THE HIGHWAY SNOWSTORM COUNTERMEASURE MANUAL

(Revised Edition 2011)

- Abridged Edition -

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Civil Engineering Research Institute for Cold Region, Public Works Research Institute, Incorporated Administrative Agency

Contents

Use of the Abridged Edition of The Highway Snowstorm Countermeasure Manual

The Abridged Edition

This is a synopsis of the *Highway Snowstorm Countermeasure Manual* revised in May 2011 (hereinafter: "the Manual"). The Manual explains basic ideas and describes technical data and general technological standards related to snow-control facilities used against snowdrifts and blowing-snow-induced visibility hindrance. The revised Manual includes the new volume "Other Blowing-snow Control Facilities" in addition to the existing volumes: "General Guide," "Snowbreak Woods" and "Snow Fences."

This abridged edition was prepared by condensing the original Manual of about 500 pages, so that the overall picture could be more easily understood and the Manual could become widely used in designing and implementing snow control measures.

Organization of the Abridged Edition

The abridged edition follows the four volumes of the full Manual, but for space reasons, the abridged edition includes only main points taken from all the volumes, and the figures and tables necessary to understand that text. Figures, tables and equations use the same numbers as in the full Manual, for easy reference, which means that these numbers are not always consecutive.

References are omitted for space. Please refer to the original Manual for a bibliography.

Volume 1: General Guide

This volume describes the general ideas for blowing-snow control and certain criteria regarding countermeasures, including the selection of blowing-snow control facilities, the procedure for establishing a plan for blowing-snow control measures, and the evaluation of risk.

Volume 2: Snowbreak Woods

This volume describes the technological standards for the planning and growth management of highway snowbreak woods.

Volume 3: Snow Fences

This volume describes the technological standards for the planning, design and maintenance of snow fences.

Volume 4: Other Blowing-snow Control Facilities

This volume describes guidelines for the planning, design, installation and maintenance of other blowing-snow control facilities, such as delineators.

For Use in Planning and Designing

Detailed conditions and the bibliography are left out from the abridged edition. For planning and designing, please refer to the full Manual.

Volume 1: General Guide

Chapter 1: General Provisions

1. Objective

To streamline operations, unify design concepts and enrich design content, this section presents technical criteria and information and explains the basic concepts for planning, designing, constructing and maintaining blowing-snow control facilities to counter snowdrifts and snowstorm-induced poor visibility.

2. Scope of Application

This section is intended for blowing-snow control facilities on highways whose development or improvement is the responsibility of the Hokkaido Development Bureau.

Chapter 2: Basic Concept of Blowing-snow Control Measures

1. Necessity of Blowing-snow Control Measures

Measures against snowdrifts and snowstorm-induced poor visibility are high priorities among efforts to ensure traffic safety on winter roads.

2. Understanding of Blowing Snow and Disasters Caused by Blowing Snow

When reviewing blowing-snow control measures for highways, it is necessary to properly understand the characteristics of snowstorm phenomena, particularly those of snowdrifts and poor visibility, and to properly understand factors contributing to snowstorm disasters.

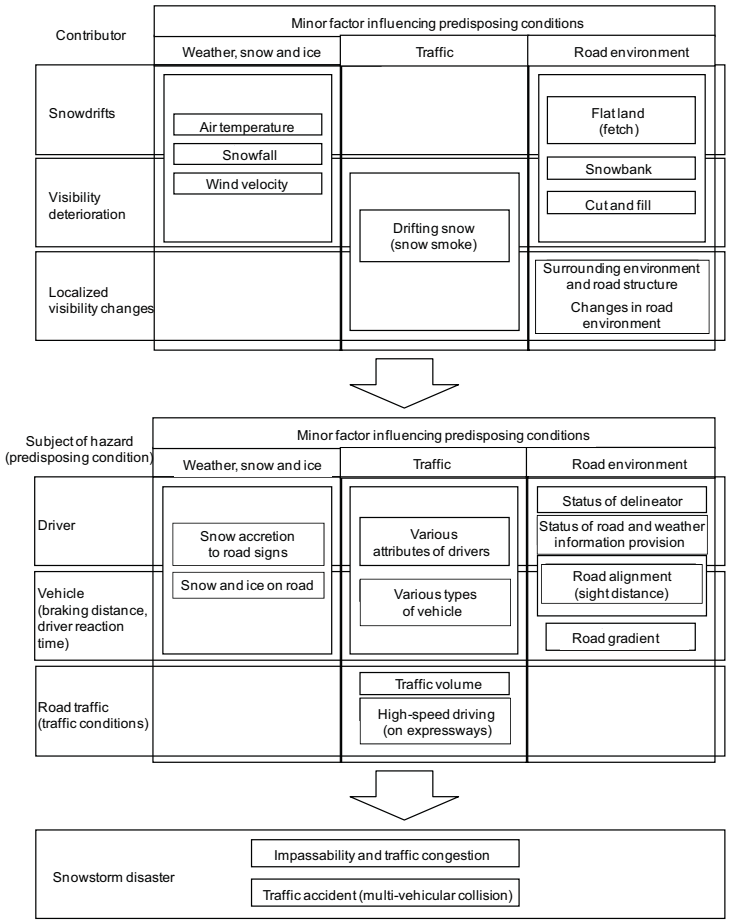


Figure 1-2-3: Factors Contributing to Snowstorm Disasters

3. Objectives and Effectiveness of Blowing-snow Control Measures

Blowing-snow control measures aim to improve reliability, safety, economic efficiency, convenience and ease of driving by preventing snowdrifts or by mitigating visibility hindrance.

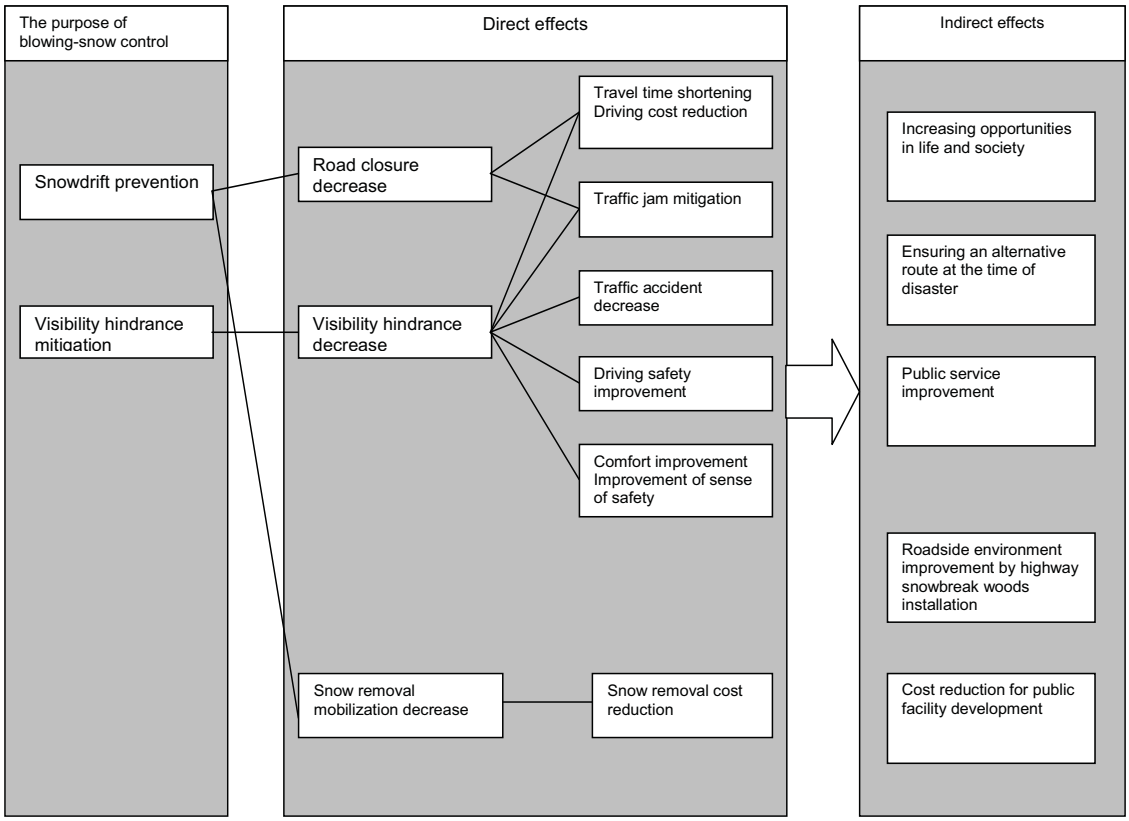


Figure 1-2-4: Objectives and Effectiveness of Blowing-snow Control Measures (created based on *Guidelines for the Evaluation of Road Investment Projects*)

4. Concept for Blowing-Snow Control Measures

4-1 Concept for basic guidelines on blowing-snow control measures

In formulating basic guidelines for blowing-snow control measures for a route, comprehensive examination according to the flow shown in Figure 1-2-5 should be made, focusing on the following.

(1) The necessity of blowing-snow control measures on the selected route

(2) The degree of snowstorm danger on the selected route

(3) The concept of blowing-snow control measures based on route location and route priority

(4) The outline of investigation on blowing-snow control measures

(1) The necessity of blowing-snow control measures on the selected route

For weather conditions in areas where the necessity of blowing-snow control facilities is to be examined, use the criteria below as a guide. When the route meets the criteria, investigate whether any blowing-snow control measures are required.

(1) Snowstorm-induced poor visibility occurs more than 10 days a year, according to the frequency distribution map of snowstorm-induced poor visibility.

(2) Maximum amount of snow accumulated in snowdrifts is $20m^3/m$ or more.

(3) There have been more than 10 road closures in the past 10 years.

(4) Traffic accidents have frequently occurred during snowstorms.

(5) Snowdrifts have obstructed snow removal operations.

(2) The degree of snowstorm danger on the selected route

Identify the degree of snowstorm danger relative to other areas and other routes by doing schematic assessment of the degree of snowstorm danger based on records of poor visibility and of existing meteorological data.

(3) The concept of blowing-snow control measures based on route location and route priority

Examine the concept of blowing-snow control measures on the selected route by clarifying the route location and route priority, and formulate basic guidelines for blowing-snow control measures. The guidelines are helpful for route determination during schematic design.

(4) The outline of investigation on blowing-snow control measures

Comprehensively consider the concept of blowing-snow control measures, planned road projects and weather conditions including blowing snow around the route that was confirmed by available materials; plan and draw up a schedule for the investigation of blowing-snow control measures.

4-2 Introduction of new technologies

Before examining and introducing blowing-snow control measures, check the latest technological trends and use new technologies as necessary, as well as using technologies for blowing-snow control measures described in the Manual.

5. Types and Concept of Blowing-snow Control Measures

5-1 Types of blowing-snow control measures

Blowing-snow control measures for roads are divided into the six categories below.
In the Manual, (2) road structures, (3) ancillary facilities and (4) large-scale structures are referred to as blowing-snow control facilities. The Manual describes design and installation criteria and other important information regarding them.

(1) Route planning (route identification considering snowstorm, avoidance of snowstorm-prone areas, use of natural woods, etc.)
(2) Road structures (drift-free cuts or drift-control fills)
(3) Ancillary facilities (highway snowbreak woods, snow fences, delineators, etc.)
(4) Large-scale structures (snow shelters)
(5) Maintenance (snow plowing and hauling, traffic control during snowstorm, etc.)
(6) Information management (monitoring, information provision, etc.)

5-2 Outline of blowing-snow control facilities

Blowing-snow control facilities (road structures, ancillary facilities and large-scale structures) are categorized by purpose, such as snowdrift control, poor visibility control and visual guidance.

Table 1-2-2: Categories of Blowing-snow Control Facilities

Category	Type	Countermeasure	Major purposes
Road structures	Drift-free cut	Drift-free cut	Snowdrift countermeasure
	Fill	Drift-control fill	Snowdrift countermeasure
		Fill with a gentle slope	Snowdrift and poor visibility countermeasure
Ancillary facilities	Highway snowbreak woods	Standard-width woods	Snowdrift and poor visibility countermeasure
		Narrow-band woods	Poor visibility countermeasure
	Snow fence	Traditional collector snow fence	Snowdrift countermeasure
		Collector snow fence	Snowdrift and poor visibility countermeasure
		Blower snow fence	Poor visibility countermeasure
		Solid barrier	Snowdrift and poor visibility countermeasure
	Delineator	Fixed post delineator	Guidance of the road width for snow removal operations, and visual guidance
		Snow pole	Guidance of the road width for snow removal operations, and visual guidance
		Delineator	Visual guidance
		Visual guidance tree	Visual guidance
		Road lighting	Traffic safety and visual guidance

5-2-1 Road structures for blowing-snow control

"Road structure for blowing-snow control" refers to modifications of the slope gradient/length by means of fills/cuts. They work by reducing snowdrifts on roads or by reducing snow particles passing at the height of the driver’s sight line, thus mitigating the visibility hindrance.

5-2-2 Highway snowbreak woods

Snowbreak woods are snow-control facilities designed to mitigate poor visibility on highways. They trap suspending/drifting snow particles in and around the woods zone to prevent snowdrifts from forming on roads, and they improve visibility on roads.

5-2-3 Snow fences

Snow fences are a snow-control facilities designed to prevent snowdrifts and improve poor visibility on roads. It captures snow or blows it away by controlling wind flow and wind velocity windward and leeward of the fence. The fences are equipped with steel snowbreak fins.

5-2-4 Delineators

Delineators are road blowing-snow control facilities that provide visual guidance to the driver and secure safety and efficiency of snow plowing/hauling by improving the visibility of the road alignment and roadsides.

5-2-5 Large-scale structures

Large-scale blowing-snow control facilities are snow shelters. The snow shelter is a structure that shelters the road completely from blowing snow, preventing snowdrifts and improving poor visibility in sections where blowing snow is severe.

5-2-6 Points bear to mind in selecting blowing-snow control facilities

For determining blowing-snow control facilities, it is necessary to comprehensively examine the following:

(1) Safety
(2) Economic efficiency
(3) Conservation of the natural environment
(4) Constructability
(5) Durability
(6) Ease of maintenance and repair
(7) Harmony with landscape

Chapter 3: Procedure for Formulating a Snow-control Facility Installation Plan, and Investigation of the Control Measures

1. Procedure for Formulating a Snow-control Facility Installation Plan and for Determining the Type of Investigation

Blowing-snow control measures for roads are examined at phases such as planning, designing, construction and post-installation. It is necessary to investigate and examine appropriate blowing-snow control measures at each phase of a road project.
After installing blowing-snow control facilities, it is necessary to continuously verify their performance and to make necessary improvements for enhancement of blowing-snow control measures.

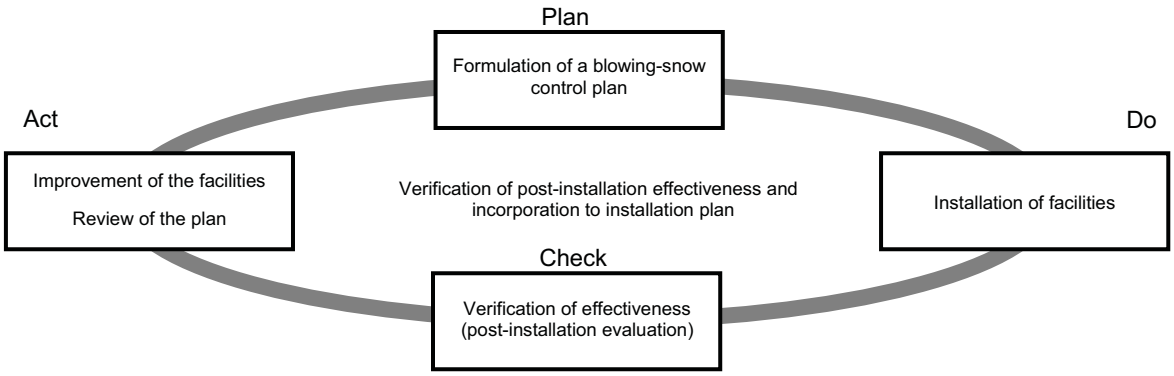


Figure 1-3-1: Flow of Blowing-snow Control Measures

1-1 Blowing-snow control plan for new routes

In formulating a blowing-snow control plan for a new route, necessary items for the design of route planning, investigation and design, construction, and maintenance at each stage should be clarified. Proper investigations should be conducted at each phase.

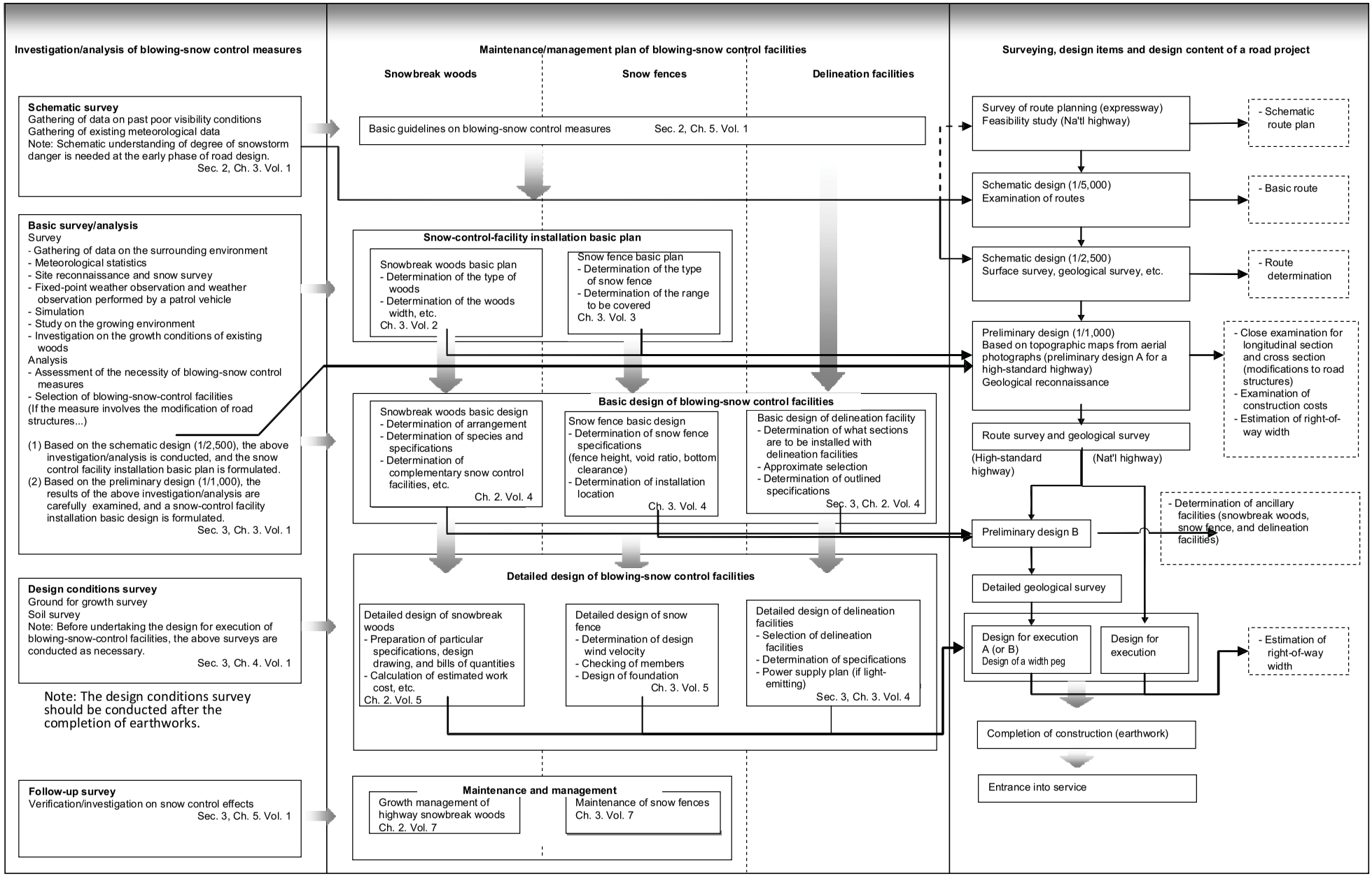


Figure 1-3-2: Procedure for Formulating a Snow-control Facility Installation Plan (New Route)

1-2 Snow-control facility installation plan for existing routes

In formulating a blowing-snow control plan for in-service routes, it is important to accurately understand blowing-snow conditions based on field investigations. Efforts should be made to compile and analyze traffic problems or accidents resulting from blowing snow and data from road patrols, so that a blowing-snow control plan can be designed according to the characteristics of the site.

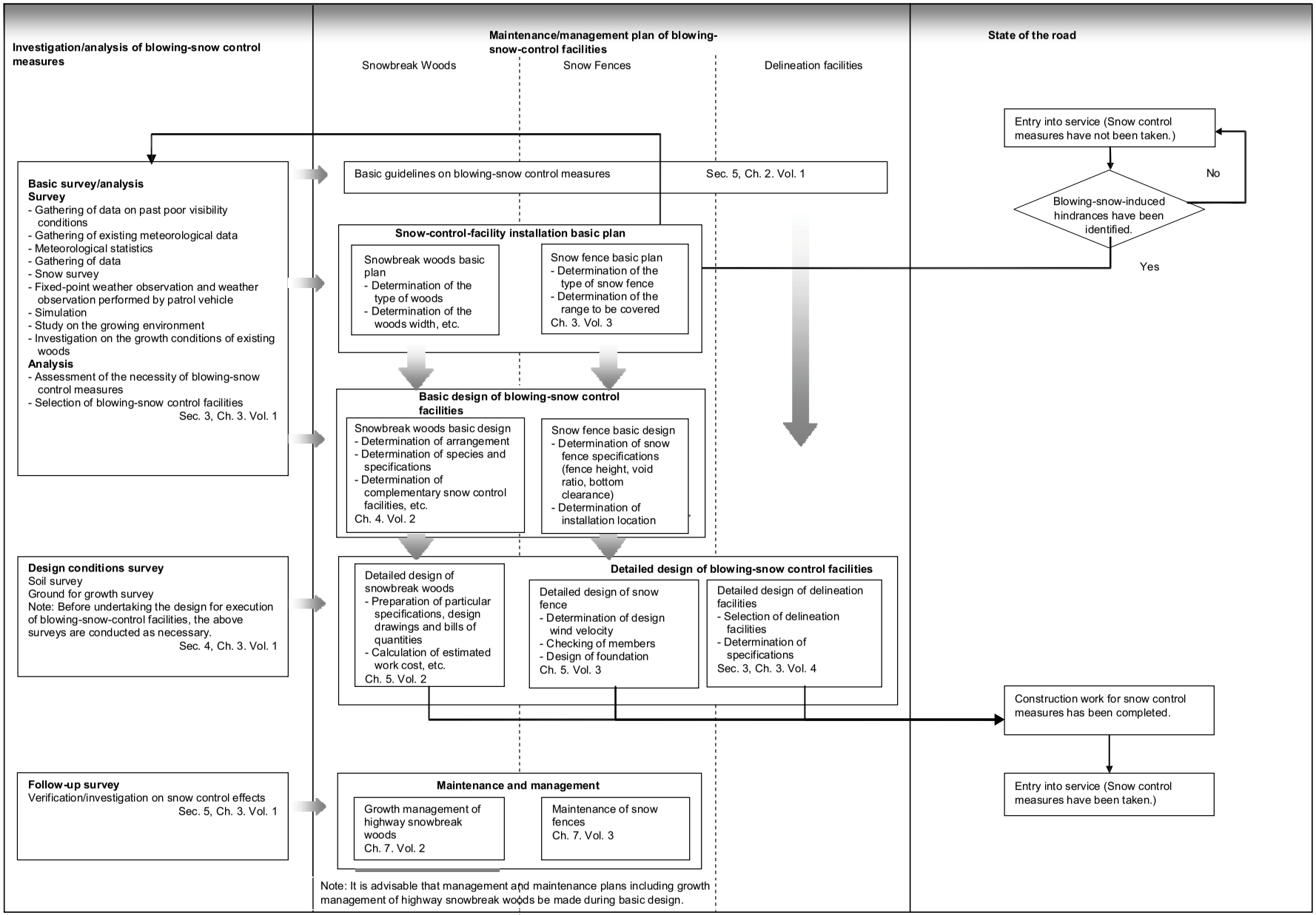


Figure 1-3-3: Procedure for Formulating a Snow-control Facility Installation Plan (Existing Route)

1-3 Type of investigation on blowing-snow control measures

Surveys required for blowing-snow control facilities are divided roughly into four: schematic survey, basic survey/analysis, design conditions survey and follow-up survey. Implement the survey that is relevant to the phase of the plan. The purpose of each survey is as follows:

Schematic survey: Understanding of weather and blowing-snow conditions in winter, comprehensive understanding of the degree of danger from snowstorm, examination of the necessity for blowing-snow control measures, examination of the items of investigation for future blowing-snow control measures , identification of a route that will mitigate blowing-snow hazards.

Basic survey/analysis: Evaluation of the necessity of blowing-snow control facilities, examination of the range covered by blowing-snow control facilities, schematic design of blowing-snow control facilities (selection of blowing-snow control facilities, determination of their specifications and installation locations), and estimation of right-of-way width

Design conditions survey: Determination of design values of blowing-snow control facilities, understanding of ground for growth on sections with highway snowbreak woods, and detailed designing of blowing-snow control facilities

Follow-up survey: Inspection and observation of blowing-snow control facilities, and verification of the effectiveness of such facilities

2. Schematic Survey

2-1 Status and procedure of schematic survey

Schematic survey is undertaken to schematically clarify the winter weather conditions and degree of snowstorm danger in and around the planned route. Its results serve as a basic material for route determination during road schematic designing, etc. Also, it serves as a basic material for formulating the basic guidelines of blowing-snow control measures on the route.

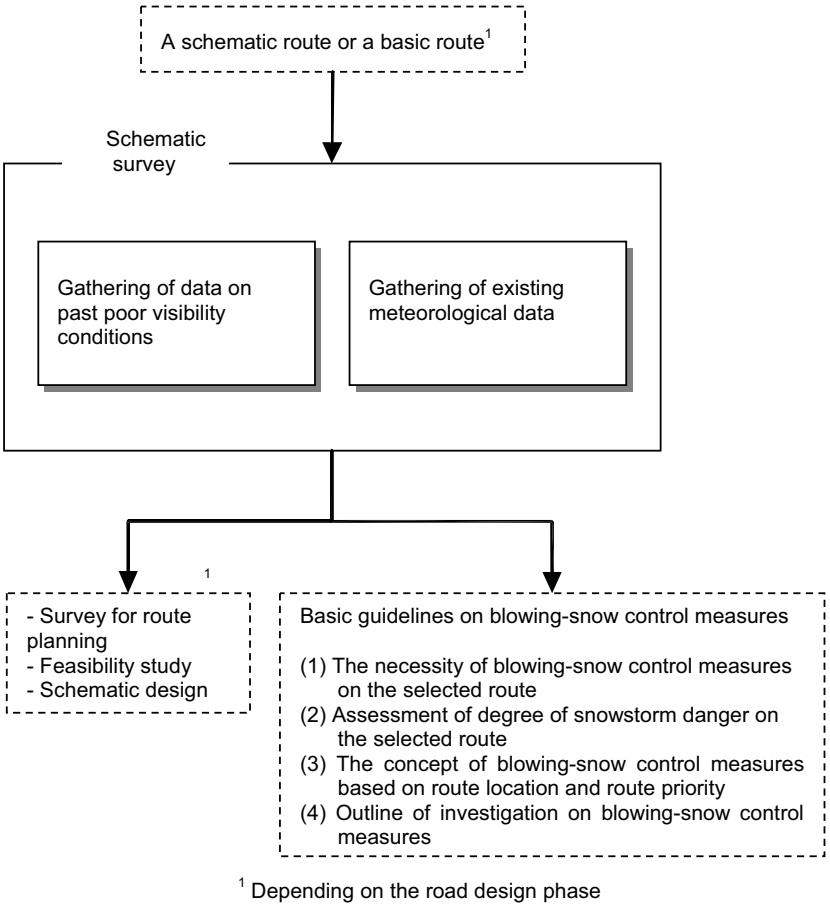


Figure 1-3-4 Procedure of Schematic Survey

2-2 Schematic survey content

A schematic survey is intended primarily to clarify the winter weather conditions and the degree of snowstorm danger. Data on past poor visibility conditions and existing meteorological data covering adjacent routes should be gathered and analyzed to understand the characteristics of blowing snow on and around the route.

3. Basic Survey/Analysis

3-1 Status and procedure of basic survey/analysis

The basic survey/analysis is primarily intended to clarify the weather and blowing-snow conditions in and around a new route or an existing route, to assess the need for control measures, to identify sections where blowing-snow hazards occur, to select blowing-snow control facilities, and to formulate a snow control facility installation basic plan and a blowing-snow control facilities basic plan.

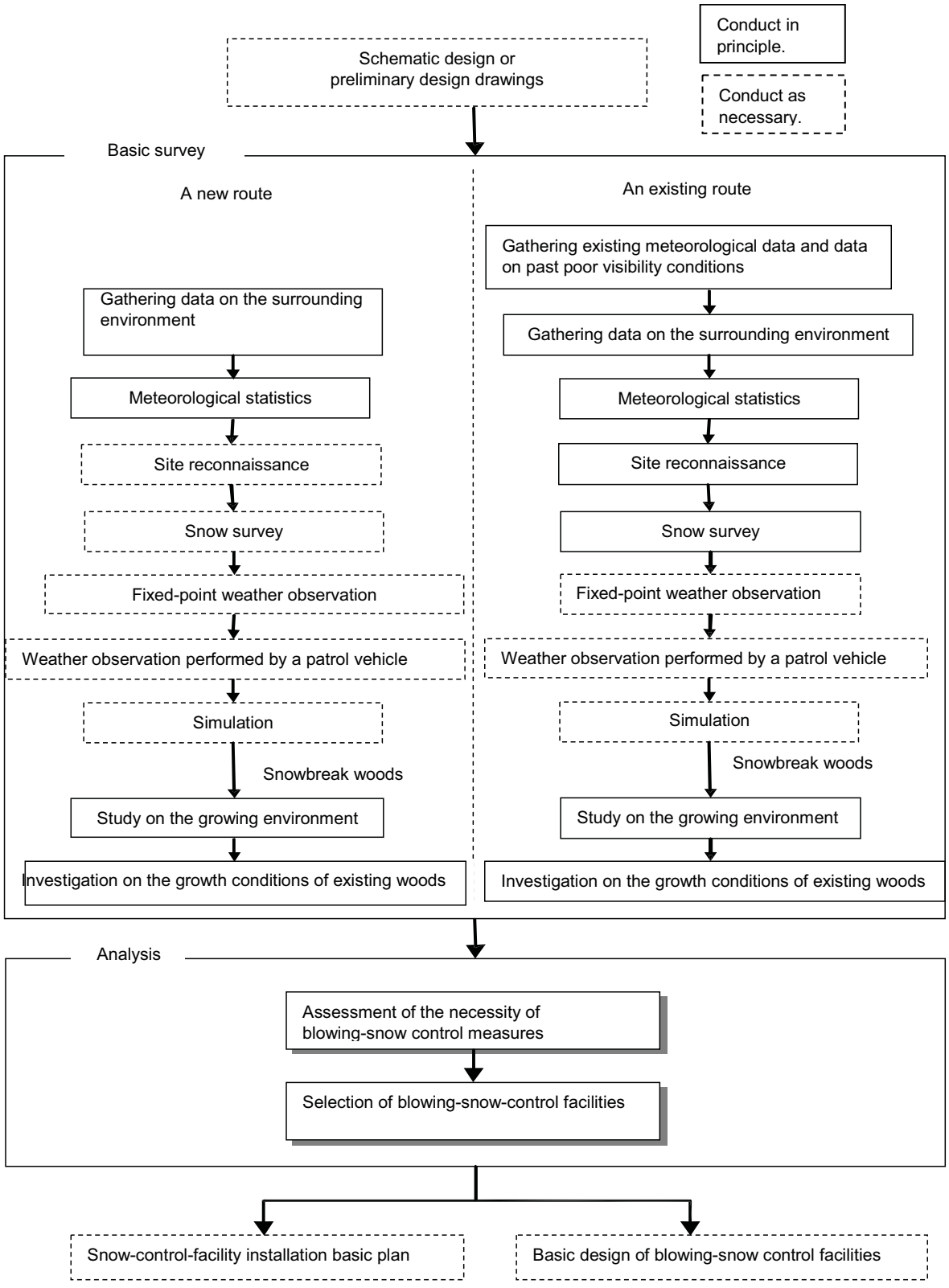


Figure 1-3-5: Procedure of Basic Survey/Analysis

3-2 Basic survey/analysis items

The main items of basic survey/analysis are meteorological statistics including the transport rate of drifting snow, analysis of pertinent documents, snow surveys, fixed-point weather observation, weather observation performed by a patrol vehicle, simulations, studies on the growing environment, and investigation on the growth conditions of existing woods toward planning a snow control facility installation basic plan and a blowing-snow control facilities basic design. Also, based on the results, evaluation of the need for blowing-snow control and selection of blowing-snow control facilities are conducted.

Table 1-3-3: Materials Related to the Examination of Blowing-snow Control Measures

Object		Documents	Investigation item
Environmental condition	Topography	Topographical map Aerial photograph	Flat land, hill, slope in a valley
	Vegetation	Vegetation map Aerial photograph	Presence or absence of vegetation, forest canopy density, tree species (coniferous, broad-leaved), woods zone width, and tree height
	Snowfield length	Topographical map Aerial photograph	Distance from a road to obstacles such as trees
Road structure	Road width	Design drawing and road register map	Number of lanes
	Fill and cut	Design drawing and road register map	Flat land, fill height, cut height, slope shape, half-cut and half-bank
- Existing snow-control facility - Road ancillary facility - Important structure	Blowing-snow control facility	Design drawing and road register map	Presence or absence of snow control facilities, type of works, and snow control effectiveness
	Lighting, tunnel, bridge	Design drawing and road register map	Location and length of each facility
Snowstorm hazard	Road closure	History of road traffic control	Numbers, sections and time of road closures
	Traffic accident	History of road traffic control	Number of traffic accidents in winter (due to visibility hindrance, etc.)
	Hindrance to maintenance	Interview with snow removal operators, etc.	Visibility hindrance, snowdrift conditions and existing blowing-snow control measures

3-3 Necessity of Blowing-snow Control Measures

3-3-1 Basic Guidelines for Assessing the Necessity of Blowing-snow Control Measures

The necessity of blowing snow control measures on roads should be comprehensively assessed by examining the following:

(1) Schematic understanding of degree of snowstorm danger: The degree of danger on the entire route is assessed based on the basic guidelines of blowing-snow control.
(2) Estimation of degree of snowstorm danger: The degree of snowstorm danger is estimated for each site along the route.
(3) Identification of sections requiring blowing-snow control measures: Decision is made with consideration given to the results of Item (2) and to weather observation by patrol vehicles, snow survey, economic efficiency and the like.

3-3-2 Calculation for Degree of Snowstorm Danger

(1) Concept for calculating the degree of snowstorm danger

When calculating the degree of danger on a certain part of the route, evaluation should be made of "snowdrift factors" and "poor visibility factors." Each factor consists of sub-factors contributing to safety/danger. The sub-factors are divided into major factors (weather conditions) and minor factors (the surrounding environment and road structure).

(2) Factors of snowstorm danger assessment

“Snowdrift factors” and “poor visibility factors” are assessed using the sub-factors shown in Table 1-3-7.

Table 1-3-7: Factors in Calculating the Degree of Snowstorm Danger

1) Snowdrift factor

Type		Risk factor	Safety factor
Major factors	Weather conditions	Volume of snow settled at snowdrifts Prevailing wind direction Maximum snow depth	
Minor factors	Surrounding environment	Flat land on the windward side	Woodland or rows of houses
	Road structure	Cut	Fill Roadside snow-piling space

2) Poor visibility factor

Type		Risk factor	Safety factor
Major factors	Weather conditions	Frequent occurrence of blowing snow Prevailing wind direction Snowfall	
Minor factors	Surrounding environment	Area of abrupt topographic change	Roadside trees and houses
	Road structure	High embankment Curve section Tunnel mouth Bridge end section and grade-separated crossing	Presence or absence of median Presence or absence of road lighting

3-3-3 Identification of sections that require blowing-snow control

Based on the calculations of degree of snowstorm danger and the results of basic surveys including site reconnaissance, snow survey, weather observation by patrol vehicles, and the like, understand the on-site blowing-snow-induced hindrances. Further, assess potential strengths and weakness against blowing-snow-induced hindrances on the route, then finally identify sections that require blowing-snow control.

3-4 Criteria for application of blowing-snow control facilities

3-4-1 Procedure for selecting blowing-snow control facilities

In selecting facilities for blowing-snow control, consideration should be given to objectives of snow control on the route, weather conditions, road structures, right-of-way and other restricting conditions. Use the procedure shown in Figure 1-3-8 as a guide. Final decision should be made in accordance with Table 1-3-9: "Criteria for Application of Blowing-snow Control Facilities" and detailed local conditions.

Table 1-3-8: Application Criteria of Blowing Snow Control Facilities (covering road structures and ancillary facilities)

Selection criteria / Blowing-snow control facilities					Road structure			Snowbreak woods		Snow fence			Delineation facilities	Large-scale facility
Cross-sectional profile	Target of countermeasure	Prevailing wind direction	Land available?	No. of lanes*	Gentle slope fill	Drift-control fill	Drift-free cut	Standard-width woods	Narrow-width woods	Trad. collector snow fence	Collector snow fence	Blower snow fence**		
Fill	Snowdrifts	Perpendicular	Yes	Multiple lanes or one lane each way	○	○	—	◎	×	○	○	×	△	○
			No	Multiple lanes or one lane each way	×	◎	—	×	×	×	○	×	△	
		Shallow angle	Yes	Multiple lanes or one lane each way	○	○	—	◎	×	○	○	×	△	
			No	Multiple lanes or one lane each way	×	◎	—	×	×	×	○	×	△	
	Snowdrifts & poor visibility	Perpendicular	Yes	Multiple lanes or one lane each way	○	○	—	◎	×	○	○	×	△	○
			No	Multiple lanes or one lane each way	×	○	—	×	×	×	◎	×	△	
		Shallow angle	Yes	Multiple lanes or one lane each way	○	○	—	◎	×	○	○	×	△	
			No	Multiple lanes or one lane each way	×	○	—	×	×	×	◎	×	△	
	Poor visibility	Perpendicular	Yes	Multiple lanes	○	○	—	○	◎	○	○	×	○	○
				One lane each way	○	○	—	○	◎	○	○	○	○	
			No	Multiple lanes	×	○	—	×	◎	×	○	×	○	
				One lane each way	×	○	—	×	◎	×	○	○	○	
		Shallow angle	Yes	Multiple lanes or one lane each way	○	○	—	○	◎	○	○	×	○	
			No	Multiple lanes or one lane each way	×	○	—	×	◎	×	○	×	○	
Flat	Snowdrifts	Perpendicular	Yes	Multiple lanes or one lane each way	—	○	—	◎	×	○	○	×	△	○
			No	Multiple lanes or one lane each way	—	◎	—	×	×	×	○	×	△	
		Shallow angle	Yes	Multiple lanes or one lane each way	—	○	—	◎	×	○	○	×	△	
			No	Multiple lanes or one lane each way	—	◎	—	×	×	×	○	×	△	
	Snowdrifts & Poor visibility	Perpendicular	Yes	Multiple lanes or one lane each way	—	○	—	◎	×	○	○	×	△	○
			No	Multiple lanes or one lane each way	—	○	—	×	×	×	◎	×	△	
		Shallow angle	Yes	Multiple lanes or one lane each way	—	○	—	◎	×	○	○	×	△	
			No	Multiple lanes or one lane each way	—	○	—	×	×	×	◎	×	△	
	Poor visibility	Perpendicular	Yes	Multiple lanes	—	○	—	○	◎	○	○	×	○	○
			No	One lane each way	—	○	—	○	◎	○	○	○	○	
			Yes	Multiple lanes	—	○	—	×	◎	×	○	×	○	
			No	One lane each way	—	○	—	×	◎	×	○	○	○	
		Shallow angle	Yes	Multiple lanes or one lane each way	—	○	—	○	◎	○	○	×	○	
			No	Multiple lanes or one lane each way	—	○	—	×	◎	×	○	×	○	
Cut	Snowdrifts	Perpendicular	Yes	Multiple lanes or one lane each way	—	—.	○	◎	×	○	○	×	△	○
			No	Multiple lanes or one lane each way	—	—	×	×	×	×	◎	×	△	
		Shallow angle	Yes	Multiple lanes or one lane each way	—	—	○	◎	×	×	○	×	△	
			No	Multiple lanes or one lane each way	—	—	×	×	×	×	◎	×	△	
	Snowdrifts & Poor visibility	Perpendicular	Yes	Multiple lanes or one lane each way	—	—	○	◎	×	○	○	×	△	○
			No	Multiple lanes or one lane each way	—	—	×	×	×	×	◎	×	△	
		Shallow angle	Yes	Multiple lanes or one lane each way	—	—	○	◎	×	×	○	×	△	
			No	Multiple lanes or one lane each way	—	—	×	×	×	×	◎	×	△	
	Poor visibility	Perpendicular	Yes	Multiple lanes or one lane each way	—	—	○	○	×	○	○	×	◎	○
			No	Multiple lanes or one lane each way	—	—	×	×	×	×	○	×	◎	
		Shallow angle	Yes	Multiple lanes or one lane each way	—	—	○	○	×	×	○	×	◎	
			No	Multiple lanes or one lane each way	—	—	×	×	×	×	○	×	◎	

Legend:
◎: Recommended, in principle.
○: Acceptable, but it is necessary to examine applicability, taking detailed local conditions into consideration.
×: Unacceptable, in principle.
△: Acceptable for combined use as a complementary snow-control facility with facilities denoted with ◎ or ○.
—: Acceptable, in principle.

Note: The above table shows standards for selecting blowing-snow control facilities.
* Additionally, road width and presence or absence of median should be taken into consideration.
** Maintenance including snow removal at the bottom part is necessary.

3-4-2 Criteria for application of blowing-snow control facilities

Select blowing-snow control facilities in view of following items on the route: (1) objectives of providing the measures, (2) weather conditions, (3) road structure and road width, (4) right-of-way conditions, (5) environmental considerations and (6) costs for installation and maintenance.

4. Design Conditions Survey

4-1 Status and procedures of design conditions survey

The design conditions survey is conducted after the basic design of blowing-snow control facilities is completed but before detailed design is undertaken. The survey is conducted to determine the design conditions for blowing-snow control facilities, especially to obtain N-values for designing snow fences and to obtain various soil data for designing highway snowbreak woods

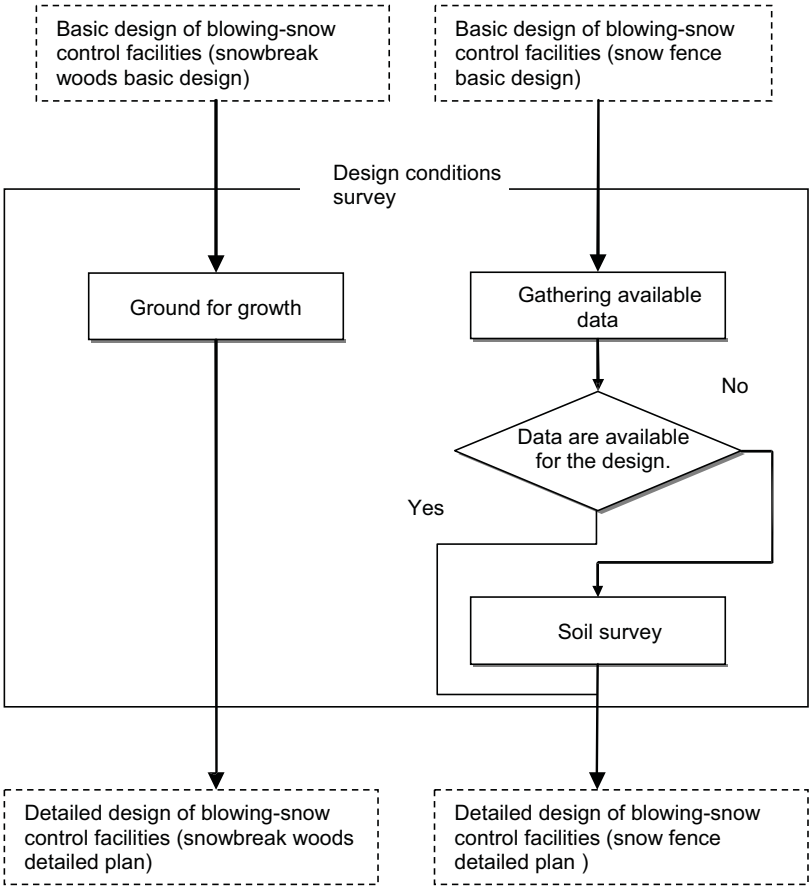


Figure 1-3-10: Procedures of Design Conditions Survey

4-2 Details of design conditions survey

The design conditions survey consists of gathering documents, making a soil survey and making a ground for growth survey. The soil survey and ground for growth survey are conducted after onsite inspection, or for a new road under construction, after identification of the necessary surveying items.

5. Follow-Up Survey

5-1 Status and procedures of follow-up survey

For a new road, follow-up survey is conducted after blowing-snow control facilities are completed and the road enters service. For an existing road, such survey is conducted after blowing-snow control facilities are completed. The purpose of the survey is to inspect/observe whether the facilities (highway snowbreak woods/snow fences) are effective for snow control. If necessary, this includes the verification of snow control effectiveness.

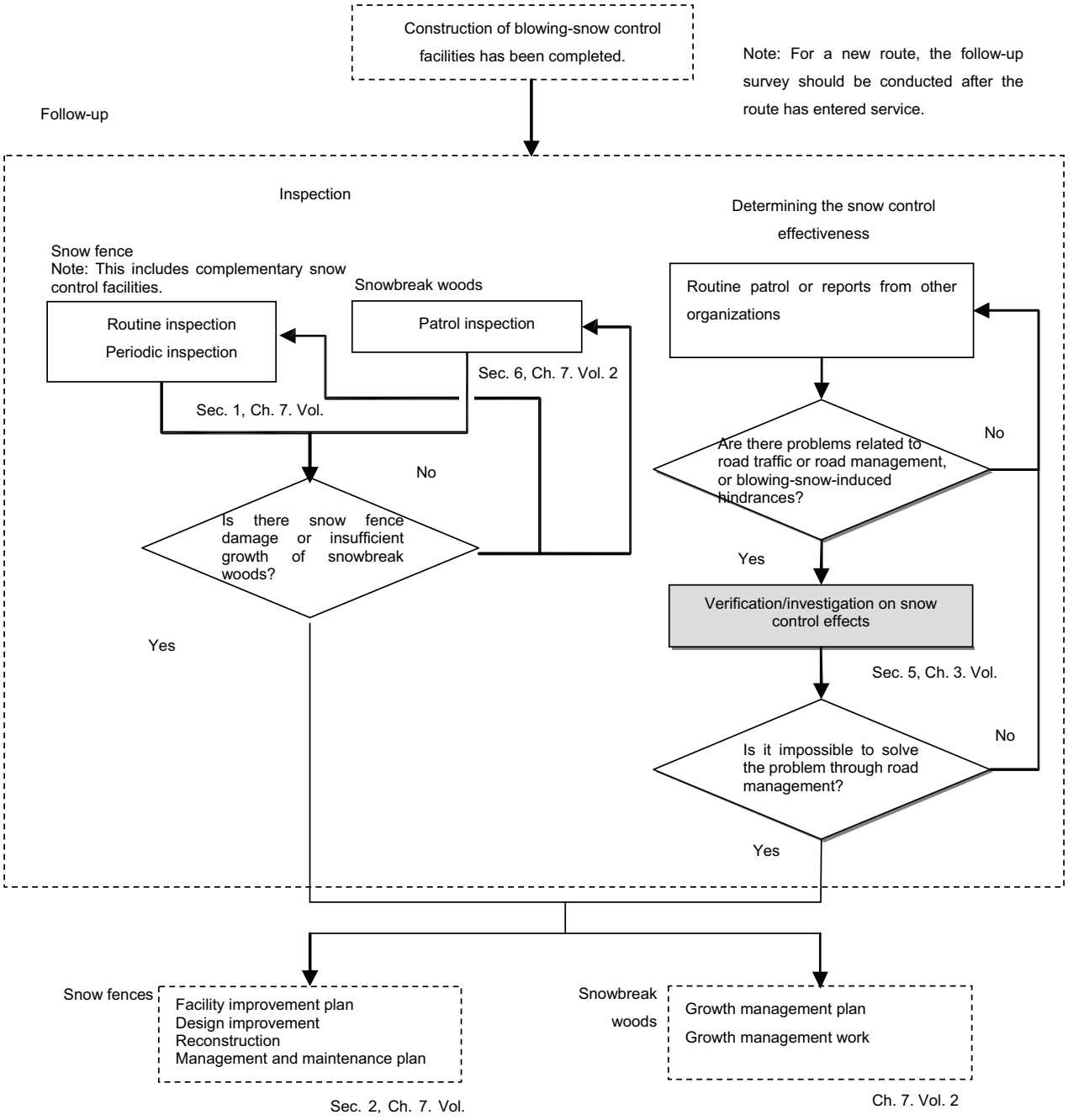


Figure 1-3-11: Procedures of Follow-up Survey

5-2 Investigation of snow control effectiveness

Investigation of snow control effectiveness aims to verify the in-service effectiveness of snow-control facilities and to identify issues related to snow control. The results should be incorporated into a plan for improving snow-control facilities or used in the maintenance of the equipment.

Volume 2: Snowbreak Woods

Chapter 1: General Provisions

1. Objective

Toward streamlined operations, unified design concepts and enriched design content, this section presents technical criteria and information, and explains the basic concept for planning, designing, and installing highway snowbreaks using trees, and for exercising growth management.

2. Scope of Application

This section is intended for highway snowbreak woods on highways under the direct or indirect jurisdiction of the Hokkaido Development Bureau.

Chapter 2: Definition, Characteristics and Basic Concept of Highway Snowbreak Woods

1. Definition of Highway Snowbreak Woods

Snowbreak woods are facilities in which trees are planted windward or on both sides of the road to reduce the velocity of winds blowing onto the road and thereby to prevent snowdrifts from forming and to mitigate poor visibility.

2. Background of Highway Snowbreak Woods

2-1 Background

In 1977 and 1978, the Sapporo Development and Construction Department of the Hokkaido Development Bureau constructed a narrow-band snowbreak woods on National Highway 12 in the Okayama district of Iwamizawa City, and undertook a study on its effectiveness. This marked the beginning of highway snowbreak woods installation in Japan.

2-2 Current conditions

As of 2009, there were about 210 locations of snowbreak woods on national highways throughout Hokkaido, mainly in Northern and Eastern Hokkaido. These had a combined extension length of about 80km.

3. Functions and Effectiveness of Highway Snowbreak Woods

3-1 Functions

The purposes of highway snowbreak woods are snowdrift prevention, poor visibility mitigation and visual guidance. Ancillary effects, such as those regarding landscaping improvement and environmental conservation, can be expected.

3-2 Effectiveness

Highway snowbreak woods reduce wind velocity to prevent snowdrift formation and to mitigate poor visibility (blowing-snow hazard prevention function), and to provide visual guidance for drivers during snowstorm (visual guidance function).

3-3 Factors contributing to snowbreak effectiveness

Factors contributing to effectiveness include width of the forest zone, crown density, tree species, tree height and height of the lowest branches.

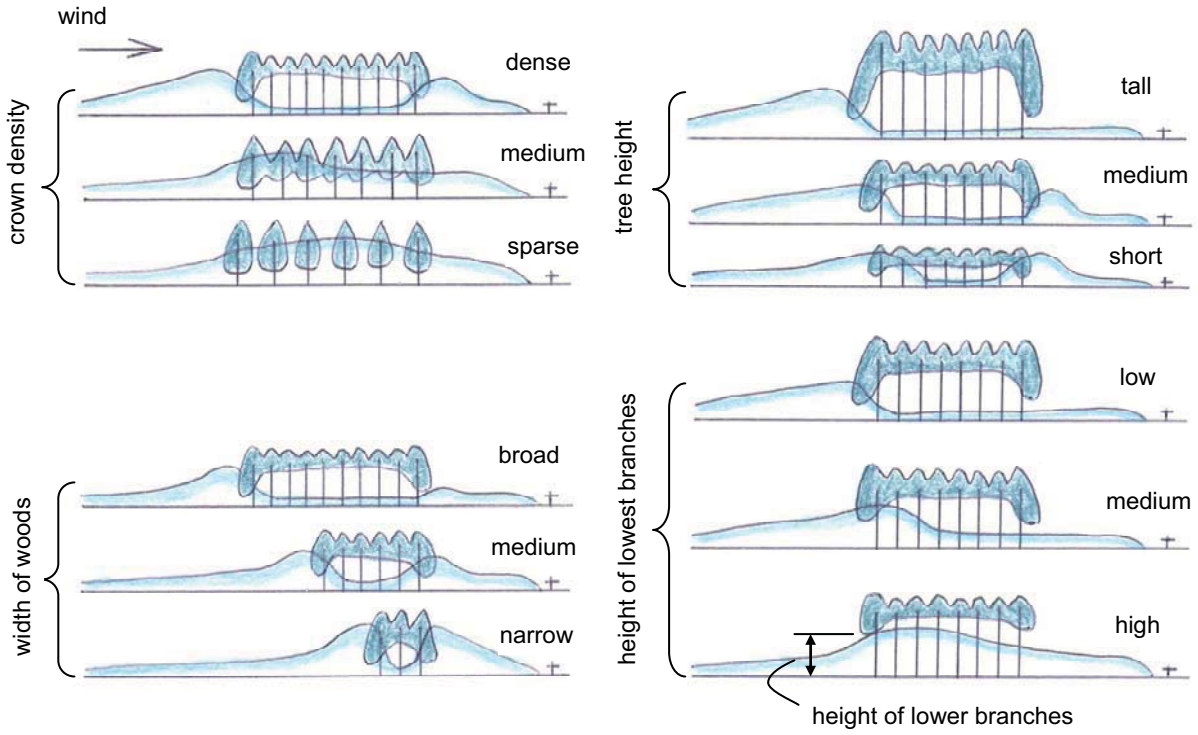


Figure 2-2-7: Relationship between Woods and Top of Snowdrift (courtesy of Shin'ichiro Saito)

Note: Snow that is wet tends to be blowing snow, and the snow particles tend to accumulate on the upwind side.

Snow that is dry tends to be drifting snow, and the snow particles tend to accumulate in the woods zone and leeward.

4. Possible effects of highway snowbreak woods development on their surroundings

Development of highway snowbreak woods may affect the surroundings in addition to exerting snow control effect. Countermeasures should be taken when such adverse effect is great.

5. Basic Concept in Creating Highway Snowbreak Woods

5-1 Characteristics and points to bear in mind when using "living materials"

In creating this "living snowbreak," live trees are used. Trees are distinguished from ordinary structures in that the appropriate growing environment needs to be secured, they change in form over time and they show great individual variation. These features should be fully understood in using trees.

5-2 Environmental stress

Various environmental conditions hinder the growth of trees. These are called "environmental stresses." In the early phase after planting, environmental stresses greatly affect the trees, and satisfactory growth cannot be expected under high environmental stress. Tremendous environmental pressures blight trees. In the early phase after planting, trees are susceptible to damage from environmental stress; thus, protective works are necessary to reduce its impact.

Table 2-2-2: Major Environmental Stresses, and Their Symptoms and Countermeasures

	Item	Cause	Symptom	Countermeasures
Air	Wind	Cold wind (in early winter and early spring)	Early withering, blighting	Windbreak and wintering facilities
		Strong wing from a fixed direction	Slanted tree form	Windbreak facilities
		Salty wind (salt adhering to leaves)	Discoloration of leaf → defoliation → blighting	Windbreak facilities
	Sunshine	Shading by other trees or buildings	Growth suppression, withering and blighting of branches and leaves; spindly growth	
	Snow accumulation	Snow pressure, snow movement	Branches breaking, bending or breaking off	Piles against snow pressure, pruning of lower branches
	Frost damage	Late frost immediately after leafing	Browning and blighting of new leaves	Replacement with other tree species
Soil	Excessive moisture	Poor surface drainage, high groundwater level	Root rot	Drainage by open or closed conduits
	Drying out	Lack of soil water retentivity	Wilting	Irrigation, ground improvement
	Harmful substances	Cadmium, aluminum, etc.	Spots and discoloration on leaves	
Water	Flooding	Impossibility of photosynthesis and respiration	Blighting	
	Flowing water	Flowing water, which causes trees to tilt, fall or wash away	Poor growth, blighting	
	Inundation	Difficulty of root respiration	Blighting	
Living things	Animal damage	Field mice, hares, deer	No winter buds or bark	Repellent application, net installation
	Competition with grass plants	Growth suppression by grass plants and competition with their roots	Rot, insufficient water → blighting	Bottom grass mowing, mulching
Artificial	Stamping pressure	Soil compaction, trodding by people	Delayed growth	Fences for keeping out people, tree circles
	Damage by mowing	Damage by mowing for maintenance	Delayed growth, blighting	Manual mowing
	Damage by fertilization	Damage to hair roots and lessening of their function	Blighting	
	Anti-icing agent	Dispersion of particles containing salt	Discoloration of leaf → defoliation → blighting	Culturing of healthy trees

Chapter 3: Basic Design of Highway Snowbreak Woods

1. Basic Plan of Highway Snowbreak Woods

In the plan, determine the following items.

(1) The purpose of the highway snowbreak woods, (2) the type of woods to be adopted (standard-width woods or narrow-band woods), (3) the basic design conditions and (4) the woods length and width (including the right- of-way width)

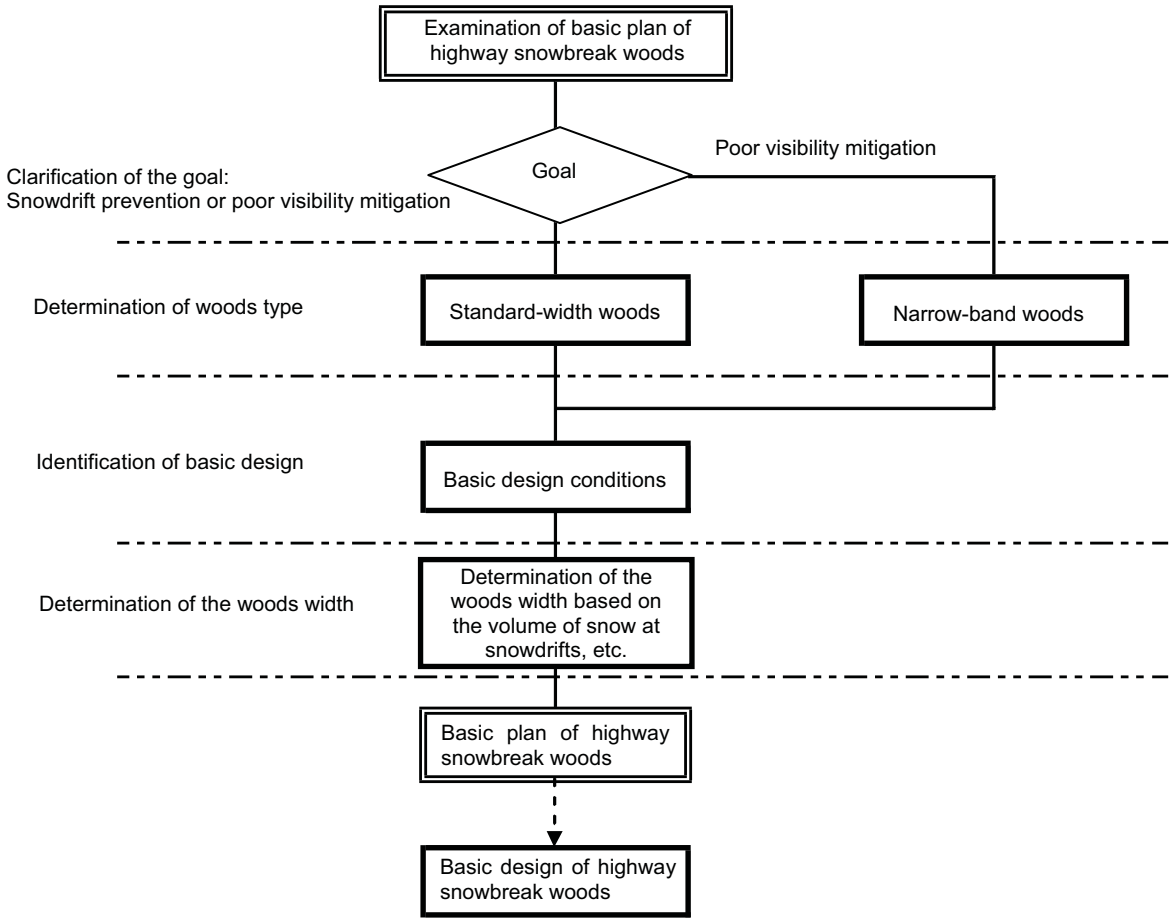


Figure 2-3-1: Flowchart of Basic Design of Highway Snowbreak Woods

2. The Basic Plan Conditions

2-1 Development of highway snowbreak woods in a zone with strong wind

When highway snowbreak woods are developed in a zone with strong winds, measures are necessary to alleviate the effects of the wind so as to minimize damage to the woods.

2-2 Development of highway snowbreak woods on cut slopes

Unlike on flat land, trees on such slopes are subject to sloping snow pressure. Therefore, it is important to take countermeasures such as snow glide prevention.

Generally the growth of woods on cut slopes is limited, because the effective soil layer is thin and the ground is hard. Also, because of the possibility that trees will fall in the future, highway snowbreak woods are installed outside of the top of the cut slope

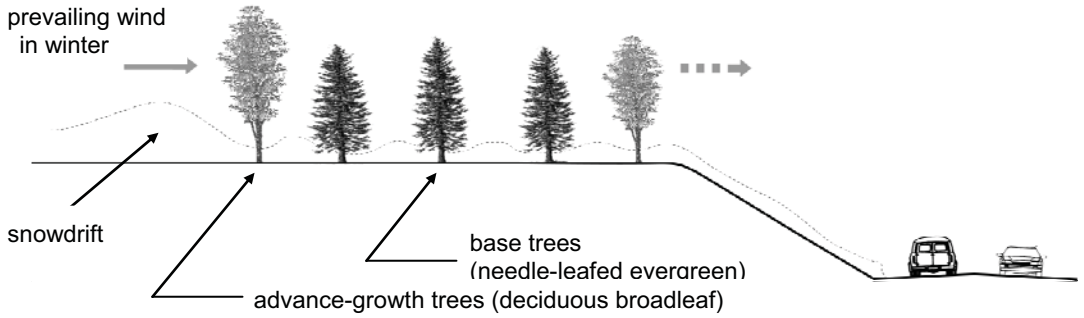


Figure 2-3-7: Location of Installation for Highway Snowbreak Woods When the Cut Slope Gradient is 1:1.7 or Less (Schematic)

3. Types of Highway Snowbreak Woods

3-1 Purpose and types of highway snowbreak woods

Highway snowbreak woods that are 10m or more in width and are developed to prevent snowdrifts and mitigate poor visibility are called “standard-width woods.” Those that are narrower and are developed to mitigate poor visibility are called “narrow-band woods.”

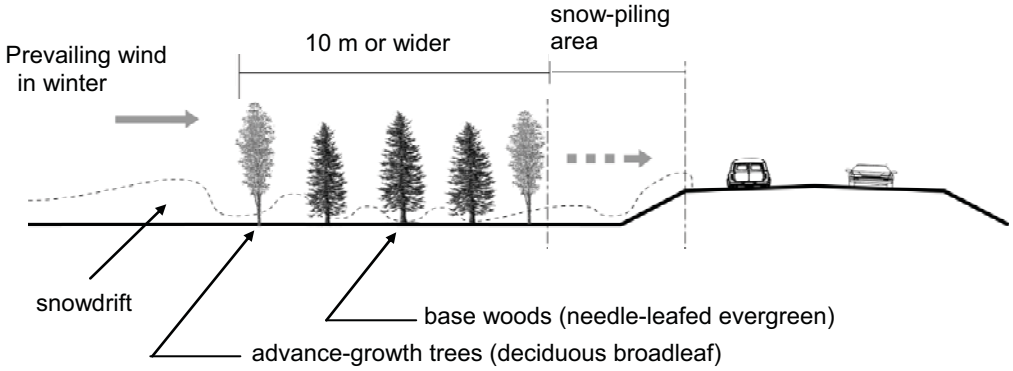


Figure 2-3-8: Cross-section of Typical Standard-width Woods

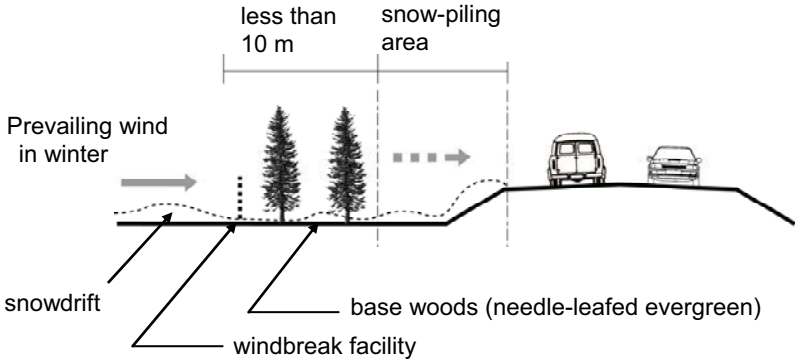


Figure 2-3-9: Cross-section of Typical Narrow-band Woods

3-2 Determination of standard-width woods' width

Standard-width woods are used at road sections where the maximum volume of snow settled at snowdrifts is 20m^3/m or greater and snowdrift-control measures are necessary.

Table 2-3-1: Maximum Amount of Snow at Snowdrifts (Annual Average) and Required Woods Width

Maximum amount of snow	Width of woods	Standard	Type of woods
20 to 30m^3/m	10m	11.0m	10-m type
30 to 50m^3/m	20m	23.0 m	10-m type
50 m^3/m and more	30m	32.0m	10-m type

3-3 Criteria for installation of narrow-band woods

Narrow-band woods are used at sections that require measures to mitigate poor visibility and where the amount of snow settled at snowdrifts is less than 20 m^3/m. Narrow-band woods can be used at road sections whose estimated volume of snow accumulated at snowdrifts is 20m^3/m or greater, provided that the snow removal operations on the route are sufficient to keep the route safely passable.

3-4 Extension of highway snowbreak woods

Even when the prevailing wind blows at a right angle to the snowbreak woods, snow blows onto the road around both ends of woods. When the wind blows from a direction oblique to the woods, the woods need to be long enough to prevent snowstorms from coming around the ends.

Chapter 4: Basic Design of Highway Snowbreak Woods

1. Basic Design of Highway Snowbreak Woods

Based on the detailed survey results, the following matters should be determined or examined in the basic design:

(1) Arrangement

(2) Specifications and quality of trees for planting

(3) Snow-control facilities for complementary use with snowbreak woods

(4) Service road

(5) Method of preparing conditions for planting of woods

(6) Protective works for trees

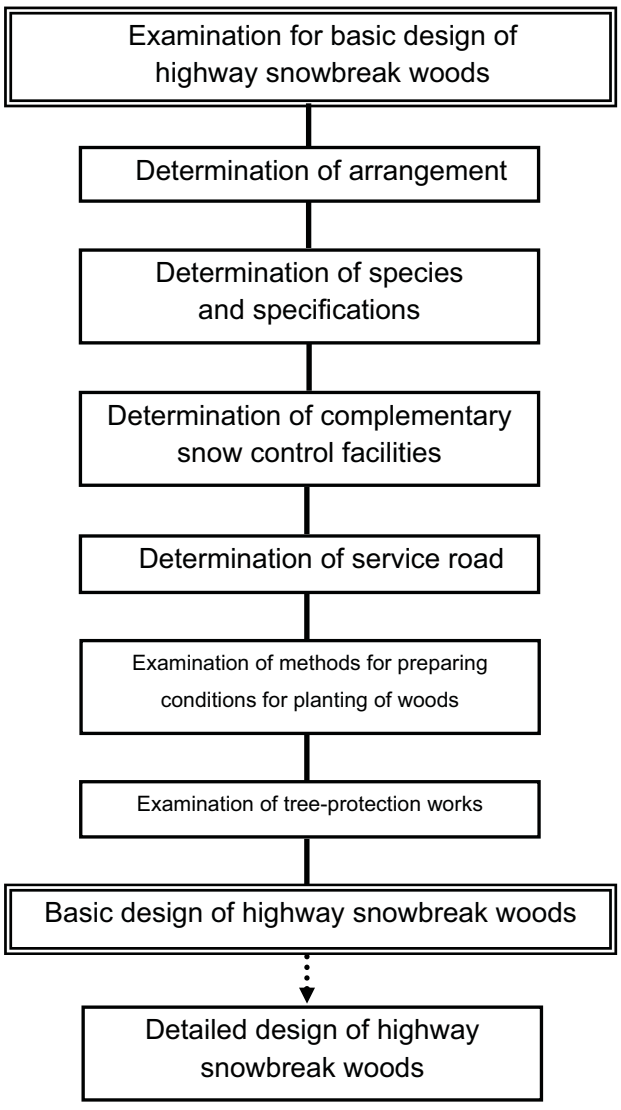


Figure 2-4-1: Procedure for Basic Design

2. Arrangement

2-1 Standard-width woods

Standard-width woods are one of three widths: 10m, 20m or 30m. The woods consist of primary trees and pioneer trees.

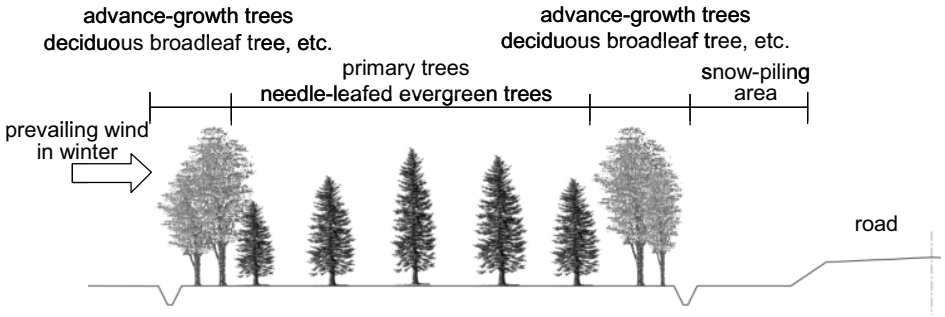


Figure 2-4-2: Basic Structure of Standard-width Woods

2-2 Narrow-band snowbreak woods

The width of woods for narrow-band woods is less than 10m, and narrow-band woods consist solely of primary trees. The primary trees consist of needle-leafed evergreens.

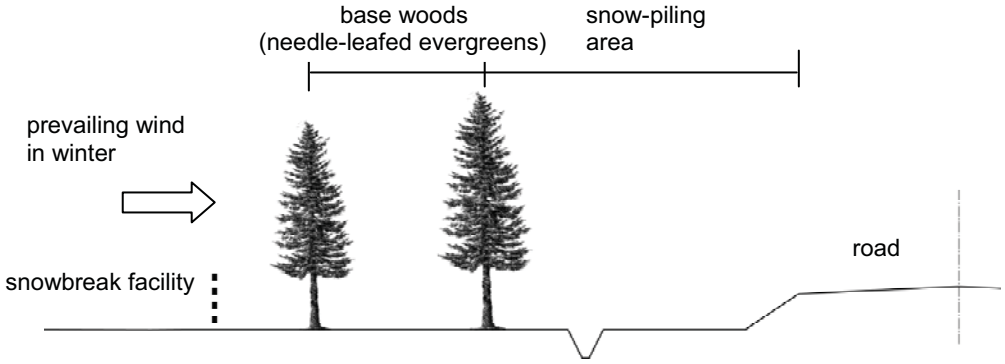


Figure 2-4-10: Basic Structure of Narrow-band Woods

Standard-width woods: 20-m type

Standard woods width: 23.0 m

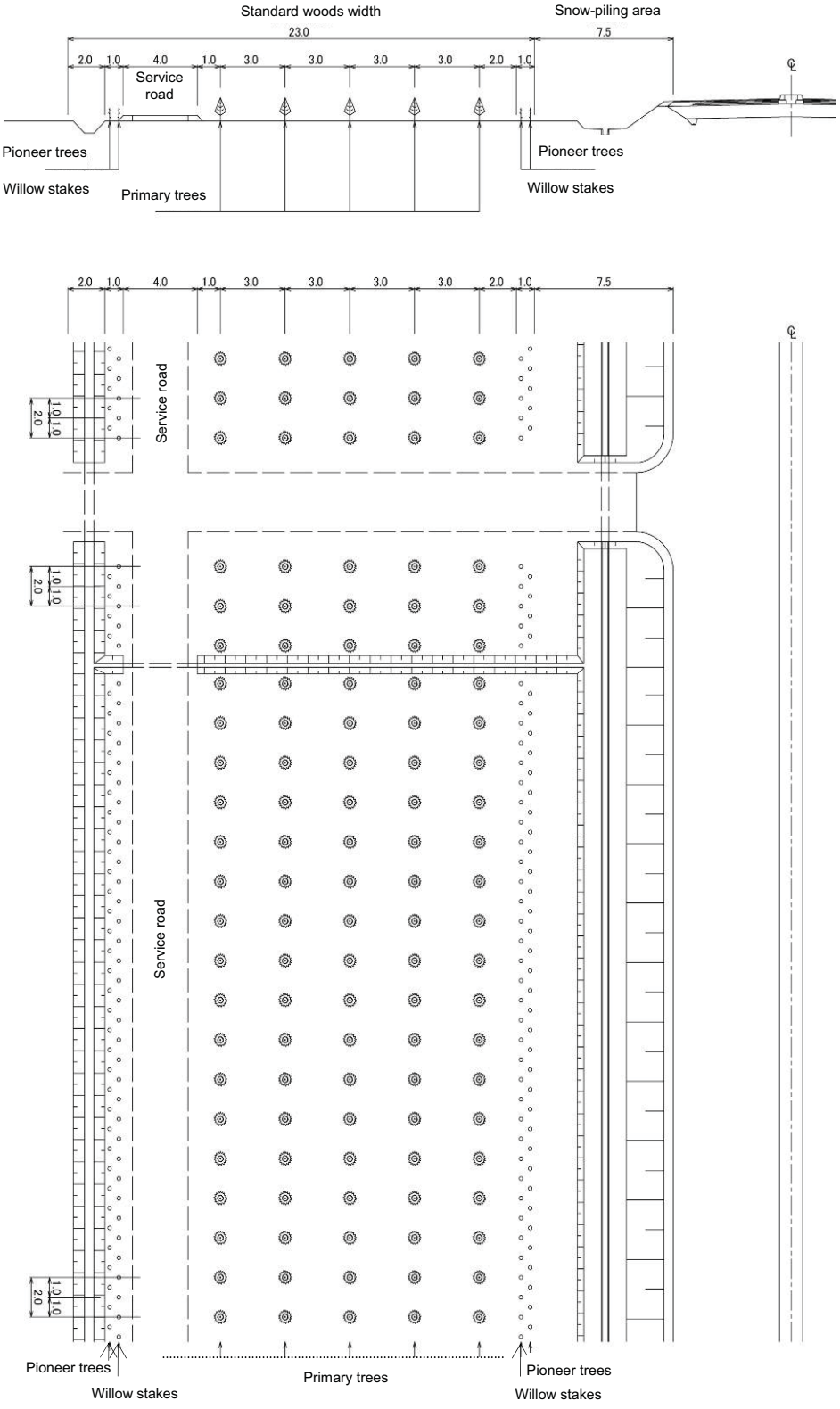


Figure 2-4-7 20-m-type Standard-width Woods (Unit: m)

2-3 Treatment of the wood ends and access roads

At the ends of highway snowbreak woods and where access roads enter the main road, visibility hindrance is caused by snow blowing from the windward direction. Even though the entrances of access road tend to be as narrow as 3 to 5m, at larger openings, such as points of intersection with arterial highways or rivers, continuous visibility hindrance could occur.

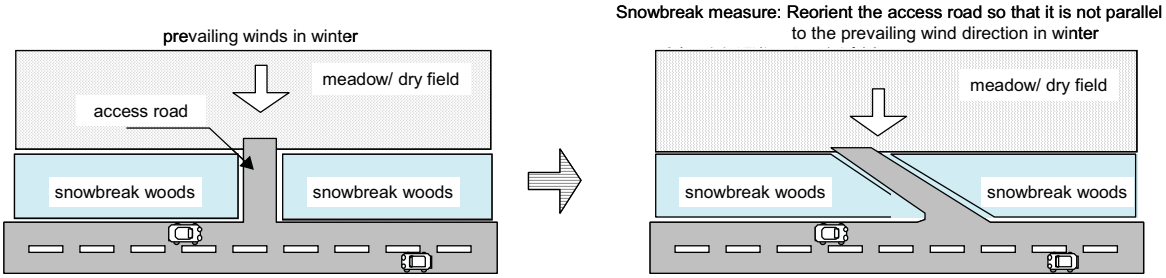


Figure 2-4-15: Orientation of Access Road

3. Species and Specifications of Trees for Planting

3-1 Requirement for selection of tree species

In selecting species for highway snowbreak woods, it is necessary to take into consideration the functions and the purposes peculiar to snowbreak woods as well as the general criteria for selecting roadside trees.

Table 2-4-1: Considerations and Requirements for Selecting Tree Species for Highway Snowbreak Woods

Item	Considerations	Requirements
Objective	The objective of developing highway snowbreak woods is to control snow by using the woods' windbreak function. Selection of tree species fulfilling the objective is the primary criteria and is critical for snowbreak woods.	- Evergreen - Dense branches and leaves - Branches are at the lower part of the tree
Environmental suitability	Required growth conditions differ by species, so it is fundamental to select tree species that are suited to the local conditions. In general, native species have the natural and social suitability of the place they grow, and are suited for planting there. Many species with high environmental suitability grow well and are resistant to damage by disease/pests.	- Suited to the local climate
Environmental acclimatization	Snowbreak woods are developed in an area where the environmental conditions are severe and where many factors hinder the growth of plants. Although it is desirable to mitigate such factors before planting, when they are unavoidable the second best policy is to select species that acclimate easily to adverse environmental conditions.	- Wind-resistant - Deep-rooted
Growth properties	The growth of trees includes extension growth phase (= growing taller), diameter growth phase (= growth in the diameter of the trunk), germinating phase and reproductive phase. Required properties depend on the purpose of planting, and highway snowbreak woods usually require species that are superior in both extension and diameter growth. It is also necessary that branches and leaves grow densely and the total surface area of leaves be large relative to the entire tree area.	- Fast initial growth - Evergreen, with large total surface area of leaves in winter
Workability	Some plant species are easily transplanted, and others are not. This property changes in different growth stages of tree species. Some species are easily transplanted as seedlings but not as full-grown trees, and the opposite is true for other species. The appropriate timing of transplanting is fairly short. Generally, species with good workability are those that can be easily transplanted and are able to take root.	- Good rooting
Manageability	After planting, trees need to be tended. Species needing little care are those that do not require fertilizer application, watering or cold protection and are less susceptible to damage by disease, insects or animals.	
Availability	Species with good availability are those that are produced in large quantities, are readily available on the market, and are easily taken out and transported from producing areas. It is necessary for the development of highway snowbreak woods that seedlings of uniform specifications be procured in large quantities	- Commercial availability

3-2 Species used for highway snowbreak woods

・ Species used chiefly for snow control (primary tree species)・ Species used to safeguard the early growth of primary trees (pioneer tree species)・ Species that grow relatively fast and serve as pioneer trees (advance-growth tree species)・ Species for landscape improvement (landscape-enhancement tree species) The following are recommended species:

Primary tree species	Pioneer tree species	Advance-growth trees	Landscape-enhance-ment tree species
Tall coniferous evergreen - Sakhalin fir - Sakhalin spruce - Norway spruce** (Narrow-band snowbreak woods) Short/mid-height coniferous evergreen - Mountain pine** - Northern white cedar**	Tall deciduous broadleaf - Willow	Tall deciduous conifer Japanese larch* Tall deciduous broadleaf - Japanese poplar - Japanese white birch - Alnus hirsuta Turcz. - Fraxinus mandshurica var. japonica Maxim.	Tall deciduous broadleaf - Quercus mongolica var. grosseserrata Rehd. et Wils. - Painted maple - Other

All species are indigenous to Hokkaido, except *introduced from Honshu, Japan’s main island, and **introduced from overseas.

3-3 Specifications of trees for planting

The specifications of trees depend on the environmental conditions for growth and the conditions of trees, such as adaptability to the environment and commercial availability.

Table 2-4-3: Categories and Specifications of Seedlings

Categories	Height	Years grown at the nursery	General use	Advantages	Disadvantages
Seedlings	0.3 - 1.0	3 - 4	For general afforestation and disaster-prevention forests	- Even if the growing environment is severe, the damage to the root system during planting is small and the rooting rate is high. - Easily available in relatively large quantity - Economical planting cost	- Requires much time before achieving snow control
Premature trees	1.2 - 2.5	8 - 9	For fairly large green spaces	- Time before achieving snow control can be shortened.	- Damage to the root system during planting is more severe than that of seedlings, thus causing growth imbalance between the root system and the upper body. Therefore, under severe growth circumstances, the rooting rate is inferior to that of seedlings. - Difficult to procure in a large quantity for some tree species
Mature trees	3.0 -	12 -	For general landscape gardening, roadside trees, etc.	- Snow control can be realized within a short time after planting	- Damage to the root system during planting is heavy, thus causing growth imbalance between the root system and the upper body. Therefore, under severe circumstances, the rooting rate is low. Particular care is needed in planting conifers. - Difficult to procure in a large quantity with the same specification - High planting cost

4. Combined Use of Complementary Snow-control Facilities

4-1 Selection and installation of complementary snow control facilities

After woods are planted at the roadside, it takes time for them to serve as a snowbreak. If there is an urgent need for snow control, examine installing complementary snow control facilities in addition to the highway snowbreak woods.

4-2 Removal of complementary snow fences

When the highway snowbreak woods have fully realized their snow control, it is possible to remove complementary snow fences.

5. Service Roads

Service roads are constructed in snowbreak woods, and these roads are used for patrol and maintenance. For 20m and 30m standard-width woods, service roads should be constructed in snowbreak woods. For 10m standard-width woods and narrow-band woods, roads passable by vehicles should be constructed.

6. Preparation of Ground for Growth of Highway Snowbreak Woods

6-1 Basic idea of ground for growth

To ensure adequate growth of highway snowbreak woods, it is essential to prepare soil conditions suitable for growth of the root system.

6-2 Principle of preparing soil conditions for growth

In preparing soil conditions for the growth of highway snowbreak woods, as great a thickness of soil layer necessary for growth of the root system as possible should be secured.

Figure 2-4-27: Minimum Effective Thickness of Soil Layer Necessary for Plant Growth

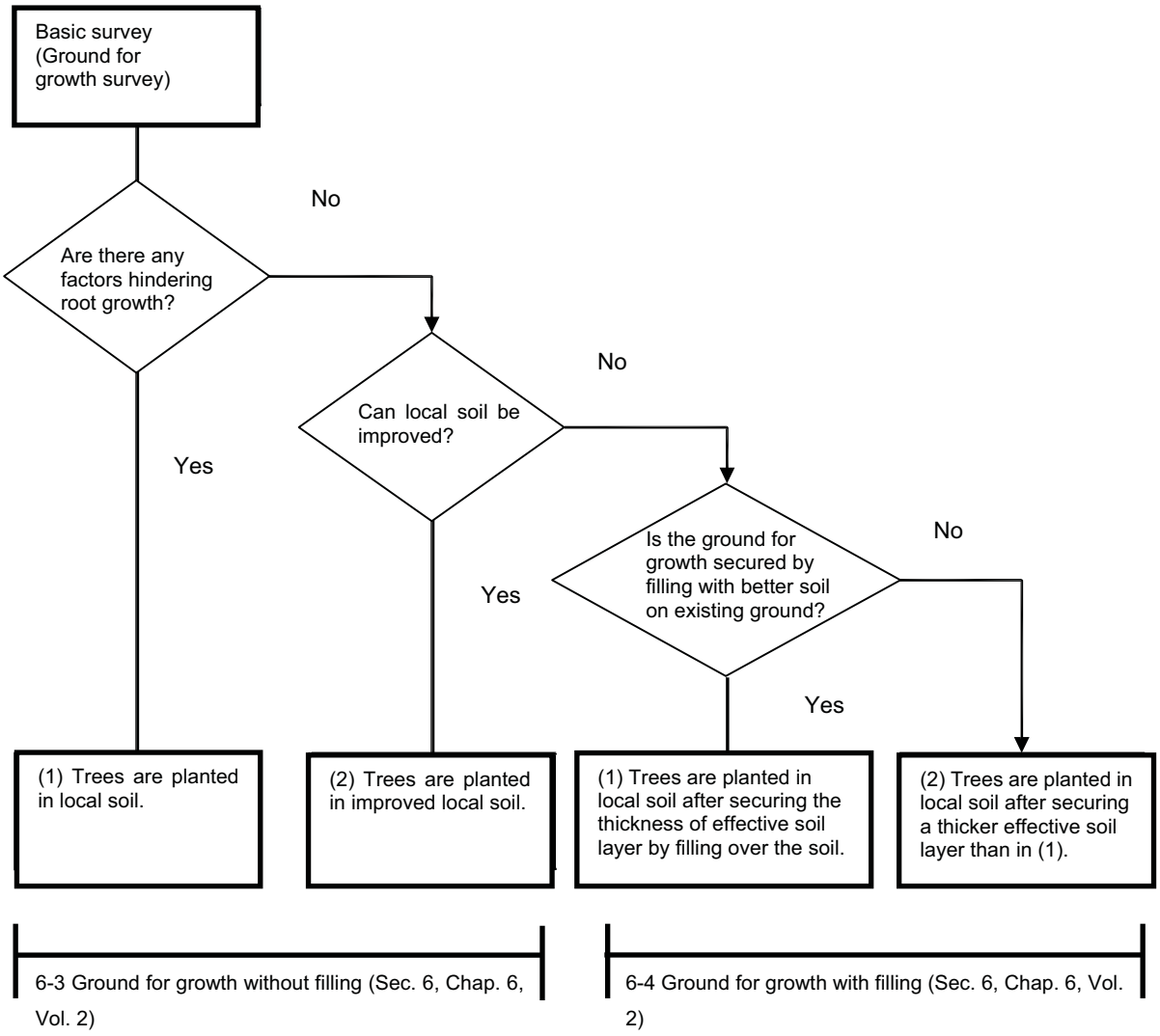


Figure 2-4-28: Examination Procedures for Preparing Soil Conditions for Growth

6-3 Ground for growth without filling

When there is nothing restricting the growth of the root system, trees are planted in local soil.

When there is something restricting the growth of the root system, local soil shall be used as the ground for growing, provided that local soil can be economically and sufficiently improved.

6-4 Ground for growth with filling

When it is confirmed that there is something restricting the growth of the root system and it is determined that efficient improvement of the soil is impossible, the ground for growth shall be secured by filling the existing ground with better soil so that the growth of trees for snowbreak continues longer than without such filling.

Soil improvement can be done by either of these methods: (1) Supply the needed thickness of effective soil layer by filling over the improved existing topsoil; or (2) Prepare the entire ground for growth by means of filling.

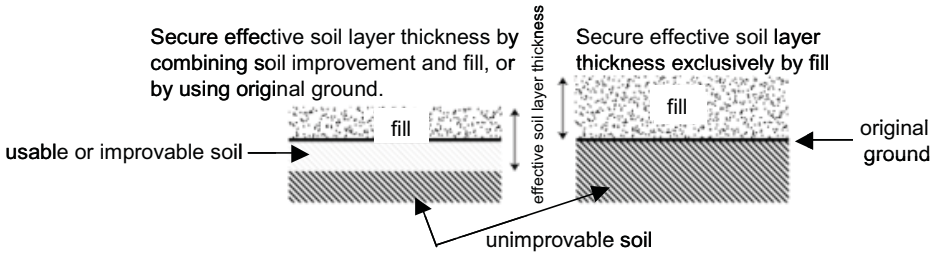


Figure 2-4-29: Method of Preparing a Foundation That Secures Effective Soil Layer Thickness

6-5 Drainage

Adequate drainage is required for soil improvement of the ground. It is important to prevent water from stagnating on the ground and to prevent the soil from being excessively moist by installing surface drainage, drainage by uncovered conduit or drainage by culvert.

Chapter 5: Detailed Design for Execution of Highway Snowbreak Woods

1. Procedure of Detailed Design for Execution

1-1 Survey and field work

In the process of the detailed design for installation of highway snowbreak woods, basic investigations such as on-site surveys and inspections are carried out prior to actual designing, toward studying the feasibility of the basic design at the planned site.

1-2 Design

In the detailed design, based on the on-site surveys and site reconnaissance, detailed examination is done on ground preparation methods, drainage, banking soil thickness, selection of tree species, shape specifications, planting arrangement, and the types and shapes of protective works for trees.

Table 2-5-2: Design for Execution

Item		Description
1.	On-site survey	On-site survey of plan, longitudinal, and cross-sectional form, etc. (Unnecessary if the road survey results are available.)
2.	Site reconnaissance	Confirmation of details of access roads, including their locations
3.	Investigation of ground for growth (survey of design conditions)	Exploring feasibility of soil improvement of ground for growth by confirming drainage, and surveying soil profile, etc.
4.	Examination	Based on on-site surveys and site reconnaissance, a basic policy is drawn up and detailed examinations are done on soil improvement of the ground for growth, planting works, tree species selection, protective works, etc.
5.	Drawing up of particular specifications	Special conditions are described in the particular specifications.
6.	Drawing up of plans	The plans needed for executing the work are laid out.
7.	Preparation of bills of quantities	Quantities are calculated based on the plans.
8.	Calculation of estimated work cost	Based on the bills of quantities, estimated work cost is calculated.

2. Results of Detailed Design

Detailed design drawings and documents that should be prepared in developing highway snowbreak woods include ground plans for planting, layout drawings, current condition plans, land preparation plans, cross-sectional drawings of soil preparation, drainage plans, detailed drawings and work specifications of respective structures, bills of quantities and bills of quantities with price estimates.

Chapter 6: Planting Work of Highway Snowbreak Woods

1. Planting Procedure

1-1 Execution procedure

In planting, the procedure shown in Figure 2-6-1 shall be followed.

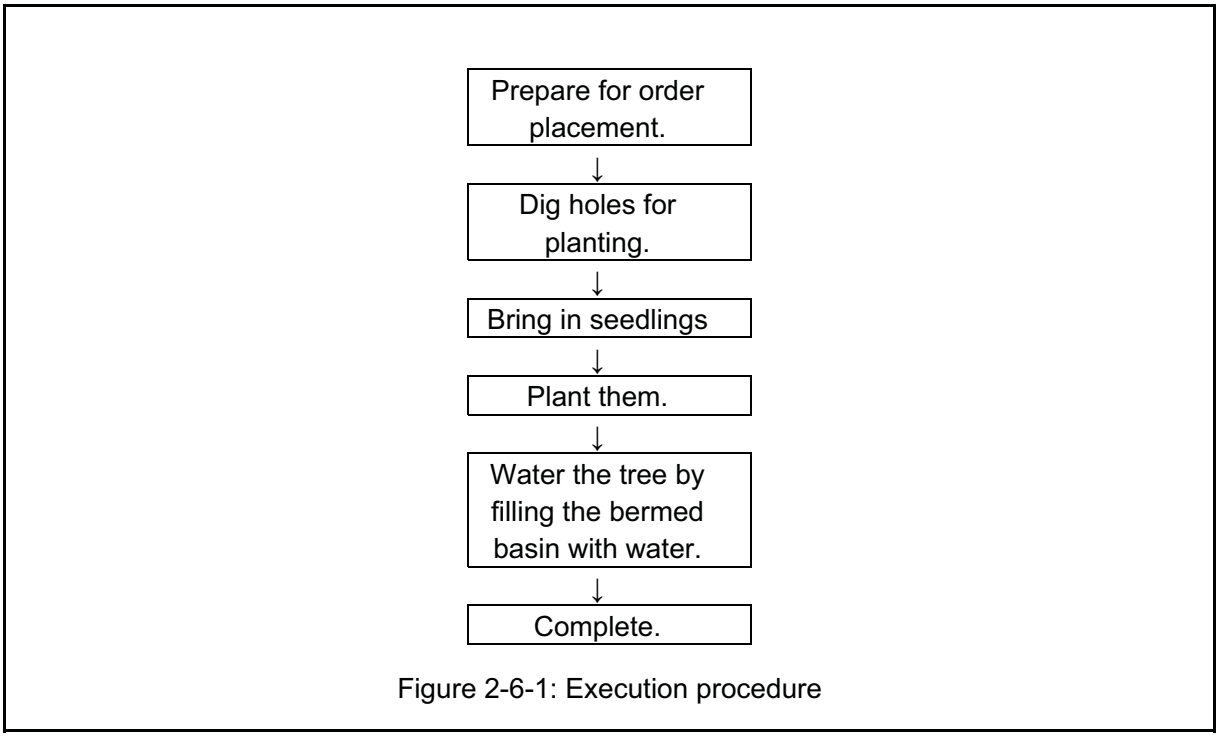


Figure 2-6-1: Execution procedure

1-2 Post-planting repairs and care

Providing care for the first year after planting greatly improves the early growth of highway snowbreak woods, and any abnormality found with trees should be addressed swiftly. The necessary work is this: (1) ameliorate it by watering, (2) tramp down roots, (3) right fallen trees and (4) conduct supplementary planting.

2. Time of Planting

2-1 Appropriate time of planting

The appropriate time of planting depends on the tree species; it is necessary to adequately control the planting process based on the understanding of the proper time for each species. Planting at an inappropriate time results in a reduced root-taking rate and reduces the growth increase in the following year.

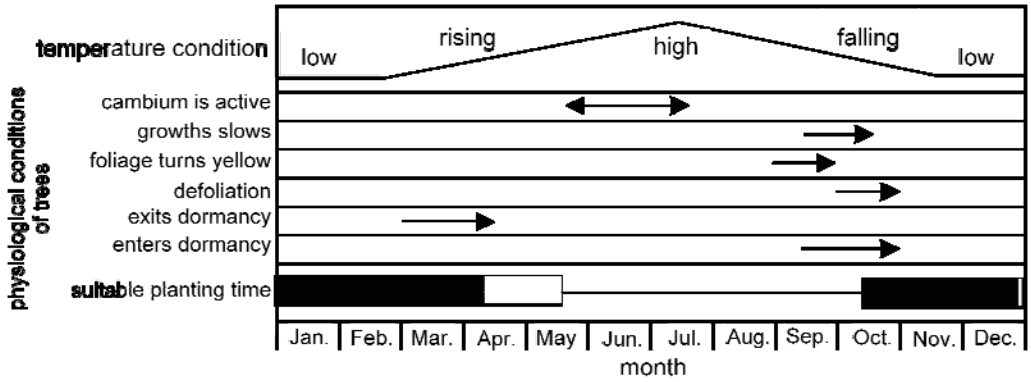


Figure 2-6-7: Physiological Conditions of Trees and Suitable Planting Time
(created based on *Plant Ecophysiology*)

2-2 Time of planting by region

The appropriate timing of planting depends on the tree species; it is necessary to adequately control the planting process based on an understanding of the proper timing for each species.

3. Points of Concern for Procuring Seedlings

In Hokkaido, highway snowbreak woods are usually installed in colder, windier regions. The environmental conditions in most of these regions are severe for tree growth. Therefore, some seedlings that are grown at nurseries under good environmental conditions cannot acclimatize to such environmental conditions.
For this reason, special considerations must be made, for example, to procure seedlings from the area near the snowbreak woods and to procure seedling of the same variety and not just the same species.

Chapter 7: Growth Management of Highway Snowbreak Woods

1. Principles of Growth Management

1-1 Aim of growth management

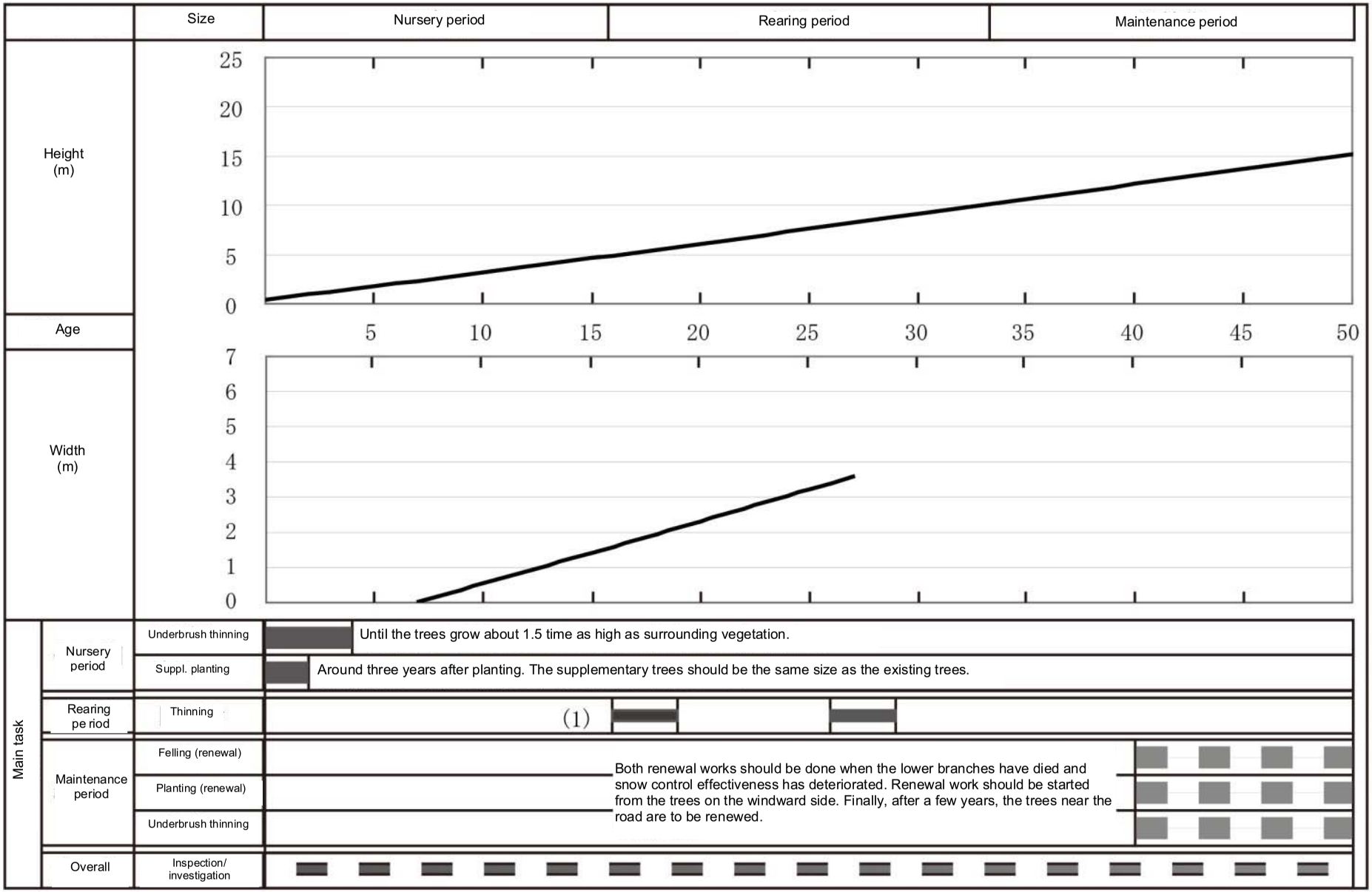
> Growth management aims at accelerating the growth of woods so that they may serve as road snowbreaks as soon as possible, and at maintaining the function of highway snowbreak woods for a long period.

1-2 Purpose of management work by phase

> The growth management process is divided into three phases according to the growth stage of trees:
> (1) Nursery period
> (2) Rearing period
> (3) Maintenance period
>
> The management goals and the chief purposes of management work vary in each of the phases.

Table 2-7-1: Three Phases, Purposes of Management Work and Tree Heights in the Growth Management of Highway Snowbreak Woods

Phase	Management goal	Purpose of management work	Status of effects	Target tree height
Nursery	Early function fulfillment	To promote tree growth, particularly by avoiding competition with other plants	Underdeveloped	Less than 5m
Rearing	Satisfactory function	To avoid competition among trees in the woods.	Fulfillment - satisfactory	5 m to less than 10 m
Maintenance	Maintenance of function	To promote growth of successor trees and to conduct selective felling for their healthy growth	Satisfactory - deteriorated	10 m or more



(1) Thinning is done when branches 1.5 – 2.0 m height above the ground touch those of neighboring trees.

Figure 2-7-1: Model Plan for Long-term Management of Highway Snowbreak Woods

1-3 Types of growth management work

Growth management work consists of “routine work” implemented for a fixed period of time or at a specific time and “non-routine work” for coping with damage.

Table 2-7-2: Routine Management Work by Phase

Phase	Details of management work
Nursery	Care of juvenile trees, supplemental planting, underbrush thinning, improvement cutting, cutting of vines, maintenance of pioneer trees
Rearing	Pruning of lower branches, thinning, maintenance of support posts
Maintenance	Rejuvenation
All phases	Periodic route inspection, measurement of growth increment, etc.

2. Management during the Nursery Period

2-1 Care of juvenile trees

Juvenile trees in the early stage after planting are taken care of by tramping down the loose soil around the roots, hilling the soil, righting fallen trees and taking measures against snow damage.

2-2 Supplemental planting

Supplemental planting is done for about three yeas after planting. Apical buds and new leaves on the upper part of trees are checked for withering. Supplemental planting is done at parts with such withering.

2-3 Underbrush thinning

Thickly growing weeds hinder the growth of the planted seedlings. Thus, underbrush thinning is the most important management work for juvenile trees (in the early stage after planting).

2-4 Evaluation of growth during nursery period, estimation of factors contributing to bad growth, and countermeasures

> During the early and mid period of nursery, the growth of seedlings is inspected and evaluated. If bad growth occurs, factors contributing to it should be investigated and estimated, and appropriate countermeasures should be taken.

The "early nursery period" is defined as the period from when trees are planted to when trees reach about 1 m in height, and the "mid nursery period" is defined as the period from when they reach 1 m in height to when they reach 3 m in height. Table 2-7-3 shows the growth ranks for the early nursery period.

To evaluate growth, observe the apical bud, the lateral bud on the crown, the growth increase of the upper part, the presence and color of new/old leaves (Figure 2-7-5).

If trees in growth ranks 3 to 5 are growing in a cluster, there may be problems with the ground for growth, wind control and other factors. In such case, estimate the factors and examine countermeasures.

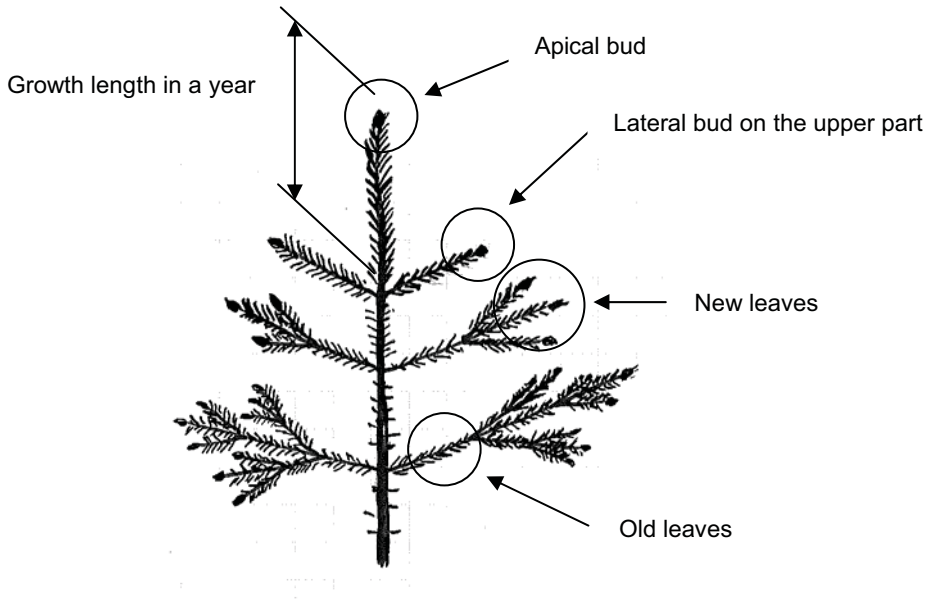
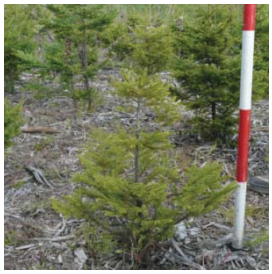
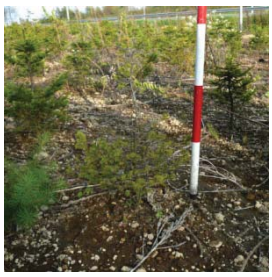
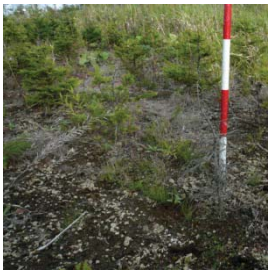


Figure 2-7-5: Points to be Checked during the Early Nursery Period.

Table 2-7-3: Evaluation of Growth in the Early Nursery Period

Growth rank	Evaluation	Schematic	Photo
Rank 1 - Growth increase in a year: 15cm or more - Blighted apical or lateral bud on the top?: No - Blighted lateral buds on the upper part?: No - Leaf color: ordinary green to dark green	- Growth is healthy. - Normal maintenance should be conducted.		
Rank 2 - Growth increase in a year: Less than 15cm - Blighted apical or lateral bud on the top?: No - Blighted lateral buds on the upper part?: No - Leaf color: Light green	- Some factors may be hindering growth. - Countermeasures may be necessary, if the leaf color or amount of leaves do not improve for several years.		
Rank 3 - Growth increase in a year: 3 - 5cm - Blighted apical or lateral bud on the top?: Yes - Blighted lateral buds on the upper part?: Yes - New leaves?: Yes - Branch on the upper part of the tree has becomes a main trunk?: Yes - Leaf color: Light green or light brown	- There has been recovery from transplanting damage - Growth has stagnated. - Countermeasures may be necessary, if the leaf color or amount of leaves do not improve.		
Rank 4 - Growth increase in a year: 0cm - Blighted apical or lateral bud on the top?: Yes - Blighted lateral buds on the upper part?: No - New leaves?: No -Branch on the upper part of the tree has become a main trunk?: No. - Leaf color: Light green or light brown	- Blight is regarded as inevitable. In principle, the tree should be replaced.		
Rank 5 - Blighting - New/old leaves?: No (Deemed a blighted tree if a few old leaves remain.)	- If the tree is deemed to be blighted, it should be replaced.		

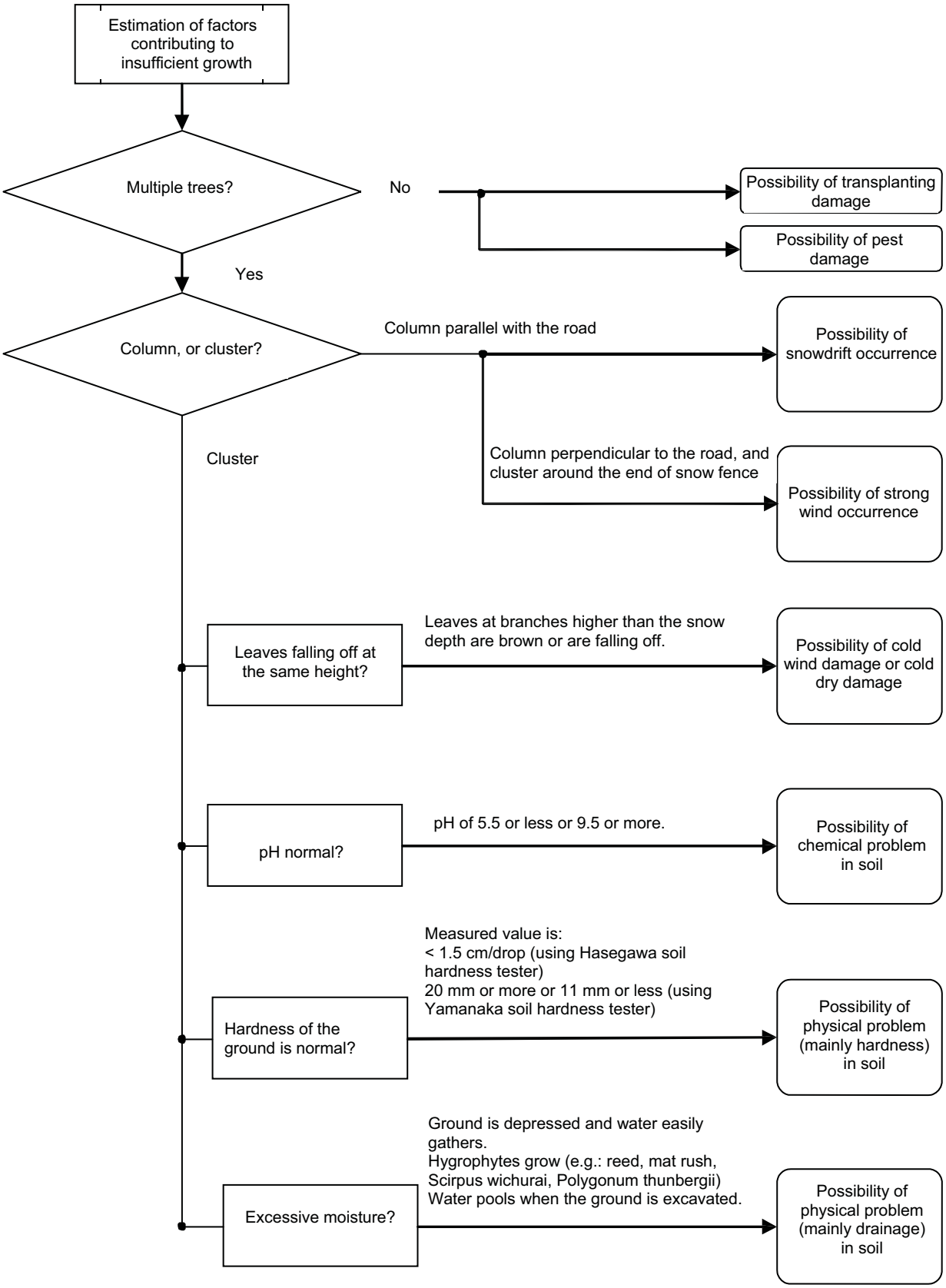


Figure 2-7-7: Flowchart for Estimating the Factors Contributing to Bad Growth during the Nursery Period

2-5 Improvement cutting and cutting of vines

Depending on tree species, improvement cutting should be done for a certain period until canopy closure has been completed.
Vines are cut as needed during inspection.

Table 2-7-8: Remarks for Improvement Cutting

Period of improvement cutting	Until canopy closure has been completed; for conifers, until neighboring tree branches cross*
Trees needing improvement cutting	Bad growth trees and damaged trees
Month of improvement cutting	June - August

*After that, thinning is done instead for the purpose of density control.

2-6 Management of pioneer trees

If pioneer trees suppress the growth of primary trees, then the upward growth of primary trees is inhibited. To promote the growth of primary trees, upper branches are cut or pruning or thinning is done.

2-7 Annual management plan during the nursery period

For the four to five years from planting until trees grow beyond being affected by the stress caused by transplanting, management work is very important and should be done according to the annual schedule below.

Table 2-7-9: Growth Management Operations in the Nursery Period (after Sawahata)

Details of work	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Frequency	Note
Care of juvenile trees (1) Tramp down roots		↔				↔				Whenever necessary	For about two years after planting, tramp down roots after the snow melts and immediately after a typhoon or other strong wind.
(2) Right fallen trees		←	—	—	—	—	→			Whenever necessary	For about two years after planting, tramp down roots after the snow melts and immediately after a typhoon or other strong wind.
Supplemental planting		↔								Whenever necessary	Evergreen coniferous trees must be planted in spring.
Grass mowing				←	→					2 or 3 times a year	Mowing depends on how thickly weeds and other plants grow.
Improvement cutting, vine cutting (Disposal of dead or damaged trees)				←	—	→				Whenever necessary	Cutting is done until canopy closure. Remove damaged and stunted trees.

3. Management during the Rearing Period

3-1 Pruning of lower branches

The lower branches of highway snowbreak woods become buried in accumulated snow and finally break. Broken branches are prime entry points for infestation by harmful bacteria and insects. Such infestations sap the tree of its vigor. As a preventive measure, the lower branches should be pruned. Pruning should not be done at the edge of the woods, because lower branches are necessary for snow control.

3-2 Density control (thinning)

The death of the lower branches of highway snowbreak woods allows snow to blow under the trees, thereby detracting from snow control. The purpose of density control of highway snowbreak woods is to maintain a certain foliage density of lower branches. For this purpose, thinning usually is not done until neighboring branches of trees touch each other.

3-3 Management of support posts

Support posts are temporary structures used until planted trees grow sufficiently, and they are removed at the appropriate time.

Photo 2-7-13: Damage to trunks (left: from delayed removal of a tie; right: from delayed removal of a support post)

3-4 Evaluation of growth during the rearing period, and estimation of factors contributing to bad growth and countermeasures

Tree growth is evaluated by inspection and observation. If a decline in snow control from insufficient growth or the death of lower branches is found, the causes should be determined and appropriate countermeasures should be taken.

3-5 Transplantation

Trees showing a decline in snow control from insufficient growth and the death of lower branches during the rearing period that is judged to be irreversible are to be replaced.

4. Management during the Maintenance Period

4-1 Time for commencing rejuvenation

To prevent rejuvenation work from detrimentally affecting the function of highway snowbreak woods, the appropriate time for commencing the work should be determined on the basis of estimates on processes of the aging and death of first-generation trees and the growth rate of successional trees.

4-2 Method of rejuvenation

Successional trees shall be planted in an empty place where a row of antecessor trees was felled for density control.

5. Maintenance against Damage

5-1 Measures against field mice

It is difficult to combat massive outbreaks of field mice. It is important to create an unwelcoming living environment for field mice and to take preventive measures based on pest forecasts.

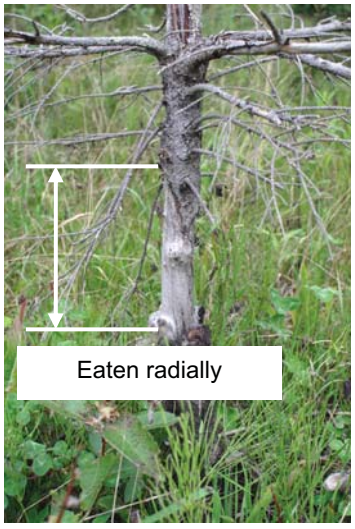


Photo 2-7-16: A Norway Spruce Killed by Field Mouse Predation

5-2 Measures against damage by insect pests

It is difficult to take preventive measures against damage by insect pests. Therefore, it is important to maintain the healthy growth of planted trees, to recognize such damage early on, and to exterminate such pests at the first sign of damage.

5-3 Dealing with wind-toppled trees

Trees tilted or blown down by strong winds lean against neighboring planted trees, causing the neighbors to topple. Furthermore, such trees usually damage the apical buds of other trees and hinder their growth. For this reason, wind-toppled trees are dealt with immediately.

6. Maintenance Work Common to Each Phase

To create highway snowbreak woods whose ability to control snow emerges early and persists, it is necessary to continue to observe tree conditions and to conduct appropriate maintenance as well as knowing the background of installation. Accordingly, it is important to keep maintenance records and to execute inspection patrols.

Table 2-7-11: Things to be Checked during Inspection Patrols

Phase	Spring	Summer
Early period of nursery	Transplanting damage, uprooting and toppling caused by snow accumulation, and damage by field mice	Growth suppression by herbaceous species, degree of growth (refer to Table 2-7-3), and insect pests
Mid period of nursery	Uprooting and toppling caused by snow accumulation, breakage by snow, and damage by field mice	Growth suppression caused by invading trees and advance-growth trees, degree of growth (refer to Tables 2-7-4 and 2-7-5), and insect pests
Rearing period	Lower branches torn off by snow accumulation	Branches crossed with neighboring planted trees' branches, degree of growth (refer to Table 2-7-8), and insect pests (A support post is judged to be necessary.)
Maintenance period		Death of lower branches, and insect pests

Volume 3: Snow Fences

Chapter 1: General Provisions

1. Objective

Volume 3 describes general technological standards and basic ideas for the purpose of simplifying the necessary operations, unifying design concepts and improving designs in connection with planning, designing, constructing and maintaining snow fences that are used to control snowdrifts and snowstorm-induced visibility hindrance.

2. Scope of Application

Volume 3 is presented for application to snow fences used for blowing-snow control on general roads developed by the Hokkaido Development Bureau. This section is intended for blowing-snow control facilities on highways whose development or improvement is the responsibility of the Hokkaido Development Bureau.

Chapter 2: Definition and Characteristics of Snow Fences

1. Definition of Snow Fences

Snow fences are blowing-snow control facilities that consist of sheet steel snowbreak fins. They are built to prevent snow from drifting onto the road and to mitigate visibility hindrance by controlling the direction and velocity of wind in front of and behind the fences (windward and leeward of the fence).

The part of a route where drifting snow particles or snow accumulation hinders traffic should be installed with snowsheds, snow removal ditches, snowmelt facilities or similar facilities that are specified by a ministerial ordinance of the Ministry of Land, Infrastructure, Transport and Tourism." (Paragraph 1 of Article 33 of Government Order on Road Design Standards). Such facilities are defined as snowdrift control facilities or avalanche control facilities.

The part of a route where there is the possibility of snowdrifts forming due to the particular topography, weather, etc., should be installed with snowdrift control facilities (and poor visibility control facilities) such as snow shelters, snow fences and snowbreak woods appropriate to the road alignment, cross-sectional profile and other road structure.

2. Background of Snow Fences

2-1 Background of Snow Fences

In Japan, snow fences for roads were first tested in 1961. Since then, tests and development have been conducted according to Japanese road conditions.

2-2 Current conditions of snow fences

As of 2009, snow fences had been installed along 300 km of national highways throughout Hokkaido.

3. Snow Fence Types and Characteristics

3-1 Traditional collector snow fence

The traditional collector snow fence is installed on the windward side of the road to reduce the wind velocity and cause blowing snow to deposit in front of and behind the fence (windward and leeward of the fence), so as to prevent suspending/drifting snow particles from blowing onto the road and snowdrifts from forming on the road.

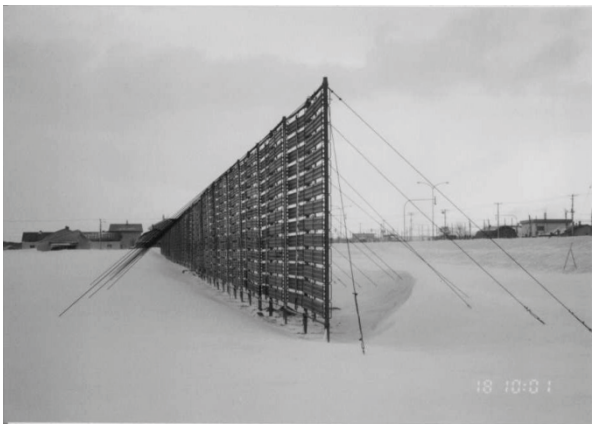


Photo 3-2-1: Traditional Collector Snow Fence

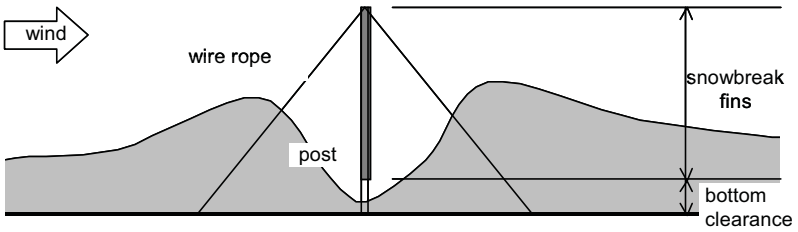


Figure 3-2-3: Structure of Traditional Collector Snow Fence

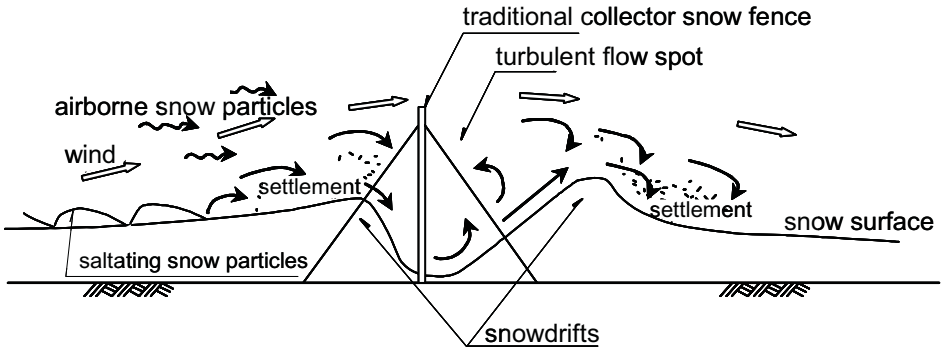


Figure 3-2-4: Windward and Leeward Drifts of Saltating Snow

3-2 Collector snow fence

The collector snow fence is similar to the traditional collector fence, but different in structure. To hold greater volumes of snow on the windward side and to increase the upwind snow control capacity, it is taller than the traditional collector snow fence, has a smaller void ratio and has no gap in the bottom part. Because the collector snow fence settles much of the suspending/drifting snow particles on the windward drifts, its leeward drifts are small. It can be built within the right of way, and windbreak performance on the road can be expected. This type of fence shows a synergistic effect of snow control and windbreak, and thus it greatly mitigates visibility hindrance.

Photo 3-2-2: Collector Snow Fence

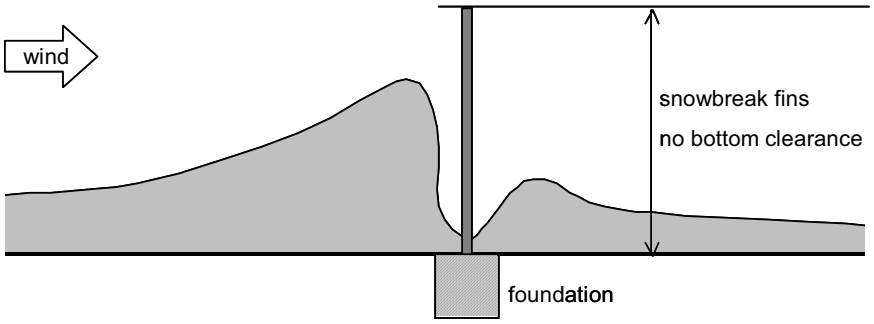


Figure 3-2-9: Structure of Collector Snow Fence

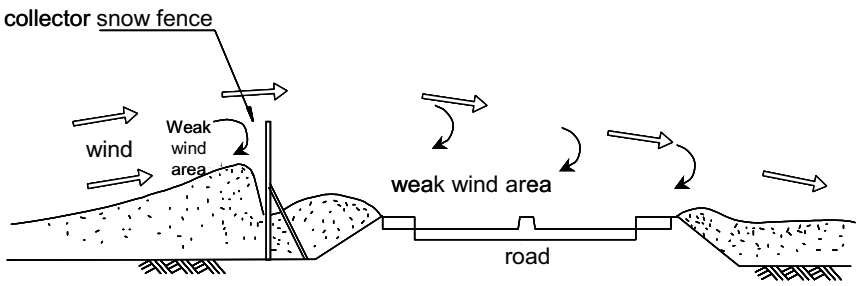


Figure 3-2-10: Snow-control Mechanism of Collector Snow Fence

3-3 Solid barrier

The solid barrier was chiefly developed to prevent snowdrifts and mitigate visibility hindrance caused by winds that blow up slopes in mountainous regions. It is a kind of collector snow fence that holds suspending/drifting snow particles on the windward side and reduces the wind velocity on roads.

Photo 3-2-3: Solid Barrier

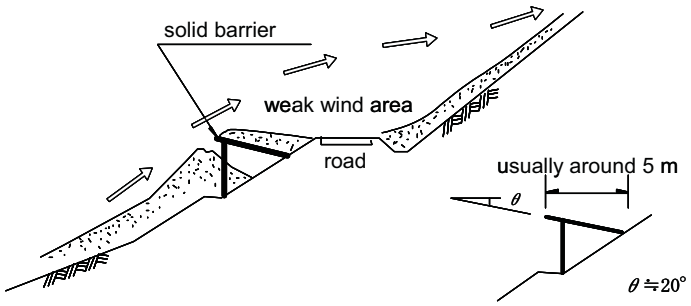


Figure 3-2-11: Installation of Solid Barrier

3-4 Blower snow fence

A blower snow fence is a snow control facility that prevents visibility hindrance. Its snow control fins retard the wind, and snow on the roadside and the surface is blown away by the strong wind that is accelerated after passing through the gaps in the bottom of the fence.

Photo 3-2-4: Blower Snow Fence

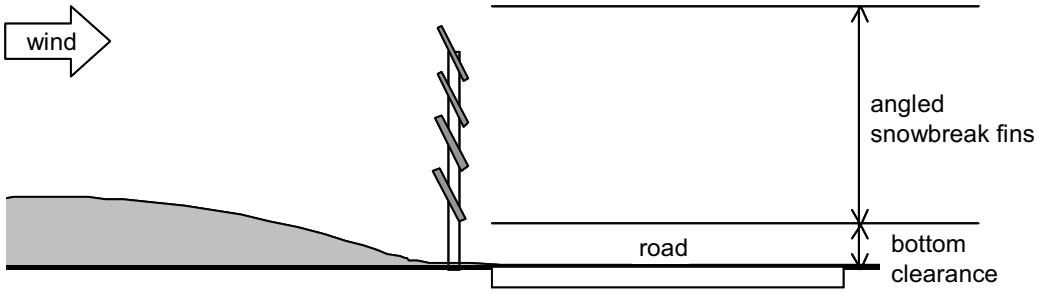


Figure 3-2-12: Structure of Blower Snow Fence

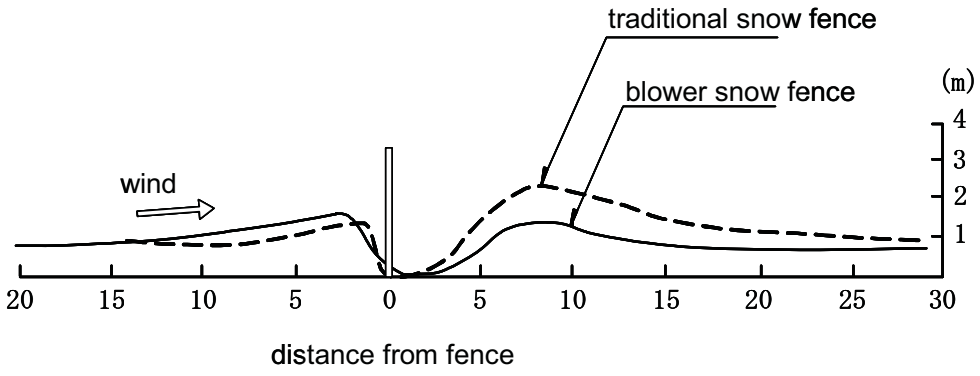


Figure 3-2-13: Windward and Leeward Drifts: Comparison between Blower Snow Fence and Traditional Collector Snow Fence (created based on Fukuzawa et al.)

Chapter 3: Master Plan for Snow Fences

1. Procedure for Formulating a Master Plan for Snow Fences

A master plan for snow fences is made in the phase of the basic survey and analysis that follows the general study of snow control measures. The following items are determined in the master plan.

(1) Types of snow fences to be installed.
(2) The range to be covered by the snow fences;

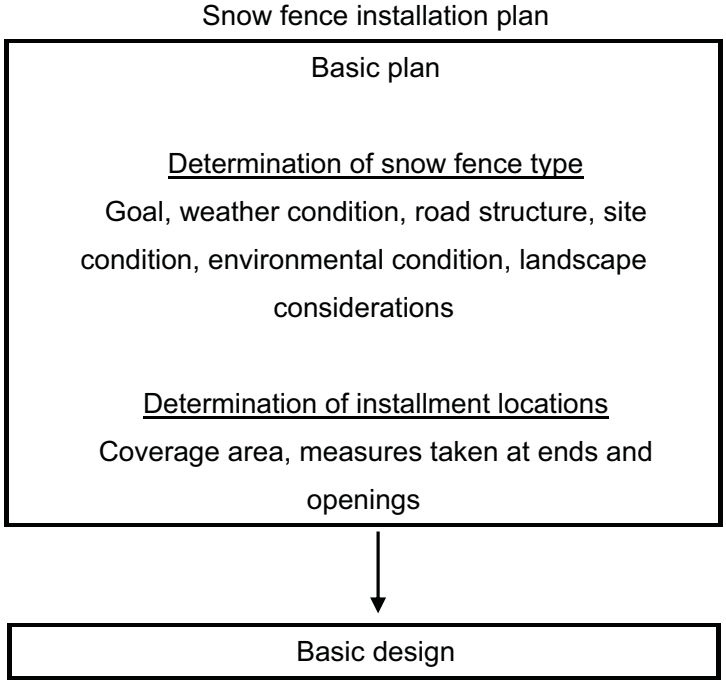


Figure 3-3-1: Procedure for Formulating a Basic Plan of Snow Fences

2. Selecting Appropriate Types of Snow Fences

The appropriate type should be chosen in accordance with snow-control purposes, as shown in Table 3-3-1. Comprehensive estimation of weather conditions, road structures, topographic conditions, environmental conditions and costs is also needed for final decision.

Table 3-3-1: Adequacy of Snow Fences with Respect to the Purposes of Snow Control

Snow control target	Type of snow fence			
	Traditional collector snow fence	Collector snow fence	Blower snow fence	Solid barrier
Snowdrift	Suitable	Suitable	Unsuitable	Used to mitigate visibility hindrance and snowdrifts caused by wind blowing up slopes in mountainous regions
Poor visibility	Careful examination needed	Suitable	Suitable	

Table 3-3-2: Applicability of Various Snow Fences according to Weather Conditions

Weather conditions		Type of snow fence			
		Traditional collector snow fence	Collector snow fence	Blower snow fence	Solid barrier
Maximum snow depth	Less than 100 cm	Suitable	Suitable	Suitable	Suitable
	100 to 150 cm	Suitable	Suitable	CEN*	Suitable
	150 cm or more	Suitable	Suitable	Unsuitable	Suitable
Wind velocity during snowstorm	Stable and strong	Suitable	Suitable	Suitable	Suitable
	Weak	CEN*	Suitable	Unsuitable	Suitable
Angle of prevailing wind direction	Almost perpendicular	Suitable	Suitable	Suitable	Suitable
	About 45 degrees	CEN*	Suitable	CEN*	CEN*
	Almost parallel	Unsuitable	CEN*	Unsuitable	CEN*
	No fixed pattern	CEN*	CEN*	Unsuitable	CEN*
Amount of snow settled at snowdrifts	Less than 40 m^3/m	Suitable	Suitable	Suitable	Suitable
	40 to 60 m^3/m	Suitable	Suitable	CEN*	Suitable
	60 m3/m or more	Suitable	CEN*	Unsuitable	CEN*

*Careful examination needed

Table 3-3-3: Weather Conditions That Should be Considered When Installing a Blower Snow Fence

Weather conditions	Weather Conditions that Should be Considered	Remarks
Maximum snow depth	100 to 150cm (examination required)	It is probable that the bottom gap will be buried. Snow plowing and hauling at the bottom clearance are required.
	150cm or more (prohibited)	It is likely that the bottom gap will be buried and snow plowing will be difficult. For that reason, a blower snow fence should not be installed.
Wind velocity	Low wind velocity during snowstorm (prohibited)	Because a stable flow of wind over the road surface cannot be achieved, the blower snow fence does not properly fulfill its function. For that reason, a blower snow fence should not be installed.
Angle with prevailing wind direction	About 45 degrees (examination required)	It is necessary to determine whether snow control extends to all the lanes. If not, a blower snow fence should not be installed.
	Almost parallel (prohibited)	Because effective snow control cannot be expected, a blower snow fence should not be installed.
	Snow blowing from the non-prevailing wind direction (prohibited)	Where blowing snow from the non-prevailing wind direction may occur, a blower snow fence should not be installed because it exacerbates the snow control problem.

Table 3-3-4: Applicability of Various Snow Fences according to Road Structure

Site condition	Road structure (on the side of the prevailing wind direction)	Type of snow fence			
		Traditional collector snow fence	Collector snow fence	Blower snow fence	Solid barrier
Type of earthwork	High embankment	Unsuitable	Suitable	Suitable	
	Low embankment to high embankment	Careful examination needed	Suitable	Suitable	
	Lower than low embankment	Suitable	Suitable	Suitable	
	Cut	Careful examination needed	Careful examination needed	Unsuitable	
	Deep cut	Unsuitable	Unsuitable	Unsuitable	
Slope in mountainous area	Slope on one side	Unsuitable	Careful examination needed	Unsuitable	Suitable
Wide road (multiple lanes)		Suitable	Suitable	Unsuitable	Careful examination needed

3. The Range Covered by Snow Fences and the Measures Taken at Ends and Gaps

3-1 The range covered by snow fences

3-2 Measures taken at ends and gaps

At ends and openings of snow fences, visibility hindrance often occurs due to drifting/saltating snow from the windward direction. Particularly near a collector snow fence with a small void ratio, visibility becomes locally poor or changeable due to drifting/saltating snow carried on converging wind currents. Where such visibility hindrance occurs frequently, countermeasures should be examined according to need. Local variations in visibility cause differences in the traveling speed of vehicles; thus, countermeasures should be determined in the light of the traffic conditions, such as the traffic volume, and accident history.

Chapter 4: Basic Design of Snow Fences

1. Procedure for Basic Design of Snow Fences

Basic design is implemented in a detailed study of snow control measures following the master plan for snow fences. After the confirmation of the types of snow fences to be installed, the following items are determined.

(1) The specifications of the snow fences (height, fin, gap at the bottom of the fence); and
(2) The locations for installing the snow fences (distance from the shoulder).

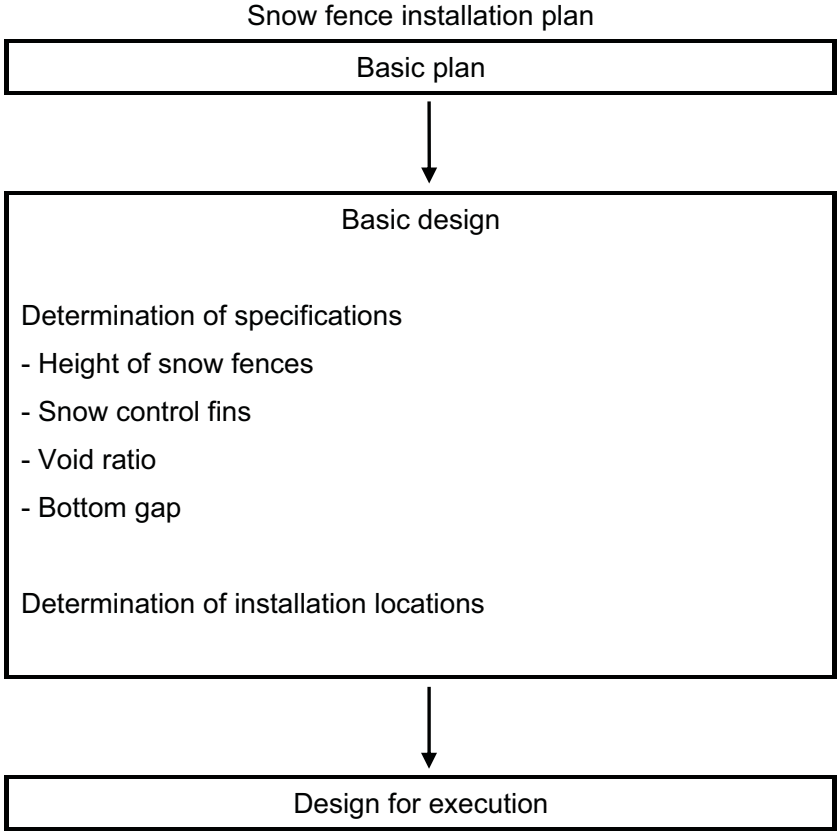


Figure 3-4-1: Procedure for Basic Design of Snow Fences

2. The Height of Snow Fences

The snow fence height is determined according to indices such as the volume of snow expected to accumulate in snowdrifts and the depth of the accumulated snow. Regarding the volume of snow accumulated at snowdrifts and the depth of accumulated snow, the maximum values of 30-year probability are used in principle.

2-1 Traditional collector snow fence

The height of a traditional collector snow fence is determined according to Figure 3-4-2 on the basis of the depth of accumulated snow and the volume of snow settled at snowdrifts on site. The standard height shall be 5.0m or less.

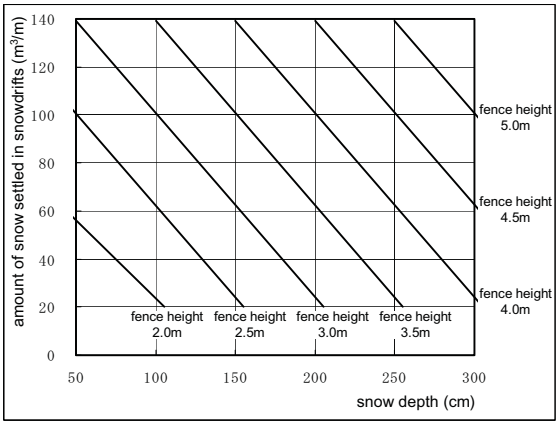


Figure 3-4-2: Relationship between Snow Depth, Volume of Snow Settled in Snowdrifts, and Height of Traditional Collector Snow Fence (Assuming a Snow Fence with a Void Ratio of 25%)

2-2 Collector snow fence

The height of a collector snow fence is determined using Figure 3-4-3 on the basis of the depth of accumulated snow and the amount of snow settled at snowdrifts on site. The standard height shall be 5.0m or less.

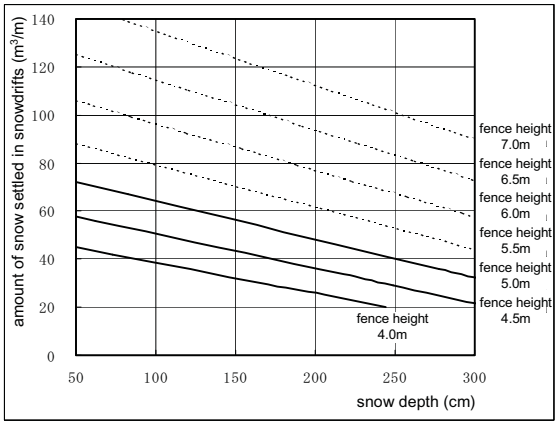


Figure 3-4-3: Relationship between Snow Depth, Volume of Snow Settled in Snowdrifts, and Height of Collector Snow Fence

2-3 Blower snow fence

The height of a blower snow fence will be determined by the length covered by the fence and the road width.

2-4 Solid barrier

The standard height of a solid barrier is about 5.0m.

3. Installation Location for Snow Fences

3-1 Traditional collector snow fence

The height of a traditional collector snow fence is determined such that the volume of snow settled at snowdrifts at the site is equivalent to the snow control capacity of the fence (Figure 3-4-6:). The location of a traditional collector snow fence to be installed is at a distance equivalent to extension of leeward drift L(m) from the edge of the shoulder. The extension of leeward drift L(m) is determined by the equation below.

$$L = (9+0.46 \cdot P) \cdot (H-Hs) \quad \text{.....(Equation 3-4-3:)}$$

Where, P = Void ratio (%), H = Fence height (m) and Hs = Snow depth on level ground (m).

Regarding the volume of snow accumulated at snowdrifts and the depth of accumulated snow, the maximum values of 30-year probability are used in principle.

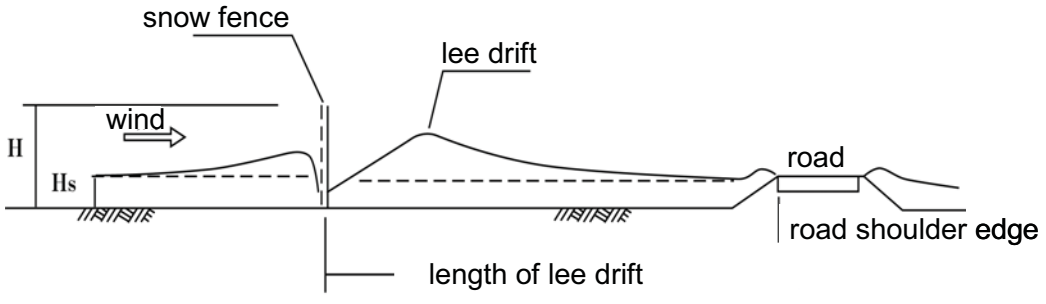


Figure 3-4-6: Length of Leeward Drift at the Snow Fence

3-2 Collector snow fence

A collector snow fence is built close to the road, in principal, and its location is determined such as to leave sufficient space for snow piles given the road structure, weather conditions and construction conditions.

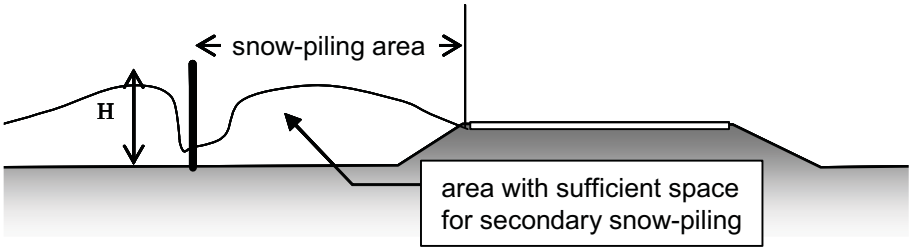


Figure 3-4-7: Location of a Collector Snow Fence

Building Snow Fences at a Road Built on a High Embankment

When a snow fence is built at a road built on a high embankment, the differences in the heights between the fence and the road surface and between the fence and the flat ground on the windward side of the road should be taken into account. The fence height should take into account height differences (road relative to flat land) and expected snow control functions, as follows:

(1) The fence height above the flat land at the roadside: Relevant to snow control capacity and prevention of blowing snow; and

(2) The fence height above the road surface: Relevant to windbreak and improvement of poor visibility on the road, and prevention of snow blowing from snowbanks along the road.

3-3 Blower snow fence

It is desirable that a blower snow fence be built as close as possible to the roadway, without encroaching on the clearance limit.

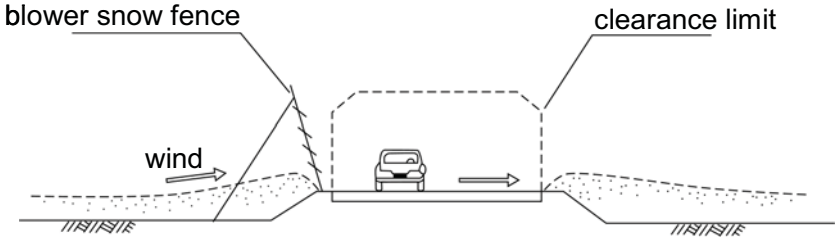


Figure 3-4-9: Location of a Blower Snow Fence, and Clearance Limit

3-4 Solid barrier

The installation location for a solid barrier should be lower than the edge of the road, as low as the maximum depth of accumulated snow at the site. Regarding the depth of accumulated snow, the maximum values of 30-year probability are used in principle.

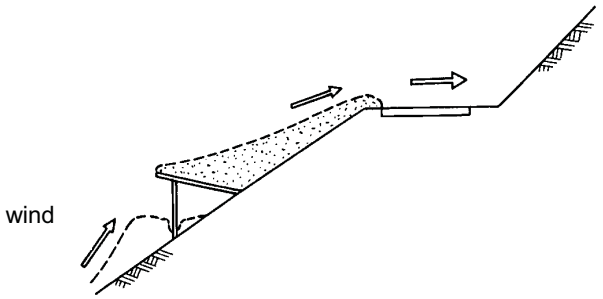


Figure 3-4-11: Location of Solid Barrier: Too Far from the Road

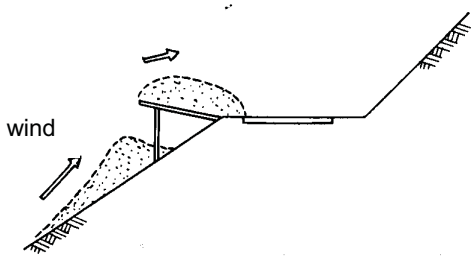


Figure 3-4-12: Location of Solid Barrier: Too Close to the Road

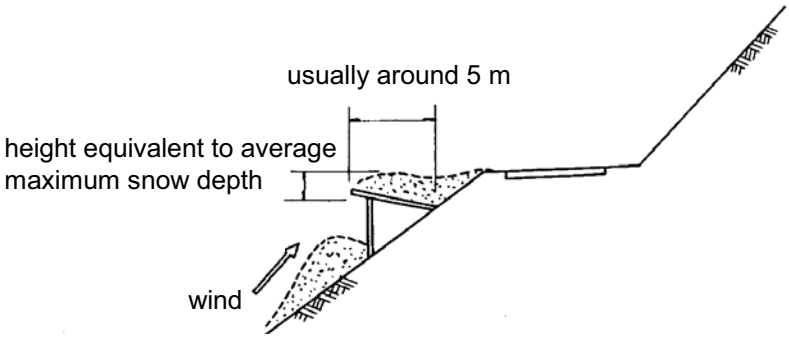


Figure 3-4-12: Proper Location of Solid Barrier

4. Snow Control Fins

4-1 Void ratio

The standard void ratio for each type of snow fence is as shown below, and it is decided in view of installation purpose (snowdrift countermeasure or visibility hindrance countermeasure), the extension of leeward drift, and the distance between the fence and the road. Each of the void ratios below indicates a ratio of voids excluding those at the bottom gap to the total area of the fence (projected area) (Figure 3-4-14).

Traditional collector snow fence ..... 25 to 30%
Collector snow fence .....0 to 10% (30% is desirable for the upper part of the fence)
Blower snow fence ..... Void ratio is irrelevant in general.
Solid barrier 0%

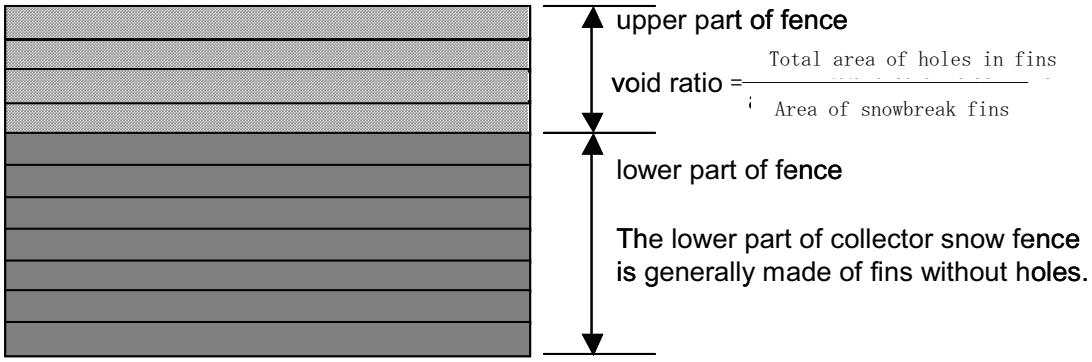


Figure 3-4-14: Void Ratio Calculation of Snow Fence (Collector Snow Fence)

4-2 Structure of the snow control fin in a collector snow fence

The standard structure of the snow control fin in the collector snow fence is as described below, and it is determined in light of the local conditions of road and weather.

(1) A half to two thirds of the height of the fence shall be void-free fins.
(2) A half to two thirds of the height of the fence shall be perforated fins with a void ratio of about 30%.

5. Gap in the Bottom Part

The standard gap in the bottom part of each snow fence is as described below, and it should be determined in view of the extension of leeward drift, and the depth of accumulated snow. Regarding the depth of accumulated snow, the maximum values of 30-year probability are used in principle.

Traditional collector snow fence ..... 50 to 60cm
Collector snow fence 0cm
Blower snow fence ..... 90 to 120cm
Solid barrier 0cm

Chapter 5: Detailed Design of Snow Fences

Detailed design is intended to decide type, materials, structural details, etc. of snow fences in view of their installation purpose (snowdrift countermeasure or visibility hindrance countermeasure), installation location, neighboring land features, design conditions including various loads (wind load, snow load, earth pressure load) and the bearing capacity of foundation, difficulty of construction and maintenance, and construction cost.

1. Design Wind Velocity

The design wind velocity of a snow fence is determined using the following equation, in which the basic wind velocity is multiplied by the horizontal extension correction coefficient.

$V = V_T \cdot u_2$ ····· (Equation 3.5.1)

Where, V = Design wind velocity (m/s) of the snow fence at the site
V_T = Basic wind velocity (m/s),
andv_2 = Horizontal extension correction coefficient (here set at 1.21).

The basic wind velocity is an expected value for a recurrence interval of thirty years at an observation point near the installation location. The design wind velocity should be 50m/s for a fence that is installed at the roadside or close to the roadside and whose toppling may results in a severe accident or traffic hindrance.

2. Design Loads

In designing snow fences, the wind load and the snow load should be accounted for.

(1) Wind load

The wind load that is perpendicular to the fence and affects in the horizontal direction is calculated as follows:

$$P_w = C_d \bullet \frac{1}{2} \bullet \rho_a \bullet V^2$$ ····· (Equation 3.5.2)

Where, P_W = Wind pressure force (N/m^2), C_d = Wind pressure coefficient (= 1.2), ρ_a = Air density (kg/m^3, usually 1.23) and V = Design wind velocity (m/s).

(2) Snow load

The snow loads in the following three conditions are taken into consideration:

a: Bracing material is pulled perpendicularly by the settlement force of accumulated snow.

When snow accumulates to a great depth and buries bracing members such as wire stays and steel pipes, a vertical force acts on the bracing members due to the settlement force of accumulated snow, and tensile force and bending force sometimes causes these to break. For fences subject to such eventuality, the settlement force of accumulated snow should be investigated in advance.

b: A fence installed on a slope is affected by the pressure of sliding snow.

When it is determined that a fence installed on a slope is subject to the pressure of sliding snow, the pressure should be considered as snow load. (For solid barriers, the pressure of sliding snow is not usually considered.)

c: The snow load acting on the snow accumulated on the roof member of a solid barrier.

3. Design Conditions

The soil pressure constant and other constants used in the design of snow fences are determined under the local soil conditions. The allowable stress of steel for wind load is considered to be a short-term stress.

(1) Constants used in calculating soil pressure and the like

In principle, the constants used in calculating soil pressure and the like are determined by means of local ground conditions and soil tests using the actual backfill material.

(2) Allowable stress

The allowable stress of a steel or concrete member from wind load is considered to be the short-term allowable stress. The short-term stress is set by multiplying the long-term allowable stress by an overdesign factor. The allowable bearing capacity is determined based on the ground conditions and other features of the site. The short-term allowable bearing capacity is set at 1.5 times the long-term allowable bearing capacity (normal value) except for soft ground.

4. Materials

Materials used for snow fences must be sufficiently strong, and their quality and configuration should be of suitable durability and workability.

5. Design of Each Member

(1) Snow control fin

The strength is calculated under the wind load condition. In calculation, the wind load is regarded as a uniformly distributed load.

(2) Support posts

For a traditional collector snow fence, collector snow fence and blower snow fence, the strength of support posts is calculated under the condition that the wind load affecting the snow control fins acts on the fin attachment to the post. Regarding solid barriers, the strength of support posts is calculated under the condition that the load of accumulated snow acts on the support. When a molded fin is attached to the support posts to form a beam, the wind load acting on the support posts is regarded as uniformly distributed load.

(3) Bracing member

Two forces affect the bracing member: the force of bearing capacity the support posts acted on by the wind pressure, and the settlement force of accumulated snow when the bracing members are buried in the snow. The larger the angle between the bracings and the support posts is, the more effective the bracings are. The angle between bracings and support posts is usually 30 to 45 degrees, because large angles are disadvantageous in terms of settlement force.

(4) Foundation

The size and depth of the foundation are determined in light of the force and the soil pressure affecting the support posts and the bracings, and the bearing capacity of the bottom surface of the foundation.

Chapter 6: Construction of Snow Fences

1. Construction Procedure

Snow fences shall be constructed as shown in Figure 3-6-1.

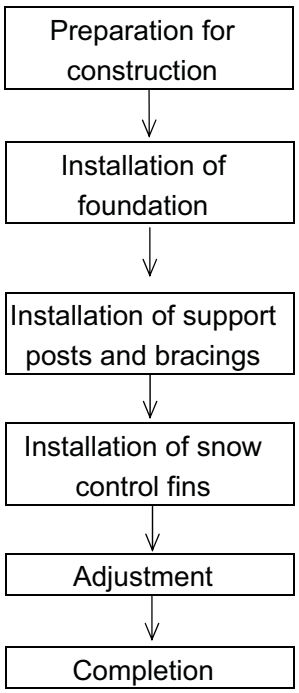


Figure 3-6-1: Construction Procedure

2. Points of Concern

In the construction of snow fences, construction techniques should be examined to select the one that suits each type of member. Because the foundation works influence the stability of the entire snow fence, it is particularly important to understand the properties and the conditions of the ground and to give sufficient consideration to construction of the foundation.

Chapter 7: Maintenance and Management of Snow Fences

1. Inspection and Maintenance

After snow fences are constructed, an inspection ledger should be prepared as a continuous record of necessary information. This ledger should be maintained and used for maintenance and repair according to need. Snow fences are inspected with respect to the following points:

(1) Damage
(2) Snow control effect
(3) Surrounding conditions, such as topography and vegetation

1-1 Inspections

Snow fence inspection shall be done to confirm that the fences are functioning effectively. These observations serve as the basis for future repair. In addition to inspection done upon routine highway patrol, it is desirable that a detailed inspection be implemented twice a year. After a snowstorm, a timely inspection should be done to observe damage to snow fences and the conditions of snowdrifts around the fences.

1-2 Maintenance of snow fences

There are two important points regarding the maintenance of snow fences: retention of the snow control function, and maintenance and repair. It is critical that snow fences be inspected to determine whether they are functioning effectively, have any structural problems, and can be appropriately maintened and repaired as the need arises. This will ensure their snow control efficacy.

2. Repairs

It is desirable that snow fences be regularly and irregularly inspected for maintenance, and that repairs be done when inspections determine them to be necessary.

3. Installation, Removal and Storage of Temporary Snow Fences

In installing a temporary snow fence, the wind direction and the topographic conditions should be examined, and care should be taken to ensure its effectiveness. This removal needs to be done carefully, so that no nuts, bolts or other small parts are lost and no members/parts are damaged. It is advisable that fences be stored indoors. When warehoused, the storage location should be according to the types of members and parts to ensure that they will be easily located for reuse.

Volume 4: Other Blowing-snow Control Facilities

Chapter 1: General Provisions

1. Objective

Volume 4 describes general technological standards for the purpose of unifying design concepts, improving designs and simplifying necessary operations in connection with planning, designing, constructing and maintaining blowing-snow control facilities other than snowbreak woods and snow fences that are used to control snowdrifts and snowstorm visibility hindrance. Such facilities include modified road structures and delineation facilities.

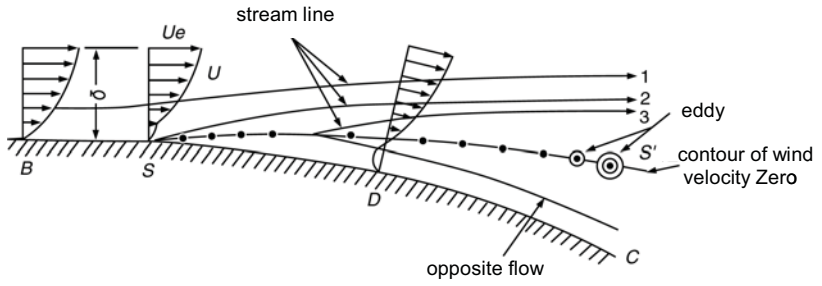
2. Scope of Application

Volume 4 addresses the installation of other facilities used for blowing-snow control on general roads developed by the Hokkaido Development Bureau.

Chapter 2: Modification of Road Structures against Blowing Snow

1. Drift-free Cut

To mitigate poor visibility and prevent snowdrifts at a cut section in an area prone to blowing snow, the drift-free cut creates stable snow cornices or snowdrifts on the cut slope by providing a gradient flatter than 1:3 on the slope that lies windward of the prevailing wind direction. It also provides a snow-piling space to decrease the height of snowbanks at the roadside.



separation of surface wind

When surface wind separates the ground surface due to changes in topography, eddies are generated and loss of shear-stress of wind causes saltating snow particles to become suspended. These particles finally deposit on the ground. (after Chang [1976])

Figure 4-2-1: Airflow at the Cut Slope (Schematic)

Photo 4-2-1: Drift-free Cut

(2) Slope length of drift-free cut

Determine the slope length required for the drift-free cut, based on the amount of snow settled at snowdrifts at the site and on the slope gradient.

(3) Parallel use of drift-free cut and other blowing-snow control measures

If not enough slope length can be secured, use snowbreak woods or fences together with drift-free cut.

2. Blowing-snow Control Using a Fill

Blowing-snow control using fill is of two types.

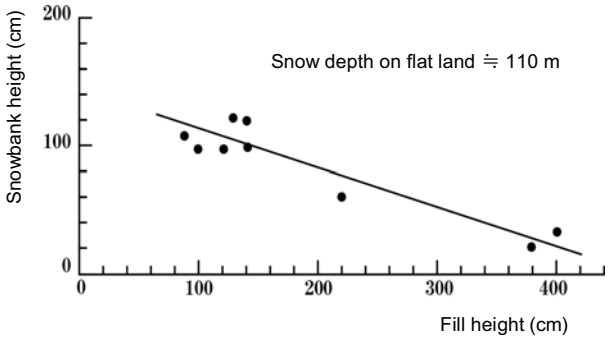
(1) Drift-control fill

(2) Fill with a gentle slope

(1) Drift-control fill

This type of fill makes it hard for snowdrifts to form on roads. It also reduces the heights of snowbanks at the roadside and thus improves poor visibility caused by snow drifting from the snowbank.

The fill height for this type should be 1.3 times the average maximum snow depth (30-year probability) at the site. If snow piled at the roadside forms banks, add the snowbank height to the fill height. However, in the case of a wide road, determine the height according to the average maximum snow depth and fill width, as the fill width also influences the size of snowbank.



Keeping the height of snowbanks lower than the height of the driver's eye line is effective in mitigating blowing-snow-induced visibility reduction. To this end, raise the fill or lower the snowbanks.

Figure 4-2-5: Height of Fill and Snowbank

(2) Fill with a gentle slope

This measure involves reducing the gradient of fill slopes to about 1:4. It is expected

1) to prevent snowdrifts from forming on roads by lowering the height reached by air that has separated at the road shoulder after blowing up from the bottom of the slope; and
2) to prevent snow particles from saltating by eliminating the need for guardrails and, thus, keeping the snow bank height at the roadside lower than it would be with guardrails.

Chapter 3: Delineation Facilities

1. Necessity and Functions of Delineation Facilities

1-1 Effect of snowstorm-induced poor visibility, and the necessity of countermeasures

In winter, drivers in cold, snowy regions normally experience snowstorm-induced poor visibility. They often experience zero visibility. During poor visibility, they rely on forward delineation facilities and other visual guidance ahead or ahead-left.

Therefore, winter roads in cold, snowy regions need poor visibility countermeasures for snowstorms as well as countermeasures for icy roads and snowdrifts.

1-2 Concept of visual guidance during snowstorm

1-2-1 Basic concept of visual guidance during snowstorm

Before the introduction of delineation facilities for snowstorms, comprehensive judgment is needed, based on an examination of the following.

(1) Visibility improvement of road markings and the road surface

(2) Development of blowing-snow control facilities such as snowbreak woods (and maintenance of existing woods) and snow fences

Additionally, it is necessary to examine the costs for development and maintenance of facilities and to consider the landscape.

1-2-2 Concept of road management standards and visual guidance

The standards of road management during snowstorm-induced poor visibility are as follows.

(1) When visibility is 50m or less, road closure is considered.

(2) When visibility is between 50m and 100m, prevention of accidents induced by poor visibility should be the goal.

(3) When visibility is 100m or more, securing smooth traffic should be the goal.

1-3 Functions of delineation facilities

Delineation facilities for snowstorms should afford the following three functions.

(1) Visual guidance of road alignment

(2) Indication of visibility range

(3) Indication of the road shoulder, to allow the driver to know the position in the lane

For winter road management, the following additional function should be provided.

(4) Assistance for safe, efficient snow removal (i.e., function of assisting snow removal).

1-4 Types of delineation facilities

1-4-1 Definitions and types of delineation facilities

Delineation facilities are road accessories that provide visual guidance to drivers and secure the safety and efficiency of snow plowing/hauling by improving the visibility of the road alignment and roadside. Types of delineation facilities for snowstorms are as follows.

(1) Delineators

(2) Snow poles

(3) Fixed-post delineators

(4) Visual guidance trees

(5) Other

There are light-emitting versions of (1), (2), and (3), to enhance recognizability at night.

1-4-2 Delineators and snow poles

(1) Delineators

Delineators are installed successively at the roadside to define the road alignment and to guide drivers' sight. There are three types for use in cold, snowy regions (Figure 4-3-3).

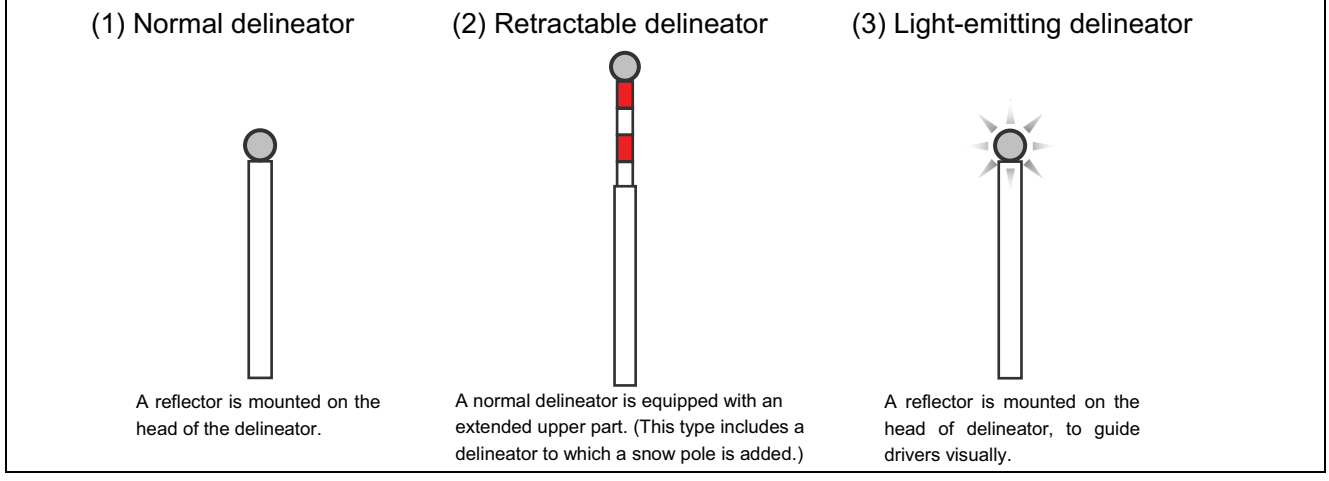


Figure 4-3-3: Delineator

(1) Normal delineator

Normal delineators are road accessories that are installed successively at the roadside to define the road alignment and to guide drivers' sight.

Photo 4-3-1: Normal Delineator

(2) Retractable delineator

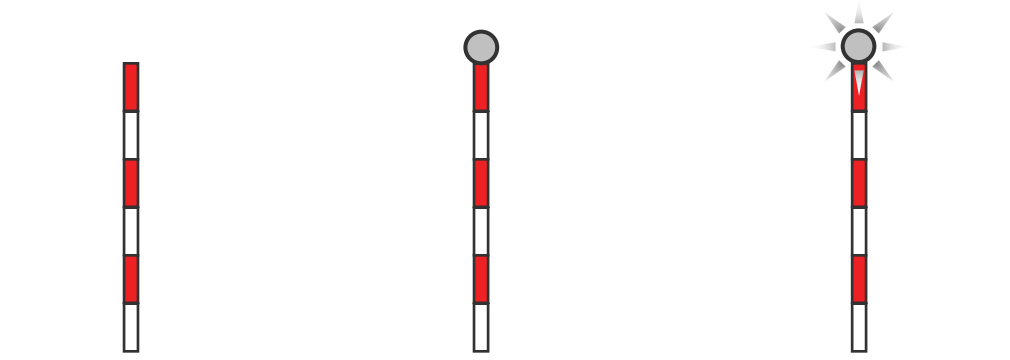
In addition to providing the delineation that a normal delineator provides, retractable delineators improve the safety and efficiency of snow removal and guide snow removal operators. The upper part of retractable delineators can be extended to adjust to roadside snow accumulation, for ease of delineation and snow removal. They are retracted in summer; therefore, they do not adversely affect the roadside scenery.

Photo 4-3-2 Retractable Delineator

(2) Snow pole

Snow poles are road accessories that are installed at the roadside in snowy regions to guide snow removal operators. There are three types (Figure 4-3-4). A light-emitting snow pole provides the same functionality as a light-emitting delineator.

(1) Normal snow pole (2) Snow pole that also serves as a delineator (3) Light-emitting snow pole



Indicating the location of the road edge, etc., it guides snow removal operators.

The head is mounted with a reflector.

The head is mounted with light-emitting equipment.

Figure 4-3-4 Snow Pole

(Color of a snow pole)

According to *Guidelines for the Design and Cons truction of Delineation F acilities*, in snowy regions, a snow pole that is added to a delineator should be white with stripes of red reflective sheet or paint.

(1) Normal snow pole

Installed at the road edge or at the edge of guard cables, these have the purposes of preventing damage to facilities and improving snow removal safety and efficiency.

Photo 4-3-3 Typical Snow Pole

(2) Snow pole that also serves as a delineator

In addition to aiding snow removal operators, it guides drivers by providing visual delineation.

Photo 4-3-4: Snow Pole That Also Serves as a Delineator

1-4-3 Fixed-post delineator with arrow-shaped pointer

Fixed-post delineators with arrow-shaped pointers are installed successively at the roadside to improve the recognizability of a road during snowstorm/snowfall, and to indicate the road width for snow removal operators (Figure 4-3-5).

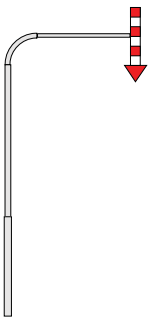


Figure 4-3-5: Fixed-post Delineator with Arrow-shaped Pointer

(Background of introduction of fixed-post delineators)
Fixed-post delineators with arrow-shaped pointers were introduced to increase the operational efficiency and speed of snow removal.

Photo 4-3-5: Fixed-post Delineator with Arrow-shaped Pointer

1-4-4 Visual guidance tree

Visual guidance trees are planted at the roadside for driver's visual guidance during snowstorm.

Photo 4-3-6: Visual Guidance Trees (National Highway 337, Ishikari)

1-4-5 Light-emitting delineation facility

A light-emitting delineation facility refers to a delineator (including a snow pole) and a fixed-post delineator with arrow-shaped pointer which is mounted with a light-emitting device to enhance recognizability at night.

1-4-6 Other delineation facilities (road lighting)

Road lighting is provided at all sections of urban streets and at intersections, pedestrian crossings, bridges and black spots at night. In addition to providing illumination, road lighting provides delineation when snow is falling or blowing. The recognizability of the road at night during snowstorms is improved by road lighting. Lighting also illuminates roadside facilities and neighboring land features that would otherwise be unrecognizable at night.

2. Planning of Delineation Facility Installation

2-1 Procedure for the planning of delineation facility installation

For a new road, at the basic survey/analysis phase of an investigation of snow-control facilities (basic design phase of snowbreak woods and snow fences), the basic plan of delineation facilities is formulated and the following items are determined, confirmed or selected.

(1) Necessity of delineation facilities
(2) Sections to be installed with delineation facilities
(3) Delineation facilities that are installed at adjacent sections
(4) Outlined selection of delineation facilities
(5) Outlined specifications of delineation facilities

Following the basic plan, design for execution of delineation facilities is conducted. During the design for execution, the following items are determined or selected.

(1) Type of delineation facility
(2) Specifications of delineation facility
(3) Power supply plan (if light-emitting)

For an existing road, the occurrence of visibility hindrance there is surveyed, and the delineation facilities installed at adjacent sections are confirmed. Then the above-mentioned plan is formulated.

2-2 Method of selecting delineation facilities

2-2-1 Selection of delineation facilities

Taking into consideration the snow conditions and the snow removal method at the section, delineation facilities are selected based on the flowchart for selecting delineation facilities against snowstorm (Figure: 4-3-6). However, the flowchart assumes normal conditions; it does not necessarily cover sections with anomalous conditions. Furthermore, for the sections where visual guidance in daytime needs to be enhanced, visual guidance trees can be installed.

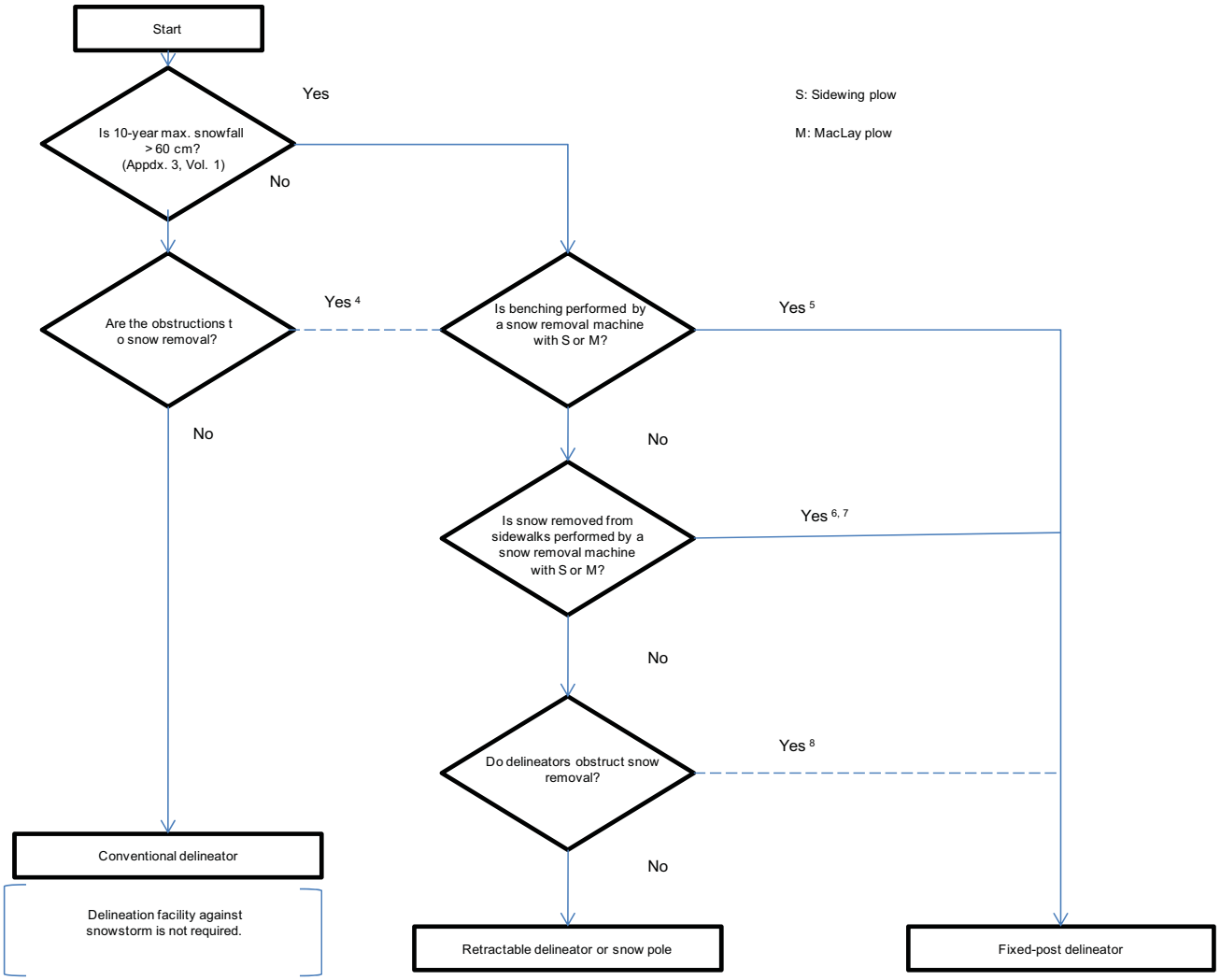


Figure 4-3-6: Flowchart for Selecting Delineation Facilities against Snowstorm

2-2-2 Criteria for the installation of snowstorm delineation facilities

Before snowstorm delineation facilities are introduced, as well as surveying the severity and frequency of snowstorm-induced poor visibility on the road, the following items should be examined.

(1) Light-emission system

(2) Development of ancillary facilities

(3) Weather conditions

(4) Road width

(5) Environmental considerations

(6) Installation and maintenance cost

2-3 Basic specifications of delineation facilities

2-3-1 Installation interval of delineation facilities

The standards of installation interval for various visual guidance facilities against snowstorm are as follows.

(1) Delineators and snow poles

Installation interval: 40m or less (At curves, consider the curve radius.)

However, if the function of general delineation is incorporated, requirements described in the *Guidelines for the Design and Construction of Delineation Facilities* should be satisfied.

(2) Fixed-post delineator

Installation interval: 80m or less (At curves, consider the curve radius.)

2-3-2 Installation location of delineation facilities

In accordance with the *Guidelines for Design and Constr uction of Delineation Facilities* and *Hokkaido Regional Dev elopment Bureau Road Desi gn Guidelines Volume 2: Road Ancillary Facilities*, the standards for installation location of various visual guidance facilities against snowstorm are as follows.

(1) Delineators and snow poles

Installation location: roadside (for light-emitting delineators, roadside or median)

(2) Fixed-post delineator

Installation location: roadside

Direction of the arrow-shaped pointer: the outside lane of roads, the front of curbs

2-3-3 Light-emission system of delineation facilities

In principle, delineation facilities should not emit light. However, use of a light-emitting system can be examined if the weather conditions on the section warrant it

2-3-4 Landscape considerations for delineation facilities

(1) Landscape considerations for routes and sections

In formulating a delineation facilities installation plan, careful thought should be given to the effects on the landscape.

The types of sections where the effects on the landscape of delineation facility installation should be given particular consideration are as follows.

(1) Sections with distinctive natural environmental features.

(2) Sections with distinctive historical resources.
(3) Sections to which neither (1) nor (2) applies, but for which consideration is otherwise needed for preserving the landscape.

(2) Landscape considerations for snowstorm delineation facilities

Landscape considerations for the introduction or renewal of delineation facilities are determined based on examples described in *The Handbook for Preserving Roadscapes in Hokkaido (Draft)*.

3. Designing Delineation Facilities

3-1 Designing delineators and snow poles

For designing delineators and snow poles, follow the *Guidelines for the Design and Construction of Delineation Facilities.*

3-2 Designing fixed-post delineators

3-2-1 Structure

For the structure and component names of fixed-post delineators, refer to *Hokkaido Regional Development Bureau Road Design Guidelines Volume 6: Standard Design Drawings.*

3-2-2 Shape and colors of arrow-shaped pointer

The standard shapes and colors of the arrow-shaped pointers of the fixed-post delineator are arrows and red-and-white stripes.

3-3 Designing visual guidance trees

3-3-1 Concept of installing visual guidance trees

Visual guidance trees are facilities that provide delineation during daytime snowstorm due to the contrast between trees and the surrounding landscape.

3-3-2 Specifications of visual guidance trees

The required specifications for visual guidance trees are as follows.
(1) Tree species: Evergreen trees
(2) Tree height: Snowbank height plus at least 1.5 m when the trees mature

3-3-3 Installation

The standards for installation of trees for visual guidance against snowstorm are as follows.
(1) Planting interval: 40 m or less
(2) Planting aligned with the road: Plant as close to the road as possible, without interfering with snow removal, mowing and other maintenance.

3-3-4 Planting method

(1) Planting method
For the planting of visual guidance trees, refer to Volume 2: Snowbreak Woods.

(2) Alleviation of snow pressure
Visual guidance trees planted on a slope should be protected by snow-pressure-resistant piles (Table 4-3-7). For the section where guardrails are installed, snow-pressure-resistant piles are not needed, because not much snow glides into trees. For the details of countermeasures to snow pressure on a slope, refer to Chapter 4, Section 4 of Volume 2, Basic Design of Highway Snowbreak Woods.

4. Maintenance of Delineation Facilities

4-1 Inspection and Maintenance

Inspection of delineation facilities is carried out during road patrols. If any problems are found, they should be repaired and other necessary measures should be taken.

4-2 Renewal

(1) Considerations for renewal

For the renewal of delineation facilities, the necessity of facilities and the appropriateness of installing light-emitting delineators should be reviewed. At that time, the following are considered.
(1) Existing blowing-snow control measures (installation of snowbreak woods/snow fences)
(2) Changes in the roadside environment (continuous buildings, growth of trees)
(3) Existing ancillary facilities (installation of guardrails/road lighting equipment)

(4) Changes in the mode of snow plowing and hauling

(5) Surrounding environment and roadscapes

(6) Facility development and maintenance costs

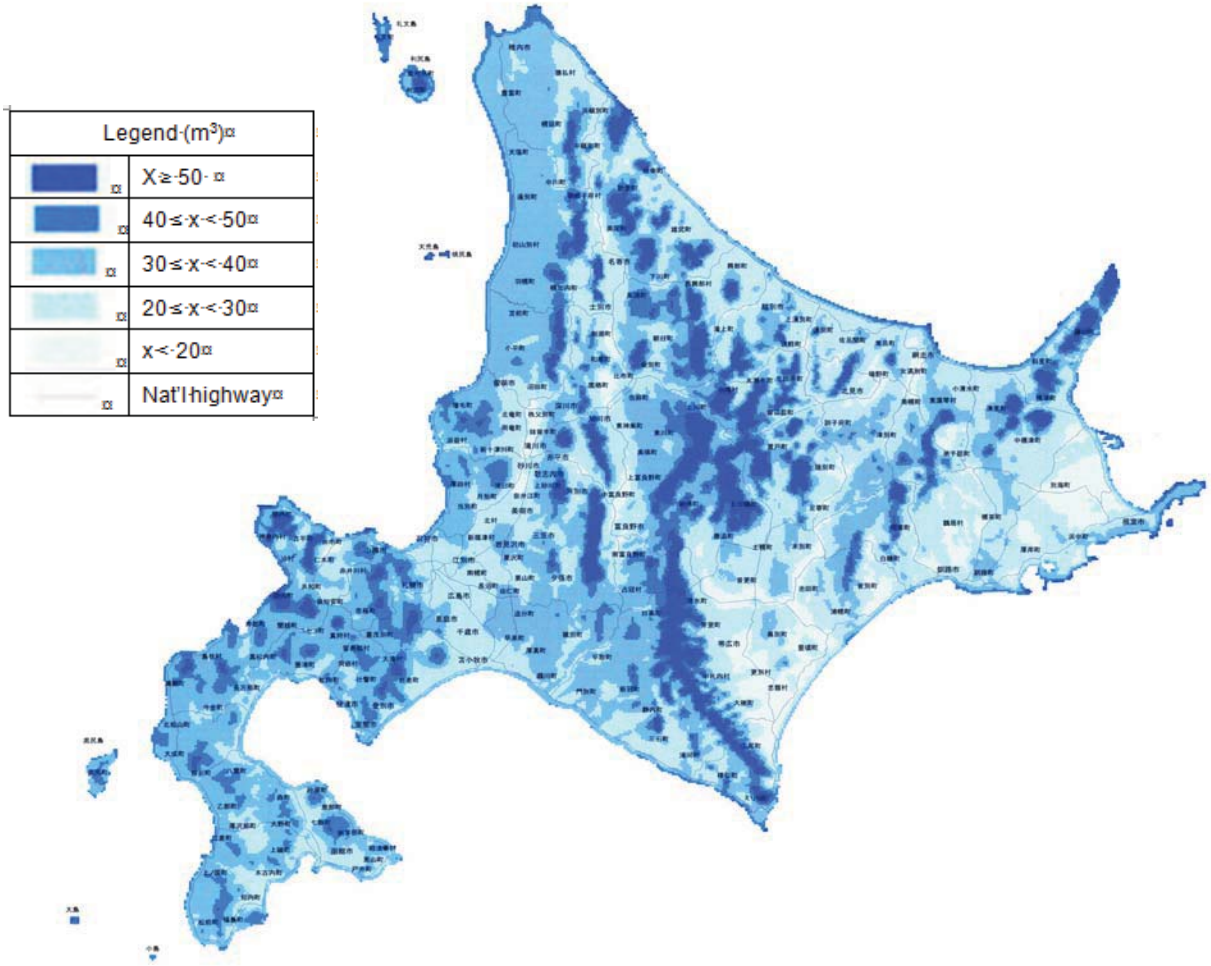


Figure 1-4-13: Volume of Snow Settled at Snowdrifts in Hokkaido

(Annual average. Statistics covering Dec. 1981 to Mar. 1996)

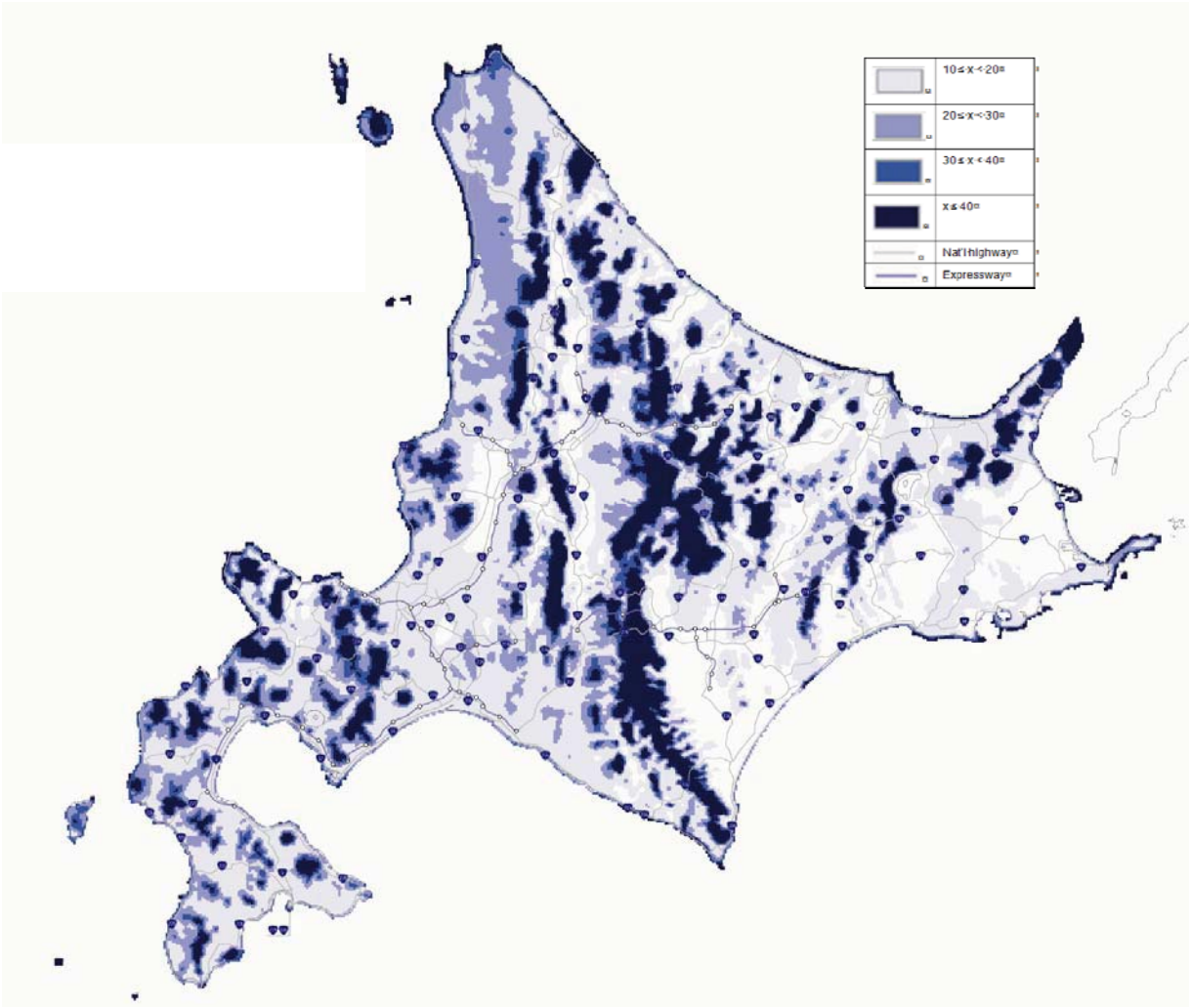


Figure 1-4-15: Distribution of Snowstorm-Induced Poor Visibility Occurrences

(Annual average. Probability of occurrence of visibility distance 200m or less. Statistics covering Dec. 1980 to Mar. 1998)

The Highway Snowstorm Countermeasure Manual

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