Chapter 13
River Ice Management Study

Section I
Study Concept

13-1. General

Operational or structural solutions to ice problems on rivers can be applied in several ways. They can be employed individually, case by case, to overcome the ice problems that are regarded as most important on a given waterway or portion thereof. This approach will solve ice problems, and in so doing, it will improve winter navigation. However, a shift of emphasis, from solving individual ice problems to maximizing the overall efficiency of winter navigation on an entire waterway, is a better technique; this results in the need for a comprehensive, system-wide approach. This system approach is essentially a planning process, culminating in the development of a River Ice Management (RIM) Plan that is unique for the waterway in question.

13-2. Objectives

The planning process works toward three objectives. First, winter navigation is to be conducted with the highest possible efficiency, approaching that of the other seasons of the year. Second, ice interruptions to navigation are to be kept as infrequent and as short as possible. Third, if a specific ice emergency does happen, all reasonable and possible ice-problem solutions will have been identified and implemented where appropriate, with the assurance that no further action could be taken to alleviate the emergency.

13-3. Elements

In the remainder of this chapter, the elements of a study leading to a River Ice Management Plan are identified and discussed briefly. Appendix C summarizes the elements in outline form. In the remaining chapters of the manual, these several elements, which include the various operational and structural solutions to river ice problems affecting navigation, are addressed in much greater detail and, in several instances, illustrated by examples.

Section II
Study Elements

13-4. River System Definition

Managing river ice is almost a basin-wide effort; so, knowing the exact configuration of the river system is very important. The primary concern is the main, navigable stem of the river. However, non-navigable reaches of the main stem that are bypassed by locks and canals are also of major interest. It is necessary to know what percentage of the flow goes through each section and what the water velocities are. The tributaries are of interest because they add ice to the system. Also to be identified are any features that affect ice passage or accumulation, e.g., channel geometry, confluences, and man-made or natural channel restrictions.

13-5. Ice Problem Identification

Proper implementation of a winter navigation plan requires that problems be identified, along with their locations and sources (see Chapter 14).

a. Certain problems are natural phenomena and are inherent to navigation during winter months. Ice jams may limit passage through a section of river. Ice accumulation in the upstream approaches at many locks causes shipping delays as vessels must wait for ice to be locked through.

b. Other problems are more directly induced by winter navigation. Ice builds up on the undersides of barges, sometimes resulting in scraping and damage to the riverbed or miter gate sills. Barges having underside ice buildup have grounded and blocked channels on the Upper Mississippi River, and the normal dredging response to a grounding is very difficult under ice conditions. Moored barges may be broken away by moving ice, resulting in damage to downstream structures. Increased traffic during periods of ice may increase bank erosion significantly.

c. The source of the ice that creates the problem needs to be identified. Possible ice sources include tributaries, upstream locks and dams passing ice, and vessels traveling out of established tracks. Once these ice problems and their ice sources are identified, an appropriate solution, whether operational or structural, can be considered. Not to be overlooked are possible future changes in the river system that may have an influence on ice formation (e.g., changes in water quality affecting freezing temperature).

d. All possible scenarios are to be considered in implementing a winter navigation plan. Past ice emergencies on the river system in question should be thoroughly examined. Emergencies have been avoided by varying operational schemes. Solutions to ice emergencies on other river systems should also be examined, so that nothing is overlooked. Once a winter navigation plan is developed, it should be analyzed with all possible ice emergencies in mind and revised as necessary.

13-6. Ice Forecasting

Forecasting river ice conditions means predicting when and where ice will form, how thick it will be, the extent of the ice cover, and how long it will last. Practically, there are two types of river ice forecasts. The first is a *Long-Term Water Temperature Forecast.* This is made (starting in the fall) to predict river water temperatures to determine when the water will reach the freezing point, making ice formation possible. The present water temperature at the time the Long-Term Water Temperature Forecast is made must be known, and a forecast of air temperatures must be made or be available. The water temperature response to changes in the air temperature can be determined by examining records of water and air temperature of previous years. This type of forecast can be made for periods of several days to several months. The second type of forecast is a *Mid-Winter Ice Forecast.* Typically, these are made for periods of a week or less, predicting the water temperature, the volume of ice that will be formed or melted, where the ice will form or melt, the extent of the river that will be covered with ice, and the ice thickness. To make a Mid-Winter Ice Forecast, the existing stages, discharges, water temperatures, and ice conditions along a river must be known. Forecasts of the air temperature, tributary discharge, and tributary water temperature must also be made or be available. Locations and amounts of possible artificial heat inputs into the river must be known. A heat balance can be determined for the river system that will indicate the volume of ice that will be formed or melted. The extent of the ice cover and its thickness are calculated using the river velocity, flow depth, and type of ice. The Mid-Winter Ice Forecast will produce forecasts of the discharge, stage, ice thickness, and water temperature at each point specified along the river. Under the RIM Program, forecasting methodologies to produce both types of forecasts were developed, and are described in greater detail in Chapter 15. Each has the ability to include real-time data provided by Corps data systems, to incorporate short-term and long-term forecasts of air temperature, and to provide the specified outputs.

13-7. Structural Solutions

Structural solutions are covered in detail in Chapter 3 and additionally in Chapter 18. In brief, they involve controlling ice by installing some type of structure or device where it will have a desired effect on either an ice cover, ice floes, brash ice, frazil ice, or ice adhering to navigation structure surfaces. The desired effect may be to divert ice away from the main channel, to prevent ice from moving out into the channel, to keep an ice cover from being broken up by wind and wave action or by ship activities, to reduce the quantities of ice passing a particular point, or to reduce the amount of frazil ice forming in a reach. In the vicinity of a navigation structure, the objective may be to block or divert moving ice from a lock entrance, to pass ice from the pool through the dam to the channel below, or to reduce or eliminate adfreezing on walls, gates, and other surfaces.

a. A common structural solution is an ice boom, which is a line of floating logs or pontoons across a waterway used to collect ice and stop ice movement (a navigable pass can be provided in the boom). The boom is held in place by a wire rope structure and buried anchors. Other solutions may use weirs or groins supplemented by booms. Artificial islands and navigation piers can also be helpful in stabilizing ice covers. The various methods for inducing a stable ice cover to form are used in locations where ice covers need to have additional stability to compensate for the disruptive forces of winter navigation or short-term weather changes.

b. Structural solutions in and around navigation projects include devices that are installed to help mitigate particular ice problems that pose a direct interference to project operation. High-flow air systems are effective in deflecting and moving brash ice away from critical locations in a great variety of circumstances. Flow inducers have also been installed in lock chambers to assist in keeping areas ice-free. Ice passage at navigation dams is made more practical by certain structural features, such as submergible dam gates, or bulkheads, which can be raised from lock chamber floors to serve as skimming weirs for passing ice. Ice accumulation on critical surfaces such as gate recess walls, strut arm roller rails, and seals can be effectively controlled by installing electrical heating devices of several specialized designs. Other proven measures for controlling ice accumulation on structure surfaces are coatings and claddings. Coatings, such as epoxies and copolymers, reduce ice adhesion forces between ice and concrete or steel surfaces. Claddings, such as high-density polyethylene, are replaceable surfaces from which ice can be chipped more easily than from concrete or steel.

c. Each of the possible structural approaches is effective for a particular ice problem. Many ice problems require a combination of structural solutions, often teamed with operational solutions, to fully mitigate the difficulties imposed by ice.

13-8. Operational Solutions

There are various operational techniques to control or mitigate ice problems at navigation projects. Thermal methods are presented in Chapter 3, Section II, with additional discussion specific to navigation projects in Chapter 18, Section III, and Chapter 19, Section III. Additionally, when lock and dam personnel apply the structural solutions as mentioned above or described in Chapters 3 and 18, these applications actually become operational techniques in themselves.

a. Moving tows in convoy, i.e., scheduling vessels to move together in large groups during periods of heavy ice conditions, has been shown to hold some promise for the navigation industry. The appeal of this to the Corps is that it can cause less ice to be produced in a winter season, and thus reduce the amount of ice that has to be locked through, diverted, or passed at a navigation project.

b. At locks and dams, the operational techniques vary from physical ice removal using various tools, to flushing ice from critical areas with towboat propwash and passing ice through the dam spillway gates. Separate lockages of ice are sometimes required to accommodate tow traffic. Maintaining high lock chamber pool levels can keep lock walls at a higher temperature than if they were exposed to cold air. As a result, ice buildup on the wall surfaces may be lessened. Careful operation of seal heaters aids substantially in reducing ice buildups at dam gates, helping to keep the gates operational.

c. Warm water discharges offer opportunities for ice suppression at certain locations. The warm water may originate from power plant cooling systems, industrial plants, or reservoir discharges. The distributions of these warm inflows influence their effectiveness in melting or weakening ice, or in maintaining open-water areas.

d. Energy from unconventional sources, such as heat from groundwater, solar heating, or wind energy, has been thought to offer promise for ice control at navigation projects. However, analyses have shown that this would be likely only in a very few restricted cases. Nonetheless, electrical heating appears to be the most efficient way to accomplish many ice control tasks at navigation projects. The key is to select the most practical source for electrical energy.

13-9. Recommended Plan

The objective of the study or system analysis, composed of the foregoing study elements, is to develop a River Ice Management Plan. In practice, it may be more reasonable to develop several alternative plans, each of which may have attractive features. While it may not be possible to apply a strict benefit–cost analysis to most ice management plans, such criteria should at least guide the choices of the feasible alternative plans from among the many variations and versions examined. Generally, it will be possible to select one of the alternative plans as the most desirable, in that it provides the highest net benefit or is most likely to eliminate chances for ice emergencies. This is then designated the Recommended Plan. The Recommended Plan may include, among other things, structural measures for improving the winter capabilities of navigation projects. For reasons of financial, personnel, and time resources, a realistic time span must be assumed to accomplish these structural improvements. Therefore, it would be most reasonable to express the Recommended Plan in terms of phases, with the individual phases chosen and ordered according to their anticipated individual benefit–cost ratios. In simple terms, as outlined in Appendix C, a system approach covering many study elements leads to a Recommended River Ice Management Plan for a given waterway or part thereof. The Recommended Plan then serves as a goal toward which subsequent operational and structural decisions lead, resulting in increased efficiency of winter navigation and the supporting operation of navigation projects.