsed August 17, 2023)

(2) Area-wide sliding collapse prevention measures

The Great East Japan Earthquake caused widespread damage to numerous residential areas, highlighting the importance of area-wide sliding collapse prevention measures. The aim of area-wide sliding collapse prevention measures is to reduce large-scale residential land damage and protect regional communities, including essential public infrastructure like utilities, roads, rivers, railways, evacuation routes, and evacuation sites. In addition to preventing the collapse and deformation of entire embankments, these measures generally also address surface deformation, uneven settlement at cut-and-fill boundaries, and retaining wall deformation resulting from the collapse and deformation of entire embankments.

When implementing these measures, it is essential and practical to evaluate effective locations and specifications by utilizing public land and, when necessary, individual residential lots, thereby addressing the entire residential area in an integrated manner.

(3) Formulation of the "Guidelines for the Promotion of Measures to Prevent the Sliding Collapse of Large-Scale Embankment Development Sites"

In September 2006, the Ministry of Land, Infrastructure, Transport and Tourism formulated the "Guidelines on Surveys to Predict Ground Movements at Large-Scale Embankment Development Sites," which outlined survey methods associated with seismic reinforcement promotion projects for residential land, and in April 2012, they created the "Guidelines for Selecting Seismic Reinforcement Methods for Residential Land," which details approaches to the selection of measures, thereby promoting the seismic reinforcement of residential land. However, the extensive damage caused by the Great East Japan Earthquake and the anticipated risks of potential major earthquakes, such as an earthquake directly beneath Tokyo or a Nankai Trough megathrust earthquake, prompted the revision of these guidelines to further enhance seismic resilience. In the revision, the previously mentioned existing guidelines were modified based on insights gained from analyzing the actual damage caused by the Great East Japan Earthquake and examples of recovery efforts. Furthermore, the revised guidelines presented a new framework for the sequence of recovery measures and methods for investigation and analysis in the event of sliding collapse. This framework was compiled and organized as follows.

- Part I: Movement Prediction Surveys (Revision of the "Guidelines on Surveys to Predict Ground Movements at Large-Scale Embankment Development Sites")
- Part II: Preventative Measures (Revision of the "Guidelines for Selecting Seismic Reinforcement Methods for Residential Land")
- Part III: Recovery Measures (Newly Formulated)

The purpose and primary subject matter of each part are outlined in the table below.

Figure 5-4-11　Contents of the “Guidelines on Surveys to Predict Ground Movements at Large-Scale Embankment Development Sites”

目的	ｶﾞｲﾄﾞﾗｲﾝの構成		
	編	主な内容	調査と対策検討の概要
滑動崩落の予防（大地震の前）	Ⅰ編 変動予測調査編	調査の手法	大規模盛土造成地を抽出し、滑動崩落のおそれがあるかどうかを調査する。
	Ⅱ編 予防対策編	対策検討の手法	Ⅰ編の調査の結果、滑動崩落のおそれがあると判断される場合は、その予防のための対策を検討し実施する。
滑動崩落の再発防止（大地震の後）	Ⅲ編 復旧対策編	調査の手法 対策検討の手法	宅地被害がまとまって発生した範囲を対象に、大規模盛土造成地に該当するかどうか、滑動崩落が生じたかどうかを調査する。 調査の結果、大規模盛土造成地に該当し、滑動崩落が生じたと判断される場合は、再発を防止するための対策を検討し実施する。 ※大地震の前に変動予測調査を実施しているかどうかにかかわらず、滑動崩落が生じた地区を対象とする。

Source: Ministry of Land, Infrastructure, Transport and Tourism, “Guidelines for the Promotion of Measures to Prevent the Sliding Collapse of Large-Scale Embankment Development Sites, with Commentary” (May 2013) https://www.mlit.go.jp/common/001090725.pdf (browsed July 31, 2023)

Seismic resistance measures for residential land are broadly classified into area-wide sliding collapse prevention measures and seismic resistance measures for individual residential lots. Area-wide sliding collapse prevention measures are intended to preserve local communities, including public facilities. As these measures are to some degree public in nature, they are implemented by authorities such as local governments after obtaining the consent of residents and other stakeholders. As such, for projects carried out on large-scale embankment sites that meet certain requirements, part of the costs are subsidized under seismic reinforcement promotion projects for residential land.

However, area-wide sliding collapse prevention measures cannot completely prevent deformation for individual residential lots, although a certain degree of effectiveness can be expected. Seismic resistance measures for individual residential lots primarily aim to prevent and reduce deformation in such individual lots. By implementing them in conjunction with area-wide sliding collapse prevention measures, they can further reinforce the safety of individual residential lots. Seismic resistance measures for individual residential lots are implemented by the owners of each lot, but in many cases, it is difficult for them to do so. Therefore, local governments should use resident briefings on area-wide sliding collapse prevention measures to explain the importance and benefits of seismic resistance measures for individual residential lots, emphasizing that implementing both together is a more practical approach, as well as provide guidance and advice when necessary.

Once a sliding collapse occurs, damage is sustained not only by individual residential lots but also by the whole community, including adjacent residential land and public facilities. Therefore, local residents and local governments must work together to implement measures against sliding collapse through an approach that includes personal responsibility, community support, and government assistance. To promote seismic reinforcement measures for residential land in a comprehensive manner, it is crucial that local governments refer to these guidelines to raise disaster preparedness awareness throughout the entire community and promote safety improvements among owners of residential land, as well as implement area-wide sliding collapse prevention measures in cooperation with owners of residential land.

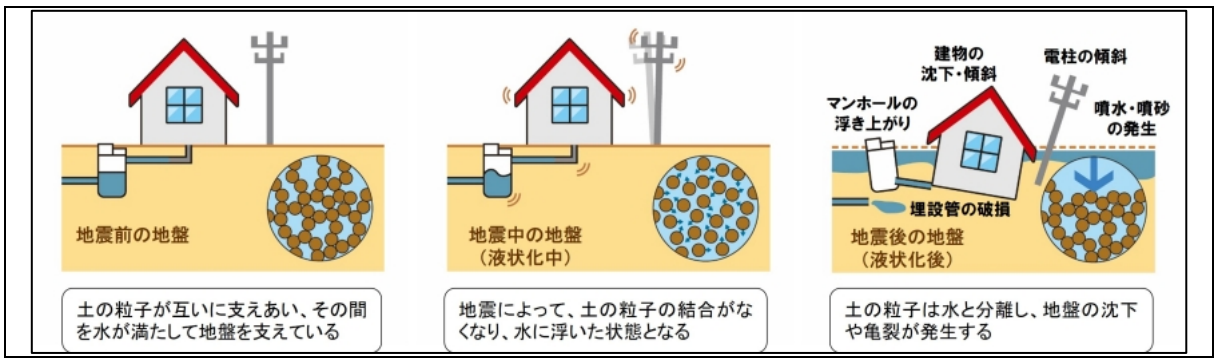
2. Liquefaction

(1) Overview of urban liquefaction countermeasure projects

During the Great East Japan Earthquake, liquefaction caused extensive damage to residential land.

Liquefaction is a phenomenon that occurs during an earthquake when the ground experiences strong shocks, causing cohesive soil particles that once supported each other to break apart, leaving the ground in a muddy state resembling a liquid. When this occurs, water gushes out of the ground, and the previously stable ground suddenly softens, causing buildings built on it to sink (or tilt), buried manholes and pipes to rise to the surface, and the entire ground to flow toward lower areas.

Figure 5-4-12 The Process of Liquefaction



Source: Ministry of Land, Infrastructure, Transport and Tourism, "The Liquefaction Phenomenon" https://www.mlit.go.jp/toshi/toshi_fr1_000010.html (browsed July 31, 2023)

Damage caused by liquefaction rarely has an immediate impact on human lives. However, reflecting on past cases reveals that liquefaction can cause a very diverse range of effects that impact human life after an earthquake, such as water and sand eruptions, sinking or tilting of detached houses, deformation of road surfaces, and damage to utility facilities, and the impact of the concurrent occurrence of these events can persist for extended periods of time.

Figure 5-4-13 Typical Forms of Damage Caused by Liquefaction and Examples of Their Effects on Life After an Earthquake

Source: Ministry of Land, Infrastructure, Transport and Tourism, "The Liquefaction Phenomenon" https://www.mlit.go.jp/toshi/toshi_fr1_000010.html (browsed July 31, 2023)

Urban liquefaction countermeasure projects are implemented to promote integrated measures for public facilities such as roads and sewage systems, along with adjacent residential land in areas that sustained significant damage due to ground liquefaction from the Great East Japan Earthquake in order to prevent future occurrence of such damage, and the following are covered by subsidies.

① Support for costs for preparing and coordinating liquefaction countermeasure project plan drafts (including relevant surveys)

② Support for costs for projects (design and construction costs) and relevant surveys that meet the following subsidy requirements and are implemented based on the liquefaction countermeasure project plan

(2) Liquefaction sites

The Great East Japan Earthquake caused liquefaction across a very wide area spanning from the Tohoku to Kanto regions.

Occurrences of liquefaction are broadly classified according to the type of terrain.

1) Coastal reclaimed land

Liquefaction of coastal reclaimed land occurred in many areas along the Pacific coast, including Tokyo Bay and Ibaraki Prefecture. In many areas along the Pacific coast, however, signs of liquefaction were obscured by the tsunami, making it impossible to determine whether liquefaction had occurred. For example, in Yuriage in Natori City, Miyagi Prefecture, photos of liquefaction were taken before the tsunami hit, but the signs were then wiped away by the tsunami.

2) Reclaimed land on rivers and ponds in plains regions

Liquefaction of reclaimed land along rivers and ponds occurred mainly in plains regions, such as along the Tone River.

For example, the areas that experienced liquefaction in Abiko City, Chiba Prefecture, were locations where marshland had been reclaimed following the collapse of the Tone River levee, while in Katori City, they were areas where part of the Tone River had been reclaimed. The Hinode district in Itako City, Ibaraki Prefecture, which suffered serious damage due to liquefaction, is where Uchina Sakaura Bay was reclaimed.

3) Sites where land was excavated and refilled after extracting iron sand or gravel

In Asahi City, Chiba Prefecture, liquefaction occurred in soil backfilled after iron sand extraction. In Kamisu City and Kashima City, Ibaraki Prefecture, it was soil backfilled after gravel extraction. This liquefaction caused damage to houses and other buildings.

A particularly large number of reclaimed land areas have been created along Tokyo Bay. Of this reclaimed land, liquefaction occurred across a large area, spanning from Yokohama City to Kawasaki City, Tokyo, Urayasu City, Ichikawa City, Funabashi City, Narashino City, and Chiba City.

In the reclaimed land that stretches from Shin-Kiba in Tokyo to Chiba City, liquefaction affected a very wide area, covering the entire region.

Figure 5-4-14 Areas Where Liquefaction Occurred in the Northern Part of Tokyo Bay

Source: Ministry of Land, Infrastructure, Transport and Tourism, "Guidance for Countermeasures Against Liquefaction in Urban Areas [Data]" (February 2016)

Figure 5-4-15 Terrain Types and Ground Classification of Liquefaction Caused by the Great East Japan Earthquake and the Areas of Occurrence

分類	主に発生した地区
海岸の埋立地	東京湾岸や太平洋沿い
平野の川、池などの埋立地	関東や東北の河川沿いなど
丘陵の造成宅地内の池などの埋立地	宮城・福島・茨城内の造成地
砂鉄や砂利を採取するために掘削し埋め戻した箇所	旭市、神栖市、鹿嶋市
河川堤防の基礎地盤や堤体	関東（特に利根川沿い）や東北の河川
埋設管敷設のために掘削	東北や関東の各地

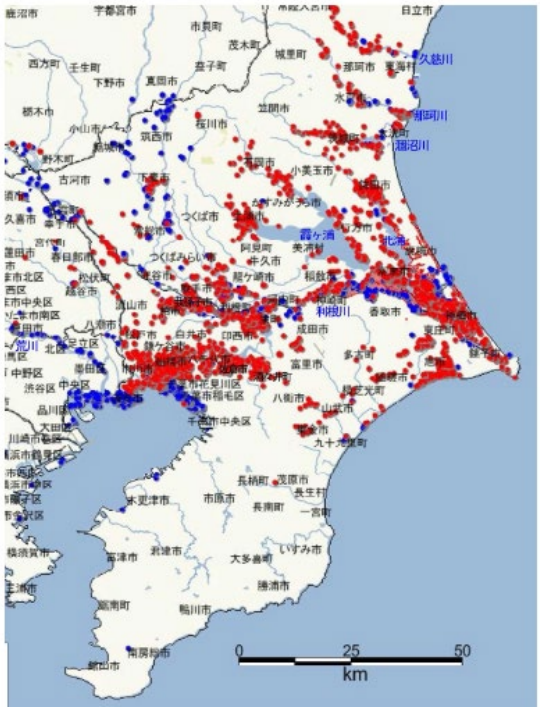
Source: Ministry of Land, Infrastructure, Transport and Tourism, "Guidance for Countermeasures Against Liquefaction in Urban Areas [Data]" (February 2016)

Figure 5-4-16　Comparison of Conventional Liquefaction Countermeasures vs. Liquefaction Countermeasures in Areas Affected by the Great East Japan Earthquake

	従来の地震による液状化被害		東日本大震災による液状化被害	
	宅地	公共施設	宅地	公共施設
被害状況	点　在	局所的	一　団	広範囲
施設復旧方針	個人負担による傾斜の個別復旧	災害復旧事業による個別復旧	個人負担による傾斜の個別復旧	災害復旧事業による個別復旧
再液状化対策	個人負担により任意で実施	重要な構造物に対して個別に実施	一団の宅地について道路等の公共施設と一体的な対策を実施	

Source:　Ministry of Land, Infrastructure, Transport and Tourism, "Guidance for Countermeasures Against Liquefaction in Urban Areas [Main Text]" (March 2014)
https: www.city.okazaki.lg.jp/1550/1567/1642/p021020_d/fil/H260331gaidansu_1.pdf (browsed July 31, 2023)

Figure 5-4-17　Areas Where Liquefaction Occurred in the Kanto Region



※●（公社）地盤工学会（2011.8）
※●若松・先名による追加地点（2014.2.28）

Figure 5-4-18　Number of Residential Lots Damaged by Liquefaction

液状化による住家被害	
岩手県	3件
宮城県	140件
福島県	1,043件
茨城県	6,751件
群馬県	1件
埼玉県	175件
千葉県	18,674件
東京都	56件
神奈川県	71件
合計	26,914件 (9都県80市区町村)

※国土交通省都市局調べ（平成 23 年 9 月 27 日）
※上記被害件数には、津波によって家屋が流出した場合等については計上されていない

Source:　Ministry of Land, Infrastructure, Transport and Tourism, "Guidance for Countermeasures Against Liquefaction in Urban Areas [Main Text]" (June 2019)
https://www.mlit.go.jp/common/001123039.pdf (browsed July 31, 2023)

(3) Implementing liquefaction countermeasures

1) Overview

In Japan, liquefaction damage was first brought to attention following the Niigata Earthquake in June 1964. In more recent years, liquefaction damage occurred during the Great Hanshin-Awaji Earthquake in January 1995 and the Niigata Chuetsu Earthquake in October 2004. These damages occurred locally in reclaimed land and other such areas and prompted the strengthening of technical standards, such as road and bridge specifications and guidelines for the design of building foundations. Since then, liquefaction measures have been incorporated into the design of critical seismic structures, such as emergency transport routes and large-scale buildings. However, for local roads and other such infrastructure, only rapid restoration measures following a disaster, such as leveling uneven road surfaces, have been deemed suitable from a cost-effectiveness perspective. Countermeasures for the liquefaction of personal assets such as residential land were generally required to be taken by individual owners and businesses. However, as a result of the Great East Japan Earthquake, liquefaction occurred over a wide area, mainly in the Kanto region, such as the Tokyo Bay area and the downstream area of the Tone River, causing extensive damage in various locations. There had never been a case of residential land damage this extensive caused by liquefaction anywhere on the globe. To restore a safe and secure living environment in the disaster-affected areas, not only did damaged buildings and roads need to be restored, but the causes and processes of liquefaction also needed to be clarified in order to prevent repeat disasters.

The Ministry of Land, Infrastructure, Transport and Tourism has no accumulated technical knowledge regarding liquefaction countermeasures in established urban areas. Furthermore, as liquefaction causes differ based on ground characteristics, selecting the appropriate countermeasures requires ground surveys, analysis, and experimental validation, along with guidance from expert investigative commissions. For these reasons, the "Technical Guideline for Evaluation of Liquefaction Damage Potential on Housing Sites" (March 2013) and "Guidance for Countermeasures Against Liquefaction in Urban Areas" (March 2014) were developed in response to concerns about ground liquefaction during moderate earthquakes, outlining the basic principles and key considerations for assessing the risk of liquefaction damage to single-family residential areas.

The purpose of the guidance in particular was to compile the latest knowledge gained from disaster-affected areas, with the aim of not only supporting reconstruction following the Great East Japan Earthquake but also aiding in the quick reconstruction of urban areas in the event of liquefaction damage caused by potential major earthquakes in the future. It explains the points that need to be investigated immediately after a disaster and the process of evaluating liquefaction countermeasures in accordance with a timeline, making its content applicable for practical use.

In general, the term “liquefaction countermeasure” can refer to, for example, the act of restoring a house damaged by liquefaction to its original condition without hindering its use in the case of housing damage. It can also refer to measures to suppress the damage caused by ground liquefaction during future earthquakes. These two concepts are often confused. Typically, tilt correction falls under the former concept (recovery measures), while measures to mitigate secondary liquefaction damage fall under the latter (preventive or additional measures). These classifications are within the narrower definitions of “liquefaction countermeasures” and “reconstruction measures.” As such, it is important to note that the guidance uses the latter definition of the term “liquefaction countermeasures.” Following the Great East Japan Earthquake, for example, when responding to consultations from disaster victims whose houses were damaged, it was not clear whether the “liquefaction countermeasures” that the victim referred to included both tilt correction of the house and the suppression of future liquefaction damage. Conversely, there were cases in which government officials explained “liquefaction countermeasures” in reference to the suppression of future liquefaction damage, but the victim misunderstood the term to include tilt correction for the house. In this way, there were instances in which communication could not be achieved due to mismatched understandings of what “liquefaction countermeasures” referred to. There were cases in which “prompt action necessary for an asset damaged due to liquefaction” was expressed in a simplified sentence like “prompt liquefaction countermeasures necessary for an asset.” The former emphasizes a need to restore the asset quickly so that it can be used again. However, when the term “liquefaction countermeasures” is used as in the latter case, it is usually interpreted to mean that measures must be taken promptly to prevent repeat liquefaction damage to the asset in the event of a future earthquake, resulting in confusion. When studying restoration and reconstruction measures for urban areas affected by liquefaction and supporting victims in rebuilding their livelihoods, it is necessary to first promote their awareness by carefully differentiating between the concepts and issues mentioned

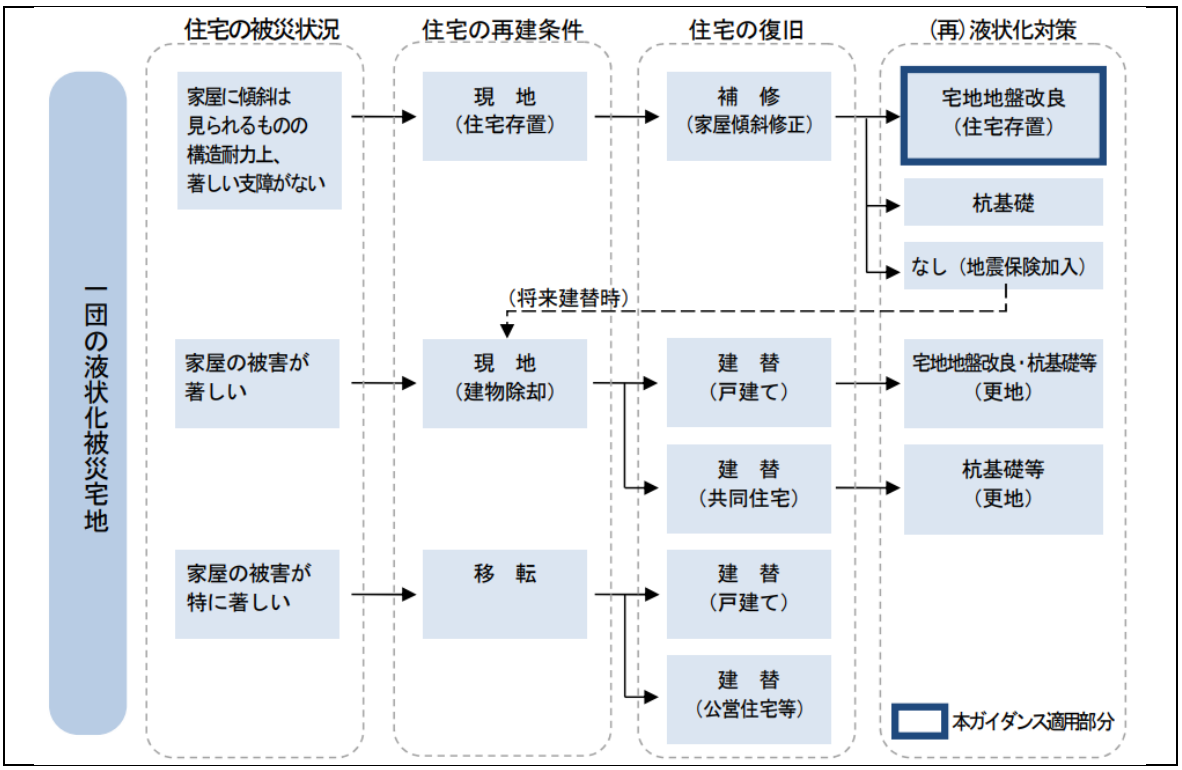
above. It is advisable to use this guidance in order to make appropriate decisions on the necessary measures according to the issues.

In addition, the implementation of preventive measures requires careful efforts, including more thorough studies.

The liquefaction countermeasures for residential land that are covered in the guidance are to be applied to areas that satisfy all of the following conditions, provided that the approach of implementing countermeasures on a district-by-district basis, integrating public infrastructure such as roads with residential land, is considered more efficient and effective than implementing countermeasures locally on a site-by-site basis.

① Topographical conditions, land development history, liquefaction maps, and other factors indicate that the (repeat) liquefaction of residential ground due to a moderate or larger earthquake is a cause for concern.
② In the event of an earthquake, roads and other public infrastructure are expected to suffer liquefaction damage, and runoff of sand and other materials from residential land may also have an impact. A failure to implement integrated countermeasures would hinder prompt restoration following the disaster, significantly impacting people's lives.
③ The target location is a consolidated area of land with both residential properties and public infrastructure, and therefore, implementing integrated countermeasures would be more efficient.
④ The extent of the housing damage does not necessitate rebuilding, and therefore, countermeasures need to be implemented with the houses left in place.

Figure 5-4-19 Scope of this Guidance in the Context of Countermeasures Against (Repeat) Liquefaction for Residential Land Affected by Liquefaction Damage



Source: Ministry of Land, Infrastructure, Transport and Tourism, "Guidance for Countermeasures Against Liquefaction in Urban Areas" (June 2019)
https://www.mlit.go.jp/toshi/content/001470556.pdf (browsed July 31, 2023)

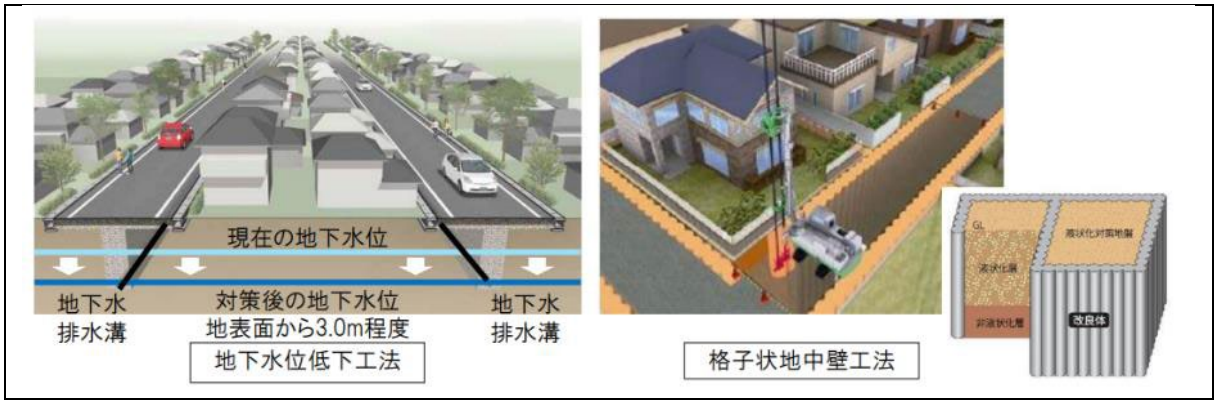
Urban liquefaction countermeasure projects were carried out in Ibaraki Prefecture (5 districts), Chiba Prefecture (4 districts), and Saitama Prefecture (1 district). Construction for these measures was completed in all planned districts by the end of 2020.

Figure 5-4-20　Areas Covered by Urban Liquefaction Countermeasure Projects (Reconstruction Grants)

都道府県	市町村	地区数
茨城県	潮来市	1 地区
	神栖市	1 地区
	鹿嶋市	3 地区
千葉県	千葉市	2 地区
	香取市	1 地区
	浦安市	1 地区
埼玉県	久喜市	1 地区
計		10 地区

Source:　Ministry of Land, Infrastructure, Transport and Tourism, “Urban Liquefaction Countermeasure Projects (Reconstruction Grants)”

Figure 5-4-21　Construction Methods for Urban Liquefaction Countermeasure Projects

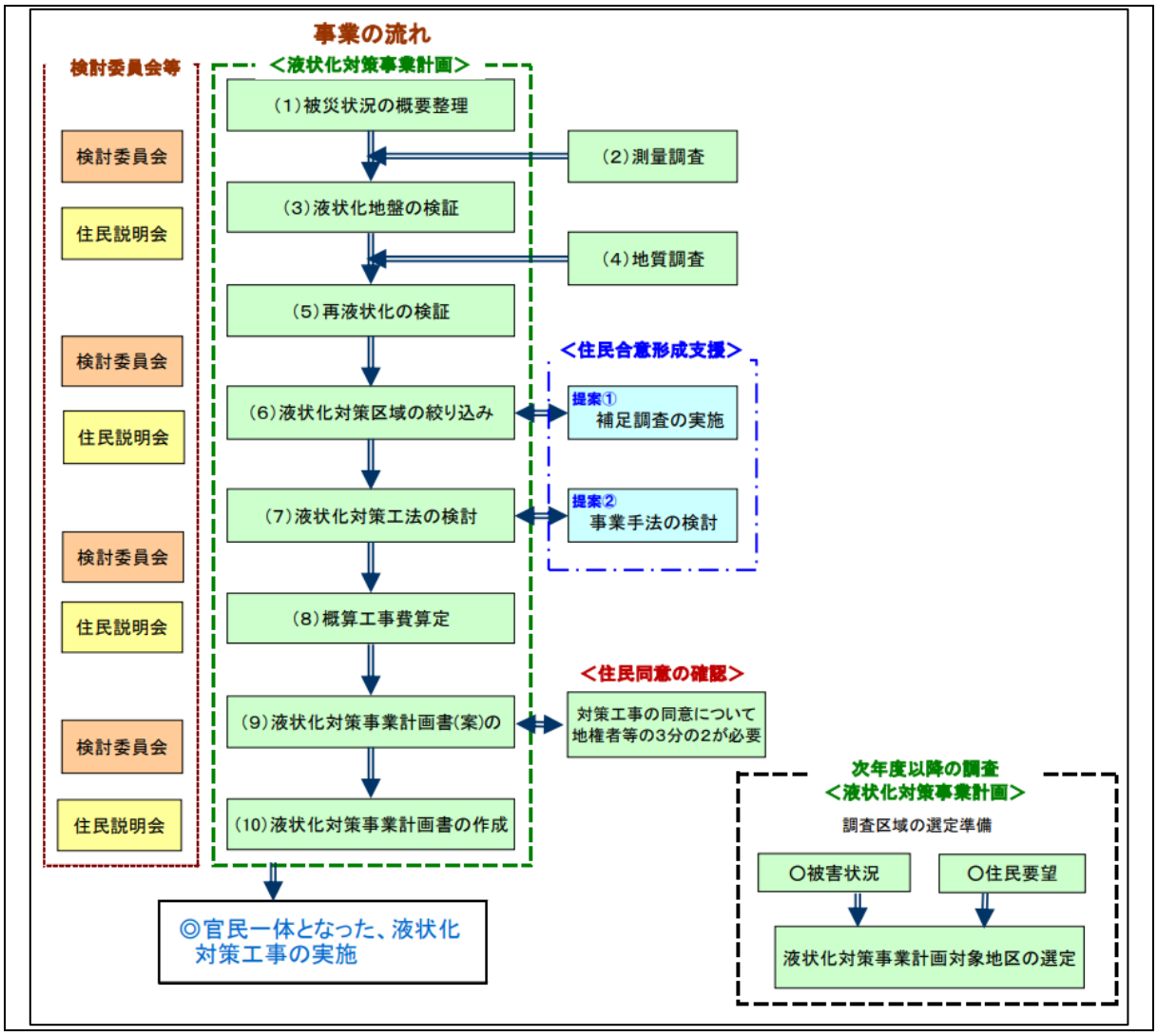


Source:　Ministry of Land, Infrastructure, Transport and Tourism, “Guidance for Countermeasures Against Liquefaction in Urban Areas [Main Text]” (June 2019)
https://www.mlit.go.jp/common/001123039.pdf (browsed July 31, 2023)

2) Liquefaction Countermeasure Project in Kamisu City, Ibaraki Prefecture

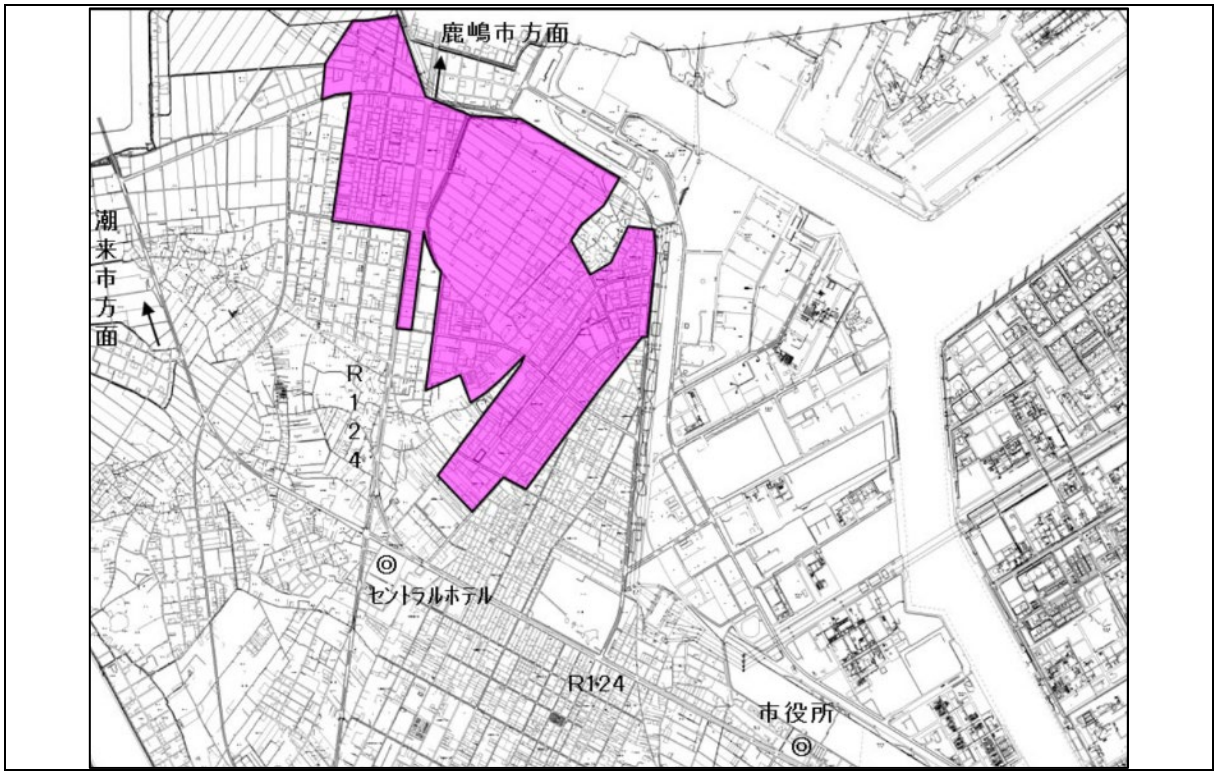
In Kamisu City, Ibaraki Prefecture, a liquefaction countermeasure project has been carried out according to the following procedure.

Figure 5-4-22 Procedure for the Liquefaction Countermeasure Project in Kamisu City, Ibaraki Prefecture



Source: Kamisu City, "Urban Liquefaction Countermeasure Project Utilizing the Great East Japan Earthquake Reconstruction Grant"

Figure 5-4-23 Survey Area Location Map for the Liquefaction Countermeasure Project in Kamisu City, Ibaraki Prefecture



Source: Kamisu City, "Urban Liquefaction Countermeasure Project Utilizing the Great East Japan Earthquake Reconstruction Grant"

3) Liquefaction Countermeasure Projects in Chiba City, Chiba Prefecture

In order to mitigate future liquefaction damage in Chiba City, urban liquefaction countermeasure projects were carried out utilizing the Reconstruction Grant system established by the national government. These projects were implemented on public infrastructure and residential land in an integrated manner. In the Isobe 4-Chome and 3-Chome districts, the projects were implemented using the groundwater lowering method.

For the Isobe 4-Chome district, the effectiveness in terms of liquefaction damage suppression was verified at the 14th meeting of the Chiba City Liquefaction Countermeasure Promotion Committee held on August 3, 2020, and the project was thus completed.

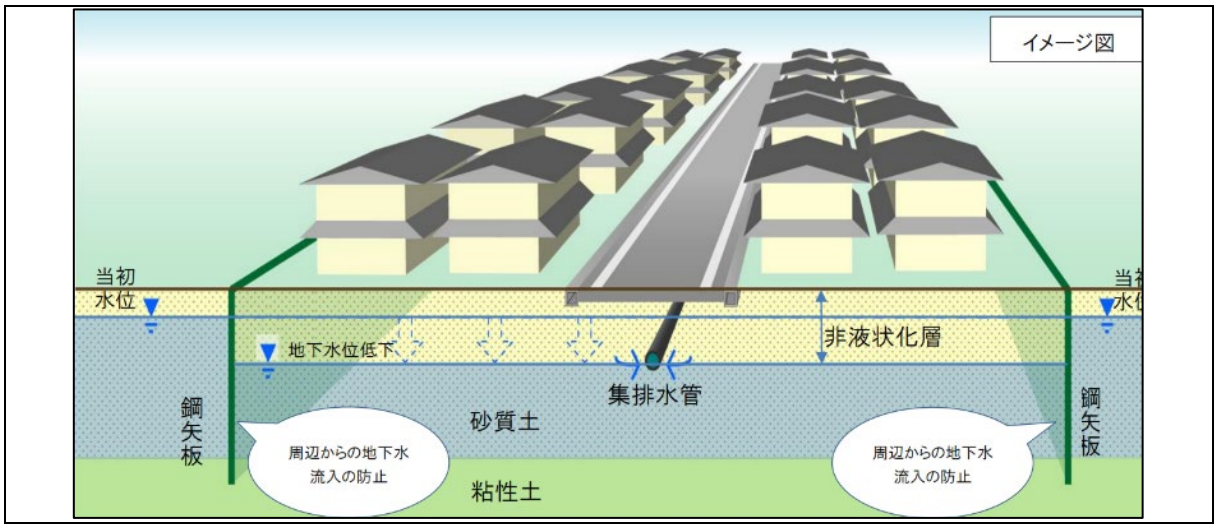
For the Isobe 3-Chome district, the effectiveness in terms of liquefaction damage suppression and reduction was verified at the 15th meeting of the Chiba City Liquefaction Countermeasure Promotion Committee held on March 5, 2021, and the project was thus completed.

The groundwater lowering method reduces the possibility of liquefaction and suppresses liquefaction damage by forcibly lowering the groundwater level of residential areas and roads, creating a non-liquefaction layer spanning the first few meters from the ground surface.

In Chiba City, the following measures have been devised to suppress liquefaction damage.

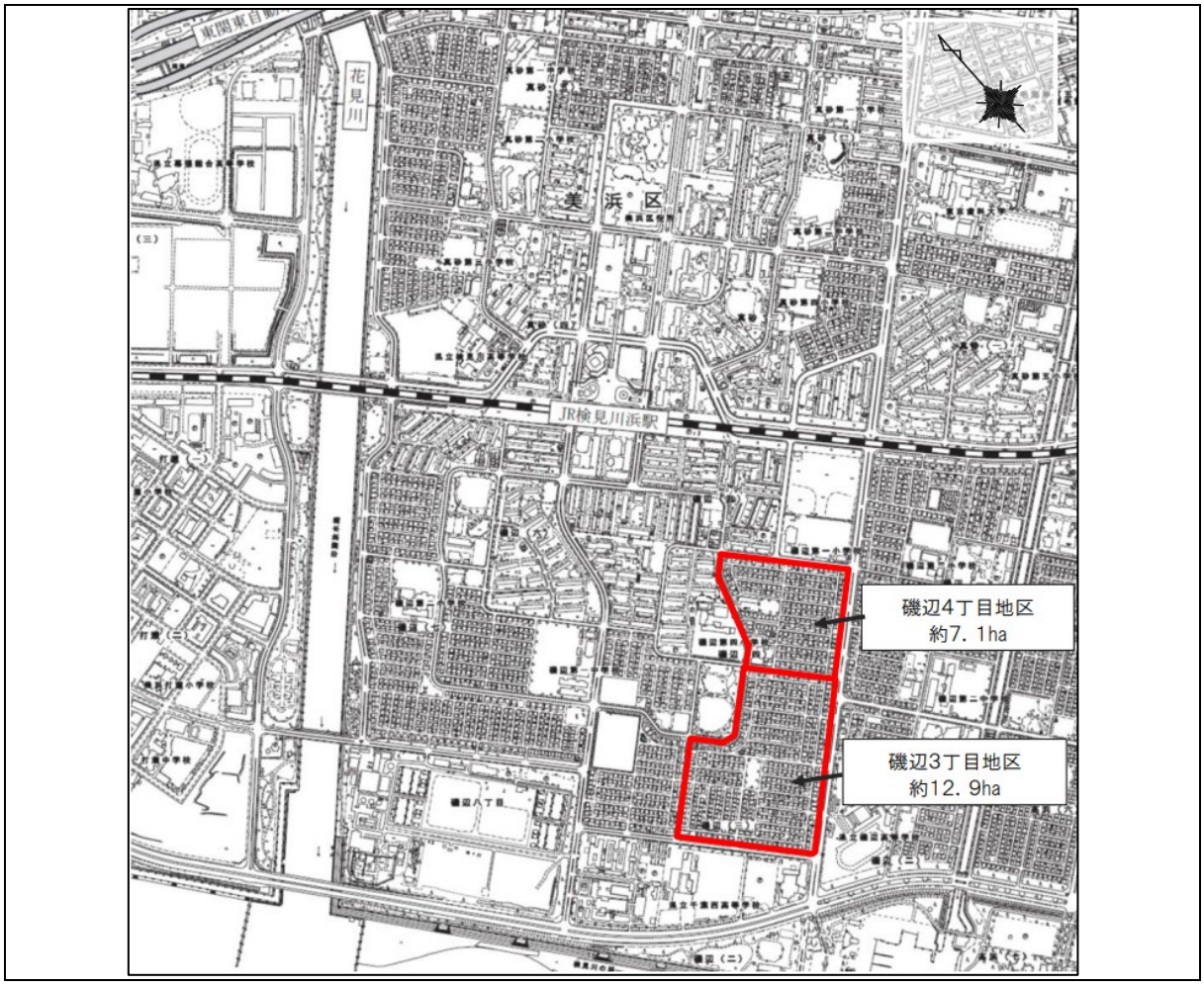
① Steel sheet piles have been placed around the perimeter of the area to block the flow of groundwater into the area.
② Groundwater is collected in drainage pipes laid within public land, such as under roads.
③ Underground water is pumped up using submersible pumps installed downstream and drained into the Kusano waterway.
④ The lowered groundwater level widens the non-liquefaction layer to mitigate liquefaction damage.

Figure 5-4-24 Conceptual Image Illustrating the Groundwater Lowering Method



Source: Chiba City, "Urban Liquefaction Countermeasure Projects"
https://www.city.chiba.jp/toshi/toshi/anzen/ekijoukataisaku.html (browsed July 31, 2023)

Figure 5-4-25 Implementation Area Location Map for the Liquefaction Countermeasure Projects in Chiba City, Chiba Prefecture



Source: Chiba City, "Urban Liquefaction Countermeasure Projects"
https://www.city.chiba.jp/toshi/toshi/anzen/ekijoukataisaku.html (browsed July 31, 2023)

Figure 5-4-26 Target Facilities of Liquefaction Countermeasure Projects in Chiba City, Chiba Prefecture

施設名称	数量	Legend
集排水管（ポリプロピレン）	6，045m	
圧送管(HIVP)・自然流下管（VP）	1，549m	
遮水壁（鋼矢板及び恒久グラウト）	2，407m	
人孔	142箇所	
水中ポンプ	10基	P（各2基）
制御盤・電源	5基	
ケーブル・配管(FRP)	375m	
観測機器	25基	

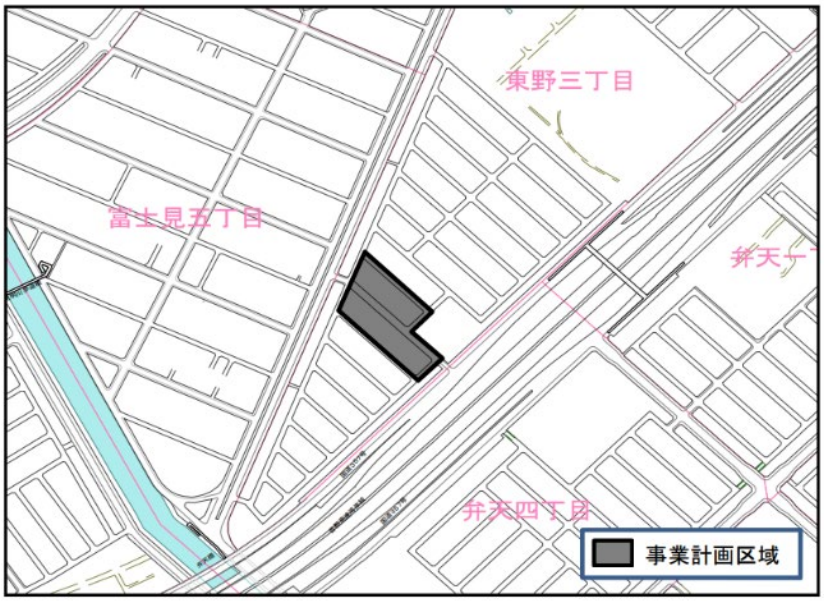
Source: Chiba City, “Urban Liquefaction Countermeasure Projects”
https://www.city.chiba.jp/toshi/toshi/anzen/ekijoukataisaku.html (browsed July 31, 2023)

4) Liquefaction Countermeasure Project in Urayasu City, Chiba Prefecture

In Urayasu City, Chiba Prefecture, the plan for the urban liquefaction countermeasure project for the Higashino 3-Chome district has been finalized as follows.

Figure 5-4-27 Urban Liquefaction Countermeasure Project Plan for the Higashino 3-Chome District in Urayasu City, Chiba Prefecture

名　　称	東野三丁目地区市街地液状化対策事業計画
区　　域	東野三丁目の一部
面　　積	約 7,950 ㎡
期　　間	平成 28 年 12 月 22 日～平成 30 年 3 月 25 日
工事に係る費用の総額	909 百万円
分担金の総額	64 百万円
事業内容	道路等の公共施設と宅地を一体的に液状化対策することで、効果的かつ効率的に面的な液状化対策を行うことが可能となり、事業地区内の宅地に加えて街区内の道路や下水道などの公共施設の液状化被害を軽減する。 施工方法は、地質調査の結果や技術開発の状況などから、「格子状地盤改良工法」を選定した。
事業目標	1．東日本大震災の本震の浦安市における地震動（対策対象地震動）に対して、液状化による顕著な被害が生じない（原則として地盤全層にわたるような液状化被害が発生しない）こと 2．レベル２地震動（直下型地震による大きな地震動）において、地震後も対策対象地震動に対する、格子状改良体としての効果が保持されること



Source: Urayasu City, "Urban Liquefaction Countermeasure Project Plan"
https://www.city.urayasu.lg.jp/todokede/shinsai/1017062.html (browsed July 31, 2023)