National Cooperative Highway Research Program

NCHRP Synthesis 272

Best Management Practices for Environmental Issues Related to Highway and Street Maintenance

A Synthesis of Highway Practice

Transportation Research Board
National Research Council

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Best Management Practices for Environmental Issues Related to Highway and Street Maintenance

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Transportation Research Board
National Research Council

Research Sponsored by the American Association of State Highway and Transportation Officials in Cooperation with the Federal Highway Administration

NATIONAL ACADEMY PRESS
Washington, D.C. 1999

Subject Areas
Energy and Environment; and
Maintenance

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

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NCHRP SYNTHESIS 272

Project 20-5 FY 1996 (Topic 28-01)
ISSN 0547-5570
ISBN 0-309-06850-9
Library of Congress Catalog Card No. 98-68127

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The project that is the subject of this report was a part of the National Cooperative Highway Research Program conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council. Such approval reflects the Governing Board's judgment that the program concerned is of national importance and appropriate with respect to both the purposes and resources of the National Research Council.

The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the American Association of State Highway and Transportation Officials, or the Federal Highway Administration of the U.S. Department of Transportation.

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Transportation Research Board
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

and can be ordered through the Internet at:

http://www.nas.edu/trb/index.html

Printed in the United States of America

PREFACE

A vast storehouse of information exists on nearly every subject of concern to highway administrators and engineers. Much of this information has resulted from both research and the successful application of solutions to the problems faced by practitioners in their daily work. Because previously there has been no systematic means for compiling such useful information and making it available to the entire community, the American Association of State Highway and Transportation Officials has, through the mechanism of the National Cooperative Highway Research Program, authorized the Transportation Research Board to undertake a continuing project to search out and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

By Staff
Transportation
Research Board

This synthesis report will be of interest to state, local, and federal agency environmental and maintenance administrators, directors, supervisors, engineers, and scientists. It describes current best management practices (BMPs) for environmental issues related to road and street maintenance. The synthesis documents relevant background and recent information with regard to management practices that can help protect, preserve, or enhance the environment while at the same time allow road maintenance organizations to carry out their fundamental mission of maintenance and repair in a cost-effective manner. Information for the synthesis was collected by surveying U.S. and Canadian state and local transportation agencies and by conducting a literature search using domestic sources.

Administrators, engineers, and researchers are continually faced with highway problems on which much information exists, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered and unevaluated and, as a consequence, in seeking solutions, full information on what has been learned about a problem frequently is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to available practices for solving or alleviating the problem. In an effort to correct this situation, a continuing NCHRP project, carried out by the Transportation Research Board as the research agency, has the objective of reporting on common highway problems and synthesizing available information. The synthesis reports from this endeavor constitute an NCHRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to specific highway problems or sets of closely related problems.

This report of the Transportation Research Board describes BMPs consisting of broad management approaches applicable to the entire maintenance program or to more than one program area. In addition, BMPs for specific maintenance activities or groups of maintenance activities are included. Finally, BMPs concerning specific environmental issues are discussed.

This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

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ACKNOWLEDGMENTS

William A. Hyman, Management Consultant, Silver Spring, Maryland and Donald Vary, Cambridge Systematics in Washington, D.C. collected the data and prepared the report.

Valuable assistance in the preparation of this synthesis was provided by the Topic Panel, consisting of John P. Burkhardt, Administrator, Department of Public Works, City of Indianapolis; John F. Conrad, Assistant Secretary for Field Operations Support, Washington State Department of Transportation; Bruce L. Johnson, CHMM, Unit Supervisor, Compliance & Investigation, Office of Environmental Services, Minnesota Department of Transportation; Brad Lamb, Regional Nonpoint Source Program Coordinator, U.S. Environmental Protection Agency, Region 6; Frank Lisle, Engineer of Maintenance, Transportation Research Board; Wayne G. McCully, Ph.D., Range Scientist, Texas Transportation Institute; Emilia Rodrigues, P.E., Director, Maintenance and Traffic Branch, Department of Transportation, New Brunswick; Carol MacQuarrie, Environmental Engineer, Department of Transportation, New Brunswick; and Robert W. Tatman, Administrative Officer, Environmental Programs, Ohio Department of Transportation.

This study was managed by Stephen F. Maher, P.E., Senior Program Officer, who worked with the consultant, the Topic Panel, and the Project 20-5 Committee in the development and review of the report. Assistance in Topic Panel selection and project scope development was provided by Sally D. Liff, Senior Program Officer. Linda S. Mason was responsible for editing and production.

Crawford F. Jencks, Manager, National Cooperative Highway Research Program, assisted the NCHRP 20-5 staff and the Topic Panel.

Information on current practice was provided by many highway and transportation agencies. Their cooperation and assistance are appreciated.

BEST MANAGEMENT PRACTICES FOR ENVIRONMENTAL ISSUES RELATED TO HIGHWAY AND STREET MAINTENANCE

SUMMARY

Highway and street maintenance is a diverse and complex set of undertakings: pavement crack and joint sealing; bridge painting; snow and ice control; erosion control; roadside vegetation management; and light, sign, and traffic signal repair and replacement. Pertinent environmental issues cut across all areas of public and regulatory concern including air quality, water quality, wetland and habitat preservation, noise, and energy usage. Moreover, driver safety and the occupational health and safety of maintenance personnel are critical issues.

Practitioners and experts from many different disciplines are needed to effectively deal with the complex interrelationships between the myriad maintenance activities and environmental issues. Among the disciplines required are management and administration, engineering, physical sciences, natural sciences, economics, industrial hygiene, and maintenance.

There is a pressing need for information regarding best management practices (BMPs) for environmental issues related to road and street maintenance. Indeed, a survey of the TRB Task Force on Environmental Maintenance identified the highest priority action the Task Force could take would be to compile BMPs useful to state, provincial, county, and city maintenance organizations in the United States and Canada. This synthesis report is a response to that need.

The impetus for the development of BMPs stems from a desire of the body politic for environmental quality. This desire is translated into practice through a variety of means. Certainly laws and regulations stipulate what agencies can and cannot do, but more important is the development of an ethos of environmental stewardship within each agency. Leadership of managers from the top to the bottom of the maintenance organization is essential to encouraging sensitivity to environmental quality in a manner compatible with cost-effective maintenance.

Maintenance and environmental managers have a large number of procedures, work methods, and technology to draw upon in planning and carrying out maintenance activities. There is a growing recognition throughout the country that by sharing information on management practices, maintenance organizations can discern those that are superior from the standpoint of cost-effective, environmentally sensitive maintenance.

This synthesis is a compilation of practices likely to increase the environmental sensitivity of road maintenance work, including many practices that have become widely adopted. An increasing number of agencies are voluntarily adopting BMPs as a part of their commitment to environmental stewardship and protection. In other instances, regulatory agencies encourage or require the adoption of BMPs.

This report contains BMPs that fall into three categories:

1. *High-level, broad-based BMPs applicable to an entire maintenance program*—planning, programmatic environmental analysis, pollution prevention programs, classification of generated wastes in the conduct of site reviews or audits, and the development of a

comprehensive training curriculum that addresses maintenance related environmental issues. These BMPs may be undertaken by managers of a department-wide level.

2. *BMPs pertinent to specific maintenance activities or program areas*—winter operations, vegetation management, bridge maintenance, buildings and grounds maintenance, vehicle maintenance, collection of litter and debris, and maintenance of signs, striping, and markers.
3. *BMPs pertinent to specific environmental issues*—hazardous wastes, wildlife and habitat, water quality, and noise.

While BMPs have a connotation of being "best" and universally applicable, in reality BMPs must be tailored to specific situations. Laws and regulations at the state, provincial, and local levels vary considerably. The climate, terrain, and ecology will often differ from one place to another, necessitating different practices. The types of equipment and materials for performing a maintenance activity frequently differ from one organizational unit to another, leading to different impacts on productivity and the cost-effectiveness of maintenance.

Based on available cost information, a number of management practices can reduce costs and improve environmental quality. However, in some instances the adoption of BMPs to ensure protection of the environment can increase costs. After perusing this report, an agency will likely discover some ideas to evaluate further and eventually adopt. These ideas come from survey results and the relevant literature. They consist of either widely accepted BMPs or exemplary practices that an agency wishes to share with others.

Some highlights from the findings of this synthesis are:

- BMPs developed with active input of regulatory agencies are most likely to ensure compliance and reduce the risks of liability and fines. Moreover, transportation agencies that develop in-house expertise in environmental areas report some success in negotiating with staff of regulatory agencies.
- Few agencies have formal procedures for adopting new practices. Such procedures include criteria for objectively evaluating prospective practices.
- Most states engage in training of some form but relatively few have developed a comprehensive training program that emphasizes practices that avoid or reduce environmental impacts.
- Knowledge of practices beneficial to the environment appear to be diffused throughout individual maintenance agencies. Previously there has not been an effective mechanism for sharing information regarding BMPs throughout the United States and Canada. Nor is there a national repository or means of dissemination.
- Some agencies are becoming highly proactive in addressing environmental issues related to maintenance. Pollution prevention programs, site reviews, scientifically defensible testing and assessments, comprehensive training, and adoption of BMPs are among the steps taken by these agencies.

Some key action items for consideration are:

- Develop criteria for evaluating alternative practices that can serve as BMPs;
- Develop a database of practices, pertinent laws and regulations, costs, dollar savings, and impacts. An internet site could serve as the repository, and could also allow for discussion among practitioners about particular practices; and
- Establish a core curriculum for environmental training, coordinate with other types of maintenance worker training, and make training programs available on interactive CD.

CHAPTER ONE

INTRODUCTION

BACKGROUND AND PURPOSE

In 1995, the TRB Task Force on Environmental Maintenance was created. Among the first actions of the Task Force was the distribution of a survey to maintenance agencies nationwide and in the Canadian provinces. The survey sought information on issues regarding environmental concerns and mandates. Respondents to that survey cited a compilation of best management practices (BMPs) protective of the environment for all maintenance activities as the most desired product or service the Task Force could offer. This synthesis of BMPs for environmental issues related to maintenance is the response to that need.

Environmental issues related to maintenance are exceedingly complex. Maintenance includes a diverse set of activities that impact a large number of environmental areas. Moreover, it is challenging to maintain a proper balance between carrying out cost-effective maintenance and protecting and enhancing the environment. The development of BMPs applicable to the diverse maintenance activities of a transportation agency requires a highly interdisciplinary approach by experts and practitioners in management and administration, law, physical sciences, natural sciences, engineering, economics, industrial hygiene, and maintenance.

The purpose of this synthesis is to compile and distill information concerning BMPs in a manner useful to maintenance and environmental managers in state, provincial, city and county transportation agencies. This being a synthesis of practice, it represents a compendium of management practices that can help protect, preserve, or enhance the environment while at the same time allowing road maintenance organizations to carry out their fundamental mission of maintenance and repair in a cost-effective manner.

This synthesis draws upon the results of an extensive literature search and a survey of transportation agencies. The available information on BMPs comes in many different forms including laws and regulations, guidance documents, published papers, reports, policy and procedure manuals, technical manuals, environmental assessments, environmental impact statements, and training materials. This information falls into three categories:

1. Broad management practices that apply to an entire maintenance program and the full range of environmental issues,
2. Practices for managing different types of maintenance activities,
3. Practices for addressing different types of environmental issues.

Why BMPs?

The impetus for implementing best practices comes both from the public's desire for environmental preservation and enhancement and from a sense of environmental stewardship on the part of public officials, managers, and staff.

The public's desire for environmental quality is expressed through the political process, the laws that elected officials enact, the regulations for translating those laws into administrative procedures and subsequent actions, and opportunities to provide input and feedback regarding general and specific approaches to dealing with environmental issues.

Environmental stewardship by public officials and managers is expressed through the exercise of leadership and management actions that protect, preserve, and enhance the environment. Actions include:

- Setting a tone that protection and improvement of environmental quality is desirable and laudatory;
- Maintaining focus on the fundamental mission and responsibility of the maintenance organization in a manner responsive to maintenance customers and stakeholders;
- Bringing to bear different perspectives and disciplines to simultaneously address maintenance and environmental issues; and
- Identifying, evaluating, selecting, and implementing practices and actions given limited resources and the tradeoffs involved.

Line staff are responsible for implementing BMPs specific to certain maintenance activities or environmental issues. Training and technical guidance aimed at pollution prevention and enhancing environmental quality is essential to widespread application of BMPs. Ultimately, line staff are the most important stewards of the environment.

Definition and Framework for Identifying BMPs

There are many possible definitions of BMPs. The TRB Environmental Maintenance Task Force defined BMPs as ". . . current innovative practices or combinations of practices that utilize technological, economic and institutional guidelines or policies to mitigate routine or unusual maintenance problems in a manner compatible with environmental quality goals."

Alternatively, best practices might be defined as belonging to one or more of the following categories:

- Practices that require less material, energy or personnel to produce the same output or result as previously achieved, thereby increasing efficiency;
- Practices that reduce the use of virgin materials;
- Practices that halt or substantially reduce the introduction of toxic or hazardous materials into the air, water or food chain; and

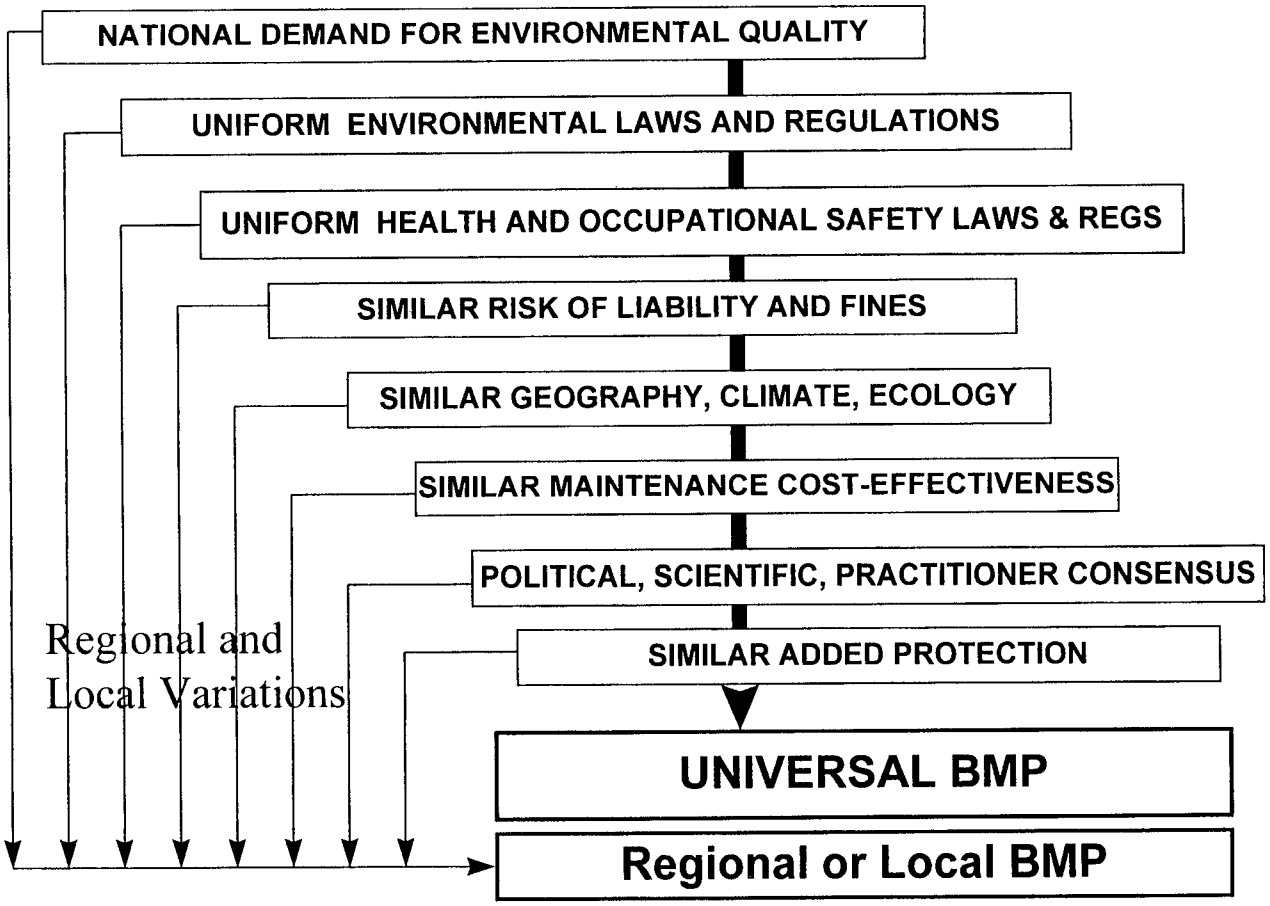


FIGURE 1 Universal and specific BMPs.

• Practices that promote or take advantage of the natural environment's regenerative or restorative capabilities.

These practices should provide at least equivalent levels of service and safety to those they replace.

In this document the term "best management practice," is not intended to imply that there is a single "best" method for addressing an environmental issue or set of issues. As a practical matter, a BMP is responsive to achieving widely adopted environmental quality goals in a manner that takes into account the environmental setting in which the practice is applied. Thus, on the one hand a BMP has some thread of universal applicability, while on the other hand it is applicable to a specific environmental context. Most of the time this dynamic tension between universal and specific applicability can only be partially resolved. Practitioners faced with a specific problem generally must select from alternative sound and relevant approaches or tailor a more general practice to fit the specific context.

Figure 1 is a useful framework for distinguishing among BMPs that have universal applicability versus specific applicability. It illustrates the factors that can lead to universal BMPs while on the other hand acknowledging that local and regional considerations may be of overriding importance and result in more site-specific BMPs. The wide, vertical arrow in Figure 1shows, in succession, the key factors that contribute to a universally applicable BMP:

1. The demand for environmental quality pertinent to a particular issue is uniform throughout the country and may well have its origin in national environmental goals expressed by the body politic.
2. Environmental laws and regulations pertinent to maintenance management are national or nearly identical from one jurisdiction to another.
3. Laws and regulations concerning occupational health and safety are uniform.
4. The liability of fines and the risk of criminal prosecution and imprisonment for failing to observe the laws and regulations is similar from one jurisdiction to another.
5. The selection, efficiency, and effectiveness of management practice does not depend upon local conditions such as geography, climate and ecology.
6. The cost-effectiveness of the management practice is similar everywhere.
7. There is a political, scientific, and practitioners' consensus that the BMP is "best."
8. There is an added measure of environmental protection beyond the minimum necessary to comply with laws and regulations and carry out maintenance cost-effectively.

Collectively these are very stringent criteria, and it is clear that few if any BMPs could satisfy all of them. However, some BMPs are more broadly applicable than others. For example, management practices for handling used oil inside a vehicle maintenance shop tend to be somewhat universally applicable. Vehicle maintenance shops are usually indoors on concrete floors and such measures as not mixing used oil with hazardous wastes, proper labeling of drums containing used oil, preventing oil from entering a sanitary sewer system or surface waters, instituting a spill prevention program, and proper handling of absorbents apply to nearly all such facilities. National and state laws and regulations as well as potential fines and criminal penalties foster such practices. Moreover, the cost-effectiveness of vehicle shop maintenance BMPs will be fairly consistent from one maintenance facility to another.

Figure 1 also shows alternative paths that lead to regional and local variations in BMPs. The most likely reasons for these variations in BMPs are differences in geography, climate, and ecology, and differences in state and local laws and regulations. For example, management practices for roadside vegetation management are likely to be highly dependent on local conditions such as terrain, soil, climate, and other ecological factors. Laws and regulations concerning plant pests will be specific to the species that might be present. Variations in local conditions may dramatically affect whether to use chemical herbicides, mechanical methods, wildflower plantings, or other biological approaches. The cost-effectiveness of different methods will vary. Agencies may have very different types of procedures and complements of labor, equipment, and material for using a particular approach.

To identify BMPs of universal applicability, a survey of maintenance agencies in North America was conducted; the survey responses, supplemented with selective follow-up telephone or personal interviews and a literature search are the primary sources of information for this report. BMPs in this report consist of the following:

- Practices that help organizations achieve their mission and protect, preserve, or enhance the environment while conforming with or exceeding federal, state, and local regulations;
- Any practice that results from regulations, guidance documents, or the literature clearly labeled as a BMP or is considered a standard practice beneficial to the environment;
- Any practice an agency identified as being a BMP or considered an *exemplary* practice the agency desired to share with others in the maintenance and environmental community; and
- Practices that received awards or commendation.

In this study, BMPs have been organized into three broad categories:

1. *High-level, broad-based BMPs*—These are BMPs usually implemented through policy, planning, and management initiatives emanating from the highest levels of an agency and are broadly applied throughout the organization or the maintenance division. These BMPs are not specific to a particular maintenance activity or environmental issue. Rather they apply to the entire maintenance program, cut across many subprogram areas, concern a number of activities within a maintenance program, or pertain to a specific environmental area that applies to more than one maintenance program or activity. Examples of such BMPs are plans containing environmental policies pertinent to maintenance, pollution prevention programs, comprehensive environmental reviews or audits, programmatic environmental impact statements, curriculum development for training programs concerning environmental issues, and organizational development intended to change or serve the whole organization.
2. *BMPs that pertain to a specific type of maintenance activity*—Maintenance organizations carry out a large number of activities pertaining to work on the following specific areas: roadway and shoulder surfaces, roadside vegetation, drainage, litter sweeping, bridge maintenance, snow and ice control, signs/striping/pavement markers, other traffic control devices, emergency maintenance, parks/rest areas/weigh stations, vehicles and maintenance equipment, materials and handling, and building and grounds. BMPs may apply to each of these specific activities.
3. *BMPs that pertain to specific environmental issues*—Many best practices, particularly those fostered by regulatory agencies, concern specific environmental issues such as stormwater runoff/water quality, air quality, noise, wetland and habitat preservation, and hazardous wastes.

In sum, it is difficult—if not impossible—to compile a definitive list of best practices by maintenance area that are universally applicable. BMPs of broader applicability are most likely to apply high-level, broad-based management practices, to regions or areas in similar environmental settings and with similar legal and regulatory requirements, or to issues and situations that can largely be insulated from their surrounding environment, such as a shop floor. Most BMPs must be tailored to fit specific situations defined by the environmental setting, the legal and regulatory requirements, the impact on the effectiveness of the maintenance activity, and the benefits and costs in relationship to other priorities and the total resources available. Note also that BMPs are evolutionary due to technological, regulatory, and other changes. Advances in technology often provide opportunities for maintenance personnel to carry out work in a more cost-effective and environmentally sensitive manner. Agencies committed to implementing BMPs demonstrate environmental stewardship under the assumption that the net effect of implementing BMPs is beneficial and responds to the desire of the public to protect, preserve, and enhance the environment.

RESEARCH APPROACH

This research has followed the standard procedure for conducting NCHRP synthesis projects. A work plan and a draft

outline of the final report was prepared and submitted to the Topic Panel at the outset to ensure the research was fully responsive to the problem statement. The work plan included a literature search on BMPs, the administration and analysis of a survey to collect information on BMPs, a draft synthesis report, and a final report.

Scope

The scope of the synthesis was unrestricted as to maintenance activities and environmental issues that might be addressed. The synthesis focused on maintenance practices of agencies responsible for highway and street maintenance in state, provincial, city, and county governments. However, in a few instances, literature from the mass transit industry and railroads was a source of information on BMPs.

Environmental issues related to construction were outside the scope. It should be noted, however, that new construction often results in additional or new types of roadway features, such as sedimentation ponds or grass swales, that must be maintained in the future. These additional maintenance features create added responsibilities and may have different kinds of environmental issues than a transportation agency has experienced in the past.

The issue of what types of recyclable materials would fall within the scope of this synthesis project arose because of ambiguity regarding the definition of maintenance. In many transportation agencies a large gray area—consisting of resurfacing, restoration, and rehabilitation projects—blurs the line between maintenance and construction activities. From time to time, these types of projects might be funded within either the maintenance or the construction program. The NCHRP panel suggested that the synthesis confine the discussion of recyclables to those materials that are collected or generated by maintenance activities other than such preservation actions as pavement resurfacing, rehabilitation, and restoration. Recyclable materials, used in reconstruction and new construction were clearly deemed out of scope if they were not collected or generated by maintenance activities. Thus recycling of used oil collected in vehicle maintenance shops is within scope and so is the recycling of tire remnants, litter, and glass picked up from the roadway or roadside.

Another issue concerning the scope of the study was the extent to which costs and savings of BMPs would be assessed. Where readily available, information on costs and savings of BMPs is included in the synthesis report. However, filling information gaps on costs and savings of BMPs was deemed outside the scope of this project because of the magnitude of the undertaking.

Literature Review

An extensive literature review was conducted for this study. Computer literature searches using TRB's Transportation Research Information Service and other sources, such as the Internet, were conducted. This search built upon an earlier computer search conducted by the TRB Environmental Maintenance Task Force, which contributed to this synthesis project. Reports and documents of transportation and environmental agencies, newsletters, trade magazines, and published lists of references also provided information.

Survey

Questionnaires were sent to state transportation agencies in each of the 50 states, the District of Columbia, and numerous counties, municipalities and Canadian provinces. The questionnaire was composed of two sections (See Appendix A). In the first section, respondents were presented a list of 15 maintenance activities (e.g., vegetation control), nine environmental issues (e.g., air quality) and 19 management practices (e.g., training, automation) and were asked to indicate any that might be considered a best practice. Respondents were encouraged to describe any practices that might provide an overall benefit to the environment and to identify practices they considered exemplary and therefore desired to share with other agencies. The intention was to encourage as large a response as possible. Following this, respondents were asked to provide a brief description of the practice and any evidence of: 1) maintenance cost impacts; 2) environmental impacts; and 3) any form of recognition for the practice. Lastly, respondents were asked for any documentation of practices noted as BMPs.

Methodological Issues

A key methodological issue, as discussed in the previous section, was how to define a BMP, and to what extent a BMP might be universally or specifically applicable.

A related methodological issue was the extent to which the researchers might apply their own judgment regarding what is a BMP. The complexity of issues, due both to breadth of maintenance and environmental issues and the need for multidisciplinary expertise in many areas—physical sciences, natural sciences, engineering, economics, law, industrial hygiene—precludes a handful of researchers from applying their own judgment concerning what is a BMP.

In order to impose some independent standard on the selection of BMPs, the researchers assembled a set of what might be termed "benchmark" reference documents. These included certain core reference documents concerning specific maintenance activities or environmental areas (e.g., snow and ice control, erosion control, stormwater runoff). The BMPs included in this report were compared to practices in the benchmark documents. As far as possible, the BMPs in this report were consistent with or exceeded minimum compliance and policy requirements contained in the benchmark documents.

Review of BMPs proposed for inclusion in this report by maintenance and environmental experts was also part of the methodology. The NCHRP Panel provided most of the technical review. In a few cases where questions persisted, the researchers sought technical review from other experts.

ORGANIZATION OF THIS REPORT

The remainder of this report is organized into three chapters and a series of appendixes. Chapter 2 describes BMPs consisting of broad management approaches applicable to the entire maintenance program or to more than one program area. Chapter 3 presents BMPs for specific maintenance activities or groups of maintenance activities. Chapter 4 presents BMPs concerning specific environmental issues. In chapters 3 and 4, BMPs are organized by subject material with the literature presented first followed by specific examples furnished in response to the survey. References follow the last chapter. Appendix A summarizes the survey results. Appendix B provides a table organizing BMP submissions by state. Appendix C includes a copy of the survey instrument.

CHAPTER TWO

HIGH-LEVEL, BROAD-BASED BMPs

Some BMPs described in this chapter help frame policy and guidelines, establish general practices, and pertain to general concerns of management—not to specific maintenance activities or environmental issues. Also included in this chapter are a number of BMPs that help high-level managers translate technological advances and new ways of doing business into superior management practices that others in the organization may adopt. Many of these more general BMPs tend to be programmatic in nature. They apply to an entire maintenance program, a subprogram, or address one or more environmental issues from a programmatic standpoint.

These broader BMPs are standard practices and belong to the canon of good or excellent environmental management. They come from regulations, broad management practices of environmental agencies and transportation organizations, published BMPs, the management and environmental literature, and responses to the survey administered as a part of this synthesis project.

There are a variety of ways to frame policy, guidance, and procedures. Some involve the broadest types of policy, strategic, and program planning. Some involve programmatic analysis that examines impacts and tradeoffs of alternative actions or allocations of resources within and between subprograms. Pollution prevention and resource conservation programs are broad and encompassing approaches to environmental management. Some approaches concern organizational development, for example, business process reengineering, reorganization, inculcation of a culture of continuous quality improvement, and human resource development through training. Computerized management and decision support systems may also encapsulate policy and guidance. Other approaches entail the development of manuals that address policies and procedures, technical issues, or BMPs. Research and development frequently bears fruit that becomes BMPs. Cooperative agreements, public/private partnerships, environmental site reviews and audits of maintenance facilities, and various types of safety management programs also contribute to sound environmental management.

Figure 2 shows the main categories of BMPs that managers at high levels of an organization typically apply in a broad manner, often in a way that affects the entire maintenance program, a subprogram, or more than one environmental issue.

FIGURE 2 High-level, broad-based BMPs.

EFFECTIVE PLANNING

Virtually all transportation agencies have a planning function. As the Interstate construction era draws to a close and with the passage of the National Environmental Policy Act, transportation planners are focusing increasingly on system preservation and environmental issues. In recent years, real-time maintenance management has received much attention because of technological advances and the need to respond effectively to varying weather conditions, incidents, and emergencies. Today maintenance management plays a crucial role in preserving both the physical condition and capacity of roadway networks.

In many agencies, consideration of environmental issues related to road and street maintenance begins with transportation planning. Planning serves to identify existing and emerging issues that need to be addressed within a comprehensive framework of policy, strategic, systems, and technical planning. Different types of planning that can be viewed as BMPs are described next with examples that address environmental issues related to maintenance.

Policy Planning

The analysis and establishment of policy via the planning process is an important planning activity of virtually all transportation agencies. Many transportation agencies develop separate policy plans, some integrate policy planning into other types of planning. Policy plans set out the broad policy framework for the development of more refined plans, transportation programs including maintenance, and operations management.

In the early 1980s the Wisconsin Department of Transportation (WisDOT) produced a State Transportation Policy Plan. That plan included a policy to strive to protect and enhance the human environment and to consider all pertinent environmental factors in the Department's decisionmaking. In support of this policy the implementation guidelines included the following:

> The Department shall use the Council of Environmental Quality scoping process as a means to ensure thorough, timely and efficient consideration of environmental impacts at all levels of decision making. . . . policy planning, system planning, programming and project development.

> The Department shall work with appropriate agencies to achieve federal water quality standards and wetland preservation. Among the activities included will be: a) involvement in studies on transportation related pollutants contained in stormwater runoff and dredge spoils and assistance in the continued development and implementation of environmentally acceptable methods for their treatment disposal; b) expansion of efforts to study the effects of deicing agents on roadside vegetation and to monitor the handling of facilities on water supplies, while continuing efforts to monitor salt usage and encourage proper maintenance of snow removal equipment; and c) monitoring the department's construction and maintenance activities in the vicinity of waterways and wetlands to ensure compliance with established environmental procedures.

> The Department shall seek to improve roadside aesthetics by promoting ways to reduce litter, by removing non-conforming billboards, and by using maintenance practices that encourage the growth of native species (Wisconsin Department of Transportation 1980).

Strategic and Long-Range Planning

A large number of transportation agencies prepare strategic and long-range plans. These plans nearly universally address issues concerning preservation, environment, technology, new laws and regulations, finance, customer service, quality and other issues that are of central concern to maintenance. The hallmark of strategic planning is to identify trends, opportunities, and strengths and weaknesses that will impact the agency in the short and long run; to identify and analyze alternative futures; and to recommend strategies to deal with expected future changes. Environmental issues of capital versus maintenance expenditures, new environmental laws and regulations, liability and threats of fines, and training on environmental management practices are among the many issues maintenance managers can effectively address within the context of strategic planning. Transportation agencies can deliver a much higher-quality product that is more responsive to environmental issues and customer needs when maintenance managers are part of a strategic planning team that works together to help determine the future direction of a transportation agency.

The *2020 Florida Transportation Plan* is an example of a long-range plan that addresses environmental issues related to road maintenance. The plan includes objectives to minimize the impact of transportation facilities and services on the environment; to increase energy conservation; and to increase the use of recycled materials, native vegetation, and wildflowers. The long-range plan emphasizes a number of areas directly relevant to state highway maintenance and says the following:

> The Department will continue to support the use of alternative fuels, energy efficient highway lighting and other techniques which help conserve energy. The department is a national leader in the use of recycled tires in highway asphalt and will continue to identify ways to use recycled products. The Department will continue to increase its use of native vegetation and continue to expand use of wildflowers to both beautify and to reduce the cost of maintaining rights-of-way (Florida Department of Transportation 1995).

System Planning

In most state and metropolitan transportation agencies, system planning involves one or a combination of the following:

1. A multidisciplinary approach to the analysis of complex systems and their interaction through a delineation of goals, objectives, alternatives, component systems (physical, environmental, social, economic), boundaries, inputs, outputs, constraints, feedback loops (involving both positive and negative amplification), and evaluation of system performance through modeling, heuristics, and other quantitative and qualitative analysis.

2. Application of the traditional four-step transportation planning process—trip generation, distribution, modal split, and route assignment—to determine travel demand and capacity bottlenecks that can be used as input to determining the capital and preservation requirements for highways and other modes.
3. The development and application of computerized decision support systems—such as pavement, bridge and maintenance management systems—to determine road and bridge needs with and without budget constraints. Pavement and bridge management systems address preservation needs at the minimum and, frequently, improvement needs as well. Maintenance management systems address both physical assets (e.g., pavements, shoulders, guardrail, signs, and signals) and services (e.g., snow and ice control, mowing, litter removal).

The Wisconsin Department of Transportation, as a part of *Translinks 21* (their long-range multimodal planning process), developed a document entitled *Environmental Evaluation Guidance* to help MPOs evaluate the environmental impacts of metropolitan transportation system plans. The guidance suggests that base case and alternative plans be assessed according to various social, economic, and environmental impacts shown in the "Outline of Environmental Review," presented in Figure 3. The base case for *Translinks 21* proposed to continue the direction and investment levels for WisDOT's current program, including highway and bridge rehabilitation and maintenance programs, adjusted only for inflation.

A. Executive Summary

B. Introduction
1. Purpose of the Review
2. Methodology
3. Description of the Scoping Process
4. Identification of System Plan Alternatives
   a. Base Case
   b. List and Description of Elements in Each Plan Alternative

C. Assessment of Potential Environmental Consequences of Plan
1. Economic and Social Impacts
   a. Economic Development
   b. Land Use
   c. Traffic Congestion
      (1) Travel Time Benefits
      (2) Change in Vehicle Miles Traveled
   d. Community and Neighborhood
   e. Noise
   f. Visual Impacts of the Plan Alternatives
   g. Historical and Cultural

2. Natural Resources Impacts
   a. Water Resources
   b. Air Quality
   c. Energy Consumption
   d. Ecosystem (including threatened or endangered specifies and habitat fragmentation)

D. Summary
1. Benefits of System Plan Alternative
   a. Positive Impacts
   b. Achievement of Transportation Goals
2. Costs of System Plan Alternatives
   a. Dollar Cost
   b. Negative Impacts

FIGURE 3 Outline of the environmental review of a metropolitan transportation system plan.

Technical Planning

To an increasing degree the delivery of maintenance services involves the application of advanced technology. One reason is the continued technological advances in equipment, materials, computers, and telecommunications. Technological change affects the environmental impacts, cost-effectiveness, and productivity of virtually all types of maintenance activities. The other reason is the growing importance of real-time maintenance management, particularly management procedures to respond to incidents, emergencies, and changing weather conditions. Indeed maintenance is now recognized as one of the user services provided by intelligent transportation systems (ITS). Best management practices explicitly include procedures to respond to technological change and to perform various types of technical planning.

For example, throughout the country, states and metropolitan regions are engaged in a variety of technical planning activities for ITS. Many states and regions address such things as roadway weather information systems (RWIS) and automatic vehicle location systems (AVL) for winter maintenance. These technical planning activities include development of a technical architecture and systems engineering. Thorough technical architecture development, such as the ITS National Architecture, includes an environmental analysis.

Environmental Planning

A department may also develop a broad-based plan focused on environmental issues. A recent example is the Environmental Protection Plan prepared by the New Brunswick Department of Transportation. This is a comprehensive document outlining the DOT's general approach to a wide range of activities that are an integral part of its mandate—highway planning, design, construction, structures and bridges, and operations. The section on operations includes a number of environmental protection measures that apply to summer and winter maintenance activities as well as bridge and ferry maintenance.

RESEARCH AND DEVELOPMENT

Most larger transportation agencies maintain a staff devoted to research on the use of new materials and establishment of new procedures for carrying out their maintenance missions. Often research is conducted in coordination with

universities, other agencies from other states, or is co-sponsored by organizations at the national level. These efforts are probably the single most effective means of developing and introducing BMPs into the maintenance toolkit of transportation agencies nationwide. Research and development by its nature pushes the state of the art in search of new and cost-effective practices. Research and development efforts are described throughout this synthesis; others are highlighted below:

- The Minnesota Department of Transportation's (Mn/DOT) Office of Maintenance has a research section that evaluates equipment and materials such as ground-oriented salt spreaders and noncorrosive deicers as well as other snow removal technologies. Mn/DOT has also conducted research on other areas, such as the use of sorbents to contain spills.
- The Indiana Department of Transportation (INDOT) is jointly conducting several environmental issue research projects. Projects include remediation of hazardous effluent from beneath newly constructed road systems; the use of foundry sand in highway construction; evaluation of a computer-aided system for planning efficient routes; bioremediation treatability studies for soils containing herbicides, chemicals, and petroleum products; effects of highway deicing compounds on water quality in a surficial aquifer and mitigation of brine runoff from salt storage facilities.
- The Texas Department of Transportation (TxDOT) conducts extensive research in several maintenance areas, in cooperation with the Texas Transportation Institute (TTI). The TxDOT/TTI Hydraulics and Erosion Control Laboratory constructs specialized sites for controlled testing of new materials and procedures. Commercially available erosion control products are among the recent products tested.

PROGRAMMATIC ENVIRONMENTAL ANALYSIS

A broad-based, high-level BMP useful for assessing alternative strategies concerning environmental issues is to perform programmatic environmental analysis. Such analysis can apply to either the overall preservation or maintenance program or to a maintenance program area. The Wisconsin Department of Transportation (WisDOT) developed a programmatic environmental analysis of the resurfacing, reconditioning and reconstruction program that was addressed within its 6-Year Highway Improvement Program, 1980-1985. The Department assessed a broad range of impacts at two program levels, one a low funding level of $210 million and the other a high level at $370 million (Wisconsin DOT 1979). A TRB research paper summarizing the effort concluded the following:

- A program-level environmental analysis is feasible and can provide useful information in formulating proposed programs.
- However, a program-level analysis cannot, and should not, approach the level of detail of a project-level environmental impact statement.
- Any environmental analysis that applies to an entire program needs to be carried out in a manner that will allow annual or biennial budget decisions and program implementation to proceed smoothly (Neumann 1980).

The Texas Transportation Institute under the sponsorship of the TxDOT prepared an environmental impact statement for a roadside pest management program. The summary to the EIS states that TxDOT was not required by state or federal regulations to conduct an EIS review of its pest management practices, but the department believed a proactive review was in the best interests of the public and the environment. The final EIS addressed five alternatives: no action; short-term remedial action approach; no-chemical approach; current practices approach; and integrated long-term and locally based approach. Four treatment measures and corresponding mitigation measures were addressed: 1) mechanical; 2) chemical; 3) cultural; and 4) biological. The EIS identifies how each of the alternative pest treatment programs impacts the environment and analyzes the alternatives. A scoping process and public comments on the draft EIS were an integral part of preparation of the impact statement. The department made a policy decision based on the final EIS to continue its current vegetation and insect management practices. The recommended approach was selected because TxDOT's vegetation and insect management practices are decentralized and treatment methods are based on situation-specific conditions, implemented by a local maintenance supervisor and vary among districts depending on local policies and priorities (Hauser 1996).

POLLUTION PREVENTION AND RESOURCE CONSERVATION PROGRAMS

Many states and localities develop specific programs to prevent pollution and promote resource conservation.

The "Pollution Prevention/Resource Conservation Plan" of the Massachusetts Turnpike Authority specifies BMPs in the areas of green procurement, solid waste reduction/reuse, toxic use reduction, energy conservation, water conservation, air pollution, non-point source control and indoor environmental pollution. Alternative practices in each of these areas were studied based on three primary factors: 1) potential for pollution prevention and resource conservation; 2) technical feasibility; and 3) financial feasibility. Detailed tables specifying the practices chosen and their priority are included in the document.

The Minnesota Department of Transportation has a vigorous pollution prevention program that includes an annual reporting process. The "Fiscal Year 1997, Pollution Prevention Summary Report" details a large number of accomplishments, including the following:

1. Eliminated the use and landfilling of clay sorbents by using different types of sorbents, burning used sorbents for energy recovery and laundering oil rags.
2. Installed approximately 20 waste oil burners to provide supplemental heat in maintenance shops.
3. Put in place a U.S. Environmental Protection Agency approved CFC training program required of all mechanics

and changed all vehicle purchasing specifications to include "environmentally friendly" refrigerant in all vehicle air conditioners.
4. Achieved a 20-percent reduction in salt/sand usage due to prewetting of salt.
5. Reduced by 60 percent the use of 1,1,1-trichloroethane used in quality assurance testing of bituminous asphalt by replacing vacuum extractors with centrifugal extractors.
6. In several districts, switched to heavy-metal-free latex pavement marking/striping paint, which eliminated a hazardous waste stream of lead, chrome, and toluene.

RISK ASSESSMENT AND LIABILITY MANAGEMENT

The pollution prevention program of Mn/DOT and other transportation agencies is rooted not only in a philosophy of environmental stewardship, but also risk and liability assessment.

An impetus for a strong and proactive approach to environmental management is to develop a systematic approach to assessing risks and liability. The simplest type of management practice, commonly used in software projects, is to develop and periodically update a comprehensive list of risks. Similarly, a comprehensive list of potential liability can be developed. To identify priorities, one can prepare a "Top 10" list with an accompanying action plan and schedule.

Besides this common-sense approach, agencies can draw on a vast literature on risk assessment that cuts across many disciplines, including engineering, economics, law, and the environmental sciences.

POLICY, PROCEDURE, TECHNICAL AND BMP MANUALS

Communication of polices, procedures, technical information, and BMPs is often accomplished through the preparation and dissemination of manuals. Manuals can set out policies and procedures, provide technical guidance, or describe BMPs.

Several states reported having developed best practice manuals in specific maintenance areas, including stormwater management, winter operations, and vegetation maintenance. A few agencies reported the development of comprehensive BMPs focused on environmental quality.

TxDOT is required by statute to conduct an environmental review of primary maintenance programs and to develop a manual of best practices and mitigation plans for each maintenance program. The environmental review is subject to public involvement and input by other state agencies. In its current form, the best practices manual consists of a series of tables describing the relevant activity, materials affecting the environment, the relevant environmental concern, and the standard practice for reducing or eliminating impacts. Pavement maintenance, maintenance enhancement, vegetation management, customer service (deicing, rest areas, etc.), bridge maintenance, and drainage are the major impact areas covered in the document. The findings of a task force convened to conduct the environmental review of current practices in effect define best practices in many areas.

In 1994, Virginia DOT initiated efforts to develop environmental BMPs for all maintenance areas. These efforts were temporarily suspended as the department sought to avoid overly prescriptive maintenance procedures and engage in business process reengineering.

ORGANIZATIONAL DEVELOPMENT AND SERVICES

Another category of high-level, broad-based BMPs involves organizational development or restructuring. Certain management functions and services that affect maintenance and the environment can be centralized or decentralized. Organizational units can be combined or separated. Management can also invoke numerous practices aimed at human resource development and improving responsiveness to the customer and the environmental quality of maintenance. Common approaches to organizational development include business process re-engineering, continuous improvement, and training programs.

Centralized Environmental Services

Many agencies have established central office staff possessing a technical and statutory knowledge of the environmental issues facing transportation agencies. These centralized units are usually involved not only in project design and construction but also in maintenance. They help ensure conformity with policies and regulations in a consistent manner throughout the department. These organizational units are also a source of quick and reliable information. Agencies with in-house expertise cite reduced maintenance costs because quick access to information reduces or eliminates lost work time, regulatory or civil penalties, and cost for remediation, clean-up, or restoration.

- The Washington State Department of Transportation (WSDOT) developed an environmental services branch in the hopes of creating a cost-effective means of solving environmental problems. Prior to this, environmental management services were purchased through a contractor, and proved to be costly. As a result of the investment in its own in-house expertise, WSDOT claims a 75 percent cost reduction through the use of more "practical solutions." The agency also claims that more environmental problems on rights-of-way and other property managed by WSDOT can be addressed. The agency states that the public now perceives that it is more responsive to environmental problems than in the past.
- The Pennsylvania Department of Transportation (PennDOT) and the Nova Scotia Department of Transportation and Public Works established their own environmental services divisions. These divisions provide technical support for maintenance and construction activities.

• The Georgia Department of Transportation (GDOT) performs its analysis and conducts its own corrective actions in responding to petroleum spills and leaking underground storage tanks. GDOT claims savings from the avoided cost of contracting out the work and an environmental benefit from a quick response that prevents groundwater contamination.

Business Process Reengineering

Transportation agencies throughout the country are engaged in business process engineering. This is an approach to organizational change that seeks to streamline business processes. Typically an advance in technology serves as an enabler. An example was the development of a prototype cradle-to-grave sign management system for the state of Arizona under an NCHRP project titled "Field Demonstration of Advanced Data Acquisition Technology for Maintenance Management." One of the field demonstrations compared the existing sign management process with a new one that used advanced technology to help manage signs through each of the following stages: sign fabrication, warehousing, distribution to districts and local shops, issuance to field crews, installation, inspection, cleaning, repairing, replacement, and disposal. The new business process, though experimental, showed a potential to more effectively manage signs, including the handling of solid waste, throughout their entire lifecycle (Hyman 1993).

Continuous Improvement/Total Quality Management (TQM)

Most state and many larger local transportation agencies have implemented some type of continuous improvement or TQM program. Continuous improvement combines a focus on the customer with a variety of techniques, including performance measurement, to improve the quality of products and services. Users of roads and streets often demand higher environmental quality from the maintenance products and services states and local governments provide.

Many states have initiated efforts to survey customers of road maintenance to determine the preferences and priorities for different types of maintenance. Others have developed customer oriented performance measures. For example, Minnesota DOT is in the process of implementing customer oriented outcome measures for a variety of products and services that have an environmental dimension to them: 1) "Clear Roads," which involves snow and ice control and removal of obstructions to traffic flow: and 2) "Attractive Roadsides," which focuses on vegetation management, noxious weeds, and litter control.

Training

The formulation of policies and procedures are but one step in improving maintenance practices. Staff responsible for day-to-day maintenance activities must understand the purpose and need for practices that mitigate environmental impacts if they are to be carried out properly. There is simply no way to monitor the thousands of individual actions that, collectively, can make a significant impact on the water, soil, air quality, flora, and fauna. Training plays a crucial role in the implementation of BMPs, particularly those that apply to specific maintenance activities and environmental issues. Training can take many different forms, including on-site training, certificate programs offered by local technical assistance programs, college and university training, and self-instruction using manuals or computer-assisted instruction. Many states engage in training of some form, but relatively few comprehensively emphasize practices that mitigate environmental impacts.

The development of a curriculum to address environmental issues related to road and street maintenance is important. Some states, such as Virginia, are establishing training academies, where a curriculum has been developed and training in major maintenance areas is available on a regular basis.

The Florida Department of Transportation (FDOT) has developed a series of courses designed to increase knowledge of environmental issues and concerns among maintenance employees. FDOT environmental staff designed and taught the classes, which include environmental contamination problem identification; environmental impacts of highway construction and maintenance; erosion control and stormwater management; underground storage tank removal; wetland vegetation identification; and threatened and endangered species.

INFORMATION TECHNOLOGY

Computer hardware and software as well as telecommunications are tools managers can use to assist in carrying out more environmentally sensitive maintenance. Information technology can be used in countless ways, including the following:

• Portable computers in which electronic versions of BMPs are stored for easy retrieval in the field:
• Decision support systems for maintenance, for example bridge, pavement, and maintenance management systems;
• Microprocessors to control application rates of deicers or herbicides;
• Digital cameras and video to document and monitor environmental conditions;
• Sensors, software, hardware, and telecommunications that comprise roadway weather information systems (RWIS);
• Computer data bases that can produce reports describing threats to environmental quality; and
• Digital maps to locate maintenance assets and environmentally sensitive areas.

Among the computer technologies embraced by maintenance agenices are geographic information systems (GIS) to document, plan, and schedule their activities. GIS increase efficiency by allowing maintenance engineers to locate facilities and vehicles quickly. In addition to their mapping abilities, the database engine of a GIS allows for storage, manipulation, and retrieval of data important to engineers, planners, and environmental analysts. In response to the survey conducted for

this synthesis study, several agencies cited the use of GIS in their daily activities. Indiana DOT uses a computer-aided routing system for designing efficient snow and ice removal routes. Riverside County, California uses a GIS to establish priority sweeping areas and routes. The city of Indianapolis, Indiana has developed a GIS-based system for managing snow and ice control operations.

The Illinois Department of Transportation has purchased and implemented a computerized material safety data sheet system for its maintenance and operations functions. The system provides instant information on whether a particular product is hazardous, and advises users of safe use, proper disposal, and emergency procedures. Users can track the amount, location, and use of hazardous materials purchased by the Department as well. The software system was designed by an outside consultant for the DOT.

ENVIRONMENTAL REVIEWS

An environmental review, sometimes referred to as an environmental audit, is a management tool involving on-site inspections that helps an agency achieve its environmental goals and objectives. Frequently, the purpose of an environmental review is to evaluate compliance with environmental regulations or to ascertain whether BMPs are being used.

In state maintenance organizations, the team conducting the review typically consists of representatives from the audited maintenance facility, district and central office personnel, and an impartial and knowledgeable environmental auditor. The reviews are scheduled ahead of time and are performed on a regular basis.

There are practical issues in undertaking environmental reviews so that the outcomes are constructive from the standpoint of both transportation and environmental regulatory agencies. DOTs do not want to be penalized for being good citizens by conducting environmental audits to detect and correct problems, and then find they are not in compliance with environmental laws. DOTs can avoid this problem by nurturing a relationship of trust and commitment to environmental compliance with regulatory agencies. Some DOTs have found that they can be proactive and aggressive in conducting environmental reviews by keeping them confidential or not calling them environmental audits. Some states refer to environmental audits as "Quality Assurance Reviews."

The Michigan Department of Transportation has implemented an auditing system to verify compliance with environmental requirements and department policies. Objectives of the audit include:

- To evaluate performance and compliance in relation to earlier reports;
- To improve the facility's level of knowledge and execution;
- To review neighboring land use and status in regard to known high risk environmental sites;
- To review previous regulatory agency documentation, testing, or inspection reports and disposal practices; and
- To inspect the physical site itself to evaluate environmental risks, including the site plan, pollution incident prevention plan, floor drain connections, and current indications of leaks and spills.

Michigan DOT's Environmental Audit is composed of the following steps:

- *Pre-Audit Conference*—An audit team reviews results of earlier audits, discusses changes in procedures and policies with staff and explains audit procedures to pertinent facility staff.
- *Physical Audit*—The team conducts a walk-through inspection of the facility, checking for conformity with applicable state and federal regulations, and good/best practices. Special attention is paid to hazardous waste storage, handling, and disposal.
- *Debriefing*—The team discusses its findings and what corrective actions, if any, should be taken.
- *Draft Report*—Following the preparation of a draft report, which is reviewed by audit participants, the maintenance district engineer and others, the environmental auditor prepares a final report.
- *Final Report*—This describes the level of compliance with regulations and policies, potential liability to which the Department is exposed under current conditions and a description of the corrective actions deemed necessary or desirable (Michigan Department of Transportation 1993).

SAFETY MANAGEMENT

Maintenance workers are exposed to countless occupational hazards in their daily activities. In the handling and application of various chemical substances, the maintenance worker encounters health risks long before they are introduced to the general population. Roadway maintenance personnel face the danger of collision with vehicles. Saws, cranes, mowers, and other powerful machinery, if mishandled, can result in injury or death. Worker training and institutional policies play a key role in promoting worker safety.

The North Carolina Department of Transportation's (NCDOT) on-line worker safety manual is comprehensive, well-structured, and with hypertext links, easy to use. The manual covers many areas, including lead exposure during NCDOT maintenance and construction operations, the proper control of asbestos to eliminate exposure, and requirements for the proper use of explosives. NCDOT's safety manual also details requirements for safely working in excavations and trenches constructed by NCDOT during routine maintenance operations on roads and bridges. The manual delineates the responsibilities of managers, supervisors, and line workers.

The New Hampshire Department of Transportation (NHDOT) tests workers annually for levels of lead in the blood stream and trains workers in respirator usage.

INDOT has eliminated the use of solvents in the fabrication of signs and thereby lowered worker exposure to these chemicals.

The Massachusetts Turnpike Authority has conducted a survey of chemicals in use by its workers. Where products

contain toxins, alternatives to these substances have been evaluated and substituted where possible.

Mn/DOT is experimenting with several innovative technologies in winter equipment that will increase operator and roadway safety. Trucks are being outfitted with fiber-optic light systems that enable drivers to see the outline of the entire truck. These systems allow the trucks to remain visible through snow clouds generated during plowing operations. Extendible-hood snow plows reduce or eliminate the snow thrown over the top or the side of the plow, which could significantly reduce driver visibility. The sliding hood is hydraulically operated, and extends up to 3 ft in length. Another plow blade, 21 ft in length and 24 in. in height, is designed to minimize "snow clouds" and eliminate the need for the wing that is normally mounted on the side of the truck. As currently configured, the plow produces a 12-ft clear swath; a conventional plow later returns and pushes the snow further aside.

Several guidance systems for snowplow operations are undergoing evaluation. Lack of visibility is an acute concern during snowstorms, as obstacles and other vehicles are obscured. The snowplow operation itself creates "snow clouds," compounding hazards. Magnetic tape has been applied to selected roadways in Minnesota to test a guidance system for snowplow drivers. Magnetic tape sensors mounted on the underbody of the trucks inform drivers of their location relative to the centerline or right pavement edge. The durability of the tape has been under evaluation. Off-the-shelf radar systems are being evaluated as well, for their ability to provide information about the speed and location of vehicles around them. These units would be capable of sensing vehicles in front, behind, and to the side of the truck.

Mn/DOT has tested the effectiveness of chemical stripping of lead paint on its bridges. OSHA and EPA regulations severely restrict worker exposure to lead; this test is part of an effort to develop safe and cost-effective means to conform to the regulations. Results of initial tests showed that airborne concentrations of lead using this process are significantly less than those of typical sandblasting operations, where full containment with vacuums systems are employed. The stripping process requires only partial containment, with sheeting placed on the floor and draped on the sides.

Mn/DOT has developed a remotely operated vehicle for use during road repair projects. The vehicle is operated from a safe and remote location within a moving work zone such as a crack-filling operation. A second generation prototype vehicle is being evaluated.

MEMORANDA OF UNDERSTANDING, COOPERATIVE AGREEMENTS AND PUBLIC/PRIVATE PARTNERSHIPS

Memoranda of understanding, cooperative agreements, and public/private partnerships have an important role to play in effectively maintaining roads and addressing environmental issues.

The Committee on Hazardous Wastes in Highway Rights-of-Way emphasizes the desirability of establishing MOUs:

> The most explicit form of cooperation DOTs and State Resource Agencies (SRAs) can adopt is a formal memorandum of understanding (MOU) delineating responsibilities between the agencies together with a standard operating procedure that lays out the division of functions between the two organizations and effectively short-circuits many of the ambiguities over responsibilities at different stages of the process (Committee on Hazardous Wastes in Highway Rights-of-Way 1993).

DOTs and environmental agencies may also enter into informal cooperative relationships or formal cooperating agreements. The increasing complexity of laws and regulations has led some state departments to form topic-specific teams or alliances with other state regulatory agencies that oversee them. The Maryland State Highway Administration (SHA) engages other state agencies on several environmental fronts. SHA produces a quarterly report on erosion and sediment control for maintenance related activities that is sent to the Maryland Department of Natural Resources (DNR). The SHA and the DNR meet monthly and discuss joint administration of the state's reforestation and roadside tree law. These meetings increase compliance with the DNR's regulations and provide an avenue for resolution of conflicts.

Many public/private partnerships have been formed, particularly in areas dealing with snow and ice control and RWIS. Among these are the Snow and Ice Cooperative Program (SICOPS), Aurora, and the Advanced Maintenance Concept Vehicle Project. Also, recently the Federal Highway Administration (FHWA) awarded a contract to a public/private partnership including the states of Iowa, Missouri, Wisconsin, and Arizona to conduct a field operational test for an RWIS as a part of an advanced rural transportation system (ARTS). The contract involves technical planning, deployment in conformance with the national ITS architecture and standards, and a formal evaluation of the benefits and costs of deploying an RWIS and related ITS services in rural areas. The evaluation will undoubtedly assess the ability of RWIS to reduce the harmful environmental side effects of deicing activities as well as potential savings in agency personnel, material, and equipment costs.

OUTREACH, DISSEMINATION, AND PUBLIC RELATIONS

Part of an effective overall approach to environmental management is having a program to reach out to both the internal and external customers of an agency, to disseminate information in a manner best suited to the audience and the nature of the material conveyed, and to build constructive relations with the general public and other agencies. This synthesis project revealed many different outreach, dissemination, and public relations efforts that collectively represent a high-level, broad based BMP.

Mn/DOT has a diverse program of this nature. Among the many things it does, Mn/DOT conducts customer oriented surveys to determine preferences of road users for different packages of products and services related to road maintenance, prepares videos on many topics, makes available to counties and cities

sample contracts for acquiring environmentally friendly striping paints, sorbents and parts washers, and publishes several environmentally focused newsletters:

- "Waste Management and Pollution Prevention," a nationally distributed newsletter that focuses on waste management, pollution prevention, and waste minimization issues;
- "Environmentally Speaking," a newsletter that focuses on storage tank compliance issues and maintenance site investigations; and
- "Minnesota Roadsides," a newsletter for roadside management.

VALUE OF HIGH-LEVEL, BROAD-BASED BMPs

Each of the management practices discussed in this chapter has a role to play in addressing environmental issues related to road and street maintenance. Most of these high-level, broad-based BMPs are proactive and allow agencies to take steps to address environmental issues, ensure regulatory compliance, mitigate adverse impacts, enhance environmental benefits, and increase the cost-effectiveness of maintenance long before field personnel undertake specific maintenance activities. The alternative is to take a more reactive approach with the risks of reduced customer satisfaction and environmental quality and greater likelihood of liability and fines.

CHAPTER THREE

MAINTENANCE AREA

INTRODUCTION

This chapter presents BMPs organized by maintenance topic. Winter operations; vegetation management; pavement and shoulder work; bridge maintenance; maintaining signs, striping, and markers; litter debris sweeping; and maintenance of buildings, grounds, and vehicles are the specific functions discussed. Generally, each section presents the purposes, tools, and techniques used in the maintenance activity, the environmental considerations involved, and relevant BMPs. Each section concludes with description of the best practices reported by state, provincial, city, and county transportation agencies through the best practices survey, where such practices have been reported.

While distinct divisions of labor and expertise are often necessary to carry out the maintenance function, several factors are at work that encourage a common environmental ethic or approach to the specific task. The first and most practical of these is the continued push toward greater operating efficiency. When dollars are saved because less fuel or materials are used to carry out maintenance activities, lower quantities of potentially harmful substances are introduced into the environment. Second, public opinion, federal and state legislation, and agency guidelines may proscribe certain environmentally damaging practices altogether. Third, coordination with internal environmental staff and external environmental agencies helps ensure a consistent and concerted commitment to environmental protection. Fourth and perhaps most important, an agency's leadership sets the tone for the overall approach toward environmental stewardship adopted by the rest of the department.

WINTER OPERATIONS

Maintaining a clear driving surface during cold-weather conditions is a significant expense for many state transportation agencies. Collectively, transportation agencies spend more than $2.0 billion each year on snow and ice removal in the United States, with deicing activities accounting for roughly one-third of that total (University of Nevada 1996). In the state of Iowa, snow and ice control make up 25 percent of the annual maintenance budget. Likewise, Washington State allocates roughly the same proportion of its budget to snow and ice related expenditures (Dye 1996). In many jurisdictions, including the Canadian provinces, the percent of the budget used for snow and ice control may exceed 50 percent. Despite their direct costs, snow and ice removal unquestionably return far more in safety benefits than they cost. The timing and level of application, general weather conditions and agents used are critical factors determining the effectiveness of snow and ice removal.

According to a 1994 TRB report, most agencies specify acceptable levels of service in written policies that guide overall winter maintenance practices (Kuemmel 1994). Often, these policies specify desired conditions and resources to be allocated to various roadways based on their functional classification. The state of Minnesota, for example, calls for a bare roadway surface before maintenance force coverage is reduced from 24 hours on high-volume (greater than 30,000 AADT) roads. Such guidelines inform the public of official winter maintenance policies, thus increasing awareness and decreasing the potential for liability issues to arise.

Anti-icing

Anti-icing is the practice of preventing the development of a bond between precipitation and road surfaces through the application of chemicals before the precipitation or soon after the start of a snowfall. The potential benefits of anti-icing are impressive—a reduction of up to 80 percent of the agents that would otherwise be used to melt ice and snow after they have formed a bond with the roadway surface (*Better Roads* 1997). A relatively new practice, the materials, technologies, and overall strategy of anti-icing represent a significant departure from traditional deicing. The success and effectiveness of anti-icing requires timely and accurate information on roadway and weather conditions and prompt and appropriate decisionmaking and action. Roadway weather information systems, described below, are an important tool used to collect, analyze, and disseminate timely weather information. FHWA has published a manual on anti-icing procedures, with recommended procedures, materials, and application rates under a variety of pavement temperatures and weather conditions (Ketcham 1996).

Reported benefits of anti-icing place benefit-cost ratios in the range of 3:1 to 11:1, as compared to traditional practices. These studies have demonstrated that preventing a bond between pavement and ice requires less material than does destroying the bond once it has formed (Barger 1997). As a result, less material is placed in the roadway environment for a given level of service and safety. The need for sand, which contributes to fugitive dust emissions and clogs drainage facilities, is reduced or eliminated entirely, producing environmental benefits and cost reductions from reduced storage, application, and subsequent sweeping needs. In fact, standard anti-icing practice discourages use of abrasives altogether, as the available evidence indicates that their use does not increase the performance of the program.

Numerous anti-icing studies have been conducted to ascertain its effectiveness and application techniques best suited for particular winter conditions. One demonstration project conducted

between 1993 and 1995 by the Massachusetts Highway Department and the Federal Highway Administration found that salt substitutes were highly effective anti-icing agents, and that the practice itself was highly cost-effective. This study of the experience of 15 states with anti-icing versus conventional practices also concluded that liquid chemicals are generally more suitable for anti-icing than solid chemicals (U.S. Army Corps of Engineers 1995).

Deicing

Deicing is the practice of removing snow and ice after it has accumulated on roadway surfaces. Typical deicing practices include plowing followed by the application of chemicals that weaken the bond between snow and pavement and abrasives, such as sand, to increase friction between road surfaces and vehicle tires. The term deicing has sometimes been used interchangeably with anti-icing to describe anticipatory measures to prevent the formation of snow and ice on roadway surfaces.

Salt As a Deicing Substance

Salt (sodium chloride) remains the principal substance used for deicing operations in the United States. On average, between 10 and 15 million tons of road salt are applied to roadway and other surfaces each year (U.S. Environmental Protection Agency 1996 and Salt Institute August, 1998, personal communication) depending on the amount of snow fall each winter. One primary reason for this is that it is a highly cost-effective deicing and anti-icing agent. A study on the cost-effectiveness of salt sponsored by the Salt Institute found that during the first four hours after application, direct road user benefits were $6.50 for every dollar spent on direct maintenance costs (Salt Institute 1993). This study did not include the costs of structural and environmental damage potentially caused by the application of salt.

High concentrations of road salt can damage roadside vegetation and reduce water quality. The accumulation of sodium can reduce the water-retaining qualities of soil, reducing plant growth, thus encouraging erosion. In addition, salt is toxic to plants, although the degree of toxicity varies by species. Damage to vegetation by salt accumulation is most likely to occur to roadside vegetation along high-speed, high-volume roads, where both salt application and spray from vehicles is greatest. Typically, five to 10 percent of trees along heavily traveled roads are adversely affected by salt application each year (Auburn University 1992).

High concentrations of salt in surface water may cause certain heavy metals to leach out of water (Auburn University 1992). These substances can potentially harm fish and other aquatic life. The potential for pollution is particularly acute in non-flowing surface water, such as ponds and lakes.

Road salt can enter drinking supplies as runoff or infiltrate through soil. States set thresholds for sodium and chloride content in drinking supplies; when these thresholds are exceeded, remedial measures are usually taken. The most common form of salt contamination occurs in private wells located near highways and storage facilities. Roughly $10 million annually is spent on mitigation measures (Auburn University 1992). According to some research, up to 90 percent of the environmental impacts associated with road salt are caused by improper storage (Iowa Department of Transportation 1996). Thus, proper storage and containment is one of the most effective means of mitigation.

There is no federal standard for maximum allowable concentrations of salt contained in the Federal Safe Water Drinking Act (Massachusetts Turnpike Authority 1995). The state of Massachusetts has set a sodium concentration of 20 mg/l applicable to individuals on a restricted salt diet as the level beyond which public notification takes place.

The corrosion-inducing properties of salt on motor vehicles, bridges, and parking garages are a significant drawback to its application. The costs of repair and rehabilitation to structures due to salt damage in the United States alone is estimated at $125–$325 million annually for bridges, and $75–$175 million for garages, in 1991 dollars (Auburn University 1992). More effective anti-corrosion materials are available, and promise to reduce these impacts.

In its 1994 report on the environmental impacts of transportation, the EPA cites several sources of the costs of roadway deicing. An Apogee Research survey of the cost estimates of damages attributable to road deicing found a range from $4.7 to $8 billion annually. A 1976 EPA study identified $8 billion in damages ($1990) from road salt. Over 90 percent of this total was attributed to vehicle and highway damage, and $600 million to water supplies, health, and vegetation (U.S. Environmental Protection Agency, 1996b).

Use of Abrasives in Deicing

Abrasives increase the traction of moving vehicles during an ice or snow storm. Sand, crushed stone, and cinders are materials typically used as abrasives. Abrasives are sometimes mixed with sodium chloride or calcium chloride to improve traction and debond ice and snow from the pavement surface. Sand that is not quickly removed after a storm can create air quality problems as moving vehicles create dusty conditions. Accumulations of sand can contribute to storm drain cleanup costs and adversely impact fish populations and habitat in adjacent streams. Abrasives removal is a significant expense. Due to the costs of clean-up on roads and drainage facilities, and because of the dust sometimes associated with their application, FHWA does not recommend the use of abrasives in its guidance manual on anti-icing practices (Federal Highway Administration 1996).

Strategies for Mitigating the Environmental Impacts of Salt Applications

Environmentally sound practices concerning deicers and abrasive materials include the following (Young 1996):

- Eliminate the use of road salt, or minimize the amount applied by determining the proper application rate. Calibrate spreaders on a regular basis;
- Site salt storage areas to prevent direct runoff into surface or ground waters, and outside of the 100-year floodplain;
- Store salt within a permanent roofed structure;
- Direct runoff from salt storage areas into suitable runoff management systems;
- Use anti-icing techniques that prevent ice and snow from bonding to road surfaces and facilitate the effectiveness of abrasives; and
- Apply abrasives that are clean, uniform in quality, and free of wood, bark, roots and other extraneous material.

Several other snow control practices are more common to other countries than to the United States. Their applicability, cost-effectiveness, environmental impacts, and potential for general public acceptance depend on the particular circumstances. Many of these techniques have not been fully investigated and will probably be the subject of further incremental research. These include:

- External and/or in-slab melting systems;
- Mobile thermal snow melters;
- Compressed air used during snow plow operations;
- Pavement materials that store and release solar energy to melt snow and ice;
- Electromagnetic energy, used to shatter ice;
- Special drainage systems designed to channel runoff for collection and treatment;
- Salt retrieval or treatment enhanced by "chelating" agents; and
- Improved tire and vehicular design to reduce the need for chemical use (Auburn University 1992).

Alternatives to Salt

Calcium Magnesium Acetate

Calcium magnesium acetate (CMA) was first identified by FHWA in the late 1970s as an alternative to road salt, and has been one of the main alternative deicing compounds used by maintenance agencies around the country since 1986. CMA melts ice more slowly than salt, but produces effective results at temperatures as low as -3.9°C (25 °F). In addition, because of its lower density (about 60 percent that of salt) it requires a larger storage capacity than salt. CMA is ground into snow and ice by the action of passing vehicles, and forms a "mealy snow." A residual amount of this meal remains in place as an anti-icing agent for the next snow event. In order to maximize the effectiveness of CMA, it must be applied before a significant accumulation of snow and ice occurs. It is thus primarily an anti-icing agent. When mixed with snow, CMA prevents snow particles from adhering to one another, retarding or preventing snow packs and ice formation. According to industry literature, CMA is applied at rates similar to those of salt, with heavier first applications and lighter subsequent applications (Cyrotech Deicing Technology 1998). CMA is available in both solid and liquid forms.

CMA is typically applied where the environmental risks of groundwater contamination, vegetation burn, and concrete spalling or corrosion are significant. Research has found the substance to have fewer adverse effects than salt. CMA is virtually non-corrosive to structures containing exposed metal parts. It does not damage concrete or cause spalling from freeze-thaw cycles. Moreover, it has shown negligible adverse impacts on common roadside vegetation and is safe for most aquatic environments. When used as a corrosion inhibitor, it is blended with road salt at rates greater than 20 percent by weight.

On a per-ton basis, CMA is significantly more expensive than salt. For this reason, it is applied in areas where concerns about environmental impacts or infrastructure damage are paramount. More widespread use of CMA is hampered by high production costs (up to 2.0 times that of salt), availability of the product, bulk volume (2.7 greater volume per equal weight) and lower efficiency than salt (Dyment 1995). Auburn University concluded that ". . . while CMA may be less detrimental to the environment and infrastructure, its bulk costs and deicing characteristics preclude its widespread use" (Auburn University 1992).

Under the Intermodal Surface Transportation Efficiency Act of 1991, the federal government provided an 80 percent matching share for funds obligated for the application of CMA on elevated structures, if such application mitigated damage to the environment caused by the transportation project funded under the appropriate title.

In addition to CMA, there are numerous other anti-icing and deicing compounds on the market, under a variety of product names. Three of them (magnesium chloride, calcium chloride and CF7) are described below:

Magnesium Chloride

Magnesium chloride is used in both anti-icing and deicing operations. It is less corrosive than salt and works at lower temperatures as well. It is used primarily as an additive to salt, and is reportedly less damaging to concrete than other common deicers. Magnesium chloride is sometimes used as an alternative to calcium chloride.

Calcium Chloride

Calcium chloride is used in both anti-icing and deicing operations. Also used as an additive to salt, it differs from other deicing agents due to its low eutectic point—it has been shown to be effective at temperatures well below -17.8°C (0 °F). According to industry literature, calcium chloride can reduce the amount of salt needed by half. A test of using calcium chloride as a prewetting agent in Ottawa found that an eight percent admixture of the substance resulted in a 20 percent reduction in the use of road salt while maintaining the desired level of service. Industry literature claims salt reductions ranging from

10 to 40 percent are possible (Miner 1995). This can result in a savings of $2.29 for each two lane-kilometer ($1.42 per two lane-mile) of roadway. It is relatively more corrosive than alternative deicers, however.

Salt is 75 percent less effective at -6.7°C (20 °F) than at -1.1°C (30 °F). Below -6.7 °C (20°F), the moisture needed by the salt to become a brine is not available. Calcium chloride draws moisture from the air, and can produce the brine needed, when used together with salt. Salt treated with calcium chloride is effective at melting ice at temperatures down to -31.7°C (-25 °F). However, blowing snow reportedly can stick to otherwise clear roads treated with calcium chloride, creating potential driving hazards (Iowa Department of Transportation 1996a).

CF7

CF7 is a potassium-acetate based, low-corrosion, liquid deicer that is effective at lower temperatures than CMA. It is sometimes used as a pre-wetting agent for CMA, an anti-icing agent or as a deicer according to industry literature. CF7 is rated "relatively harmless" to aquatic life. It is thus appropriate where deicing speed, environmental impacts, or corrosion are concerns.

Low-corrosion deicers are available and in use to some extent in Idaho, Oregon, Montana, Alberta, British Columbia, and other states. A new formulation of calcium chloride that produces 80 to 90 percent less corrosion than sodium chloride has been introduced (Public Works 1996). The state of Idaho sets strict standards for the corrosive qualities and levels of heavy metals and precipitates allowed in deicers.

Prewetting

Solid chemicals used in deicing remain inert until the application of energy to them produces a liquid film. Prewetting, or applying a liquid to a dry deicing agent, accelerates the formation of this film and thus enhances the efficiency of deicing agents. Prewetted anti-icing agents tend to bounce less, and adhere better to the road, causing less waste and producing a longer-lasting effect. Anti-icing agents can thus be applied at a lower rate of application, increasing the efficiency of deicing operations (Ketchum 1996).

There are three primary means of prewetting (Auburn University 1992):

- Prewetting of stockpile,
- Prewetting while loaded, and
- Prewetting by spreader spray system.

Prewetting agents include salt, brine, CMA, calcium chloride, magnesium chloride, and water.

Winter Equipment

The information age has brought digital technology and other innovations to winter operations. These advances promise to increase the efficiency of snow and ice control efforts, producing less waste and enhancing safe driving operations.

Digital Spreaders

Digital spreader controllers allow for precise application control, and accurate information on application rate, mix, speed, and amount of material spread.

Zero-Velocity Spreaders

The efficiency of deicing and anti-icing equipment has been significantly advanced with the introduction of zero-velocity spreaders (Figure 4). A zero-velocity spreader projects deicing material out of the rear of the spreader at a speed equal to the truck's forward speed, producing a net speed of near zero relative to the roadway. The deicing or abrasive material lands gently on the roadway surface, with minimal bouncing from the target area. With such a system, trucks can travel at much higher speeds than previously, decreasing the safety hazard caused by the speed differential with surrounding traffic and increasing the productivity of the spreader. In a typical application, a narrow swath of deicing material is placed near the crown of the road, where it forms a brine. The action of traffic passing over the brine causes it to migrate toward the edge of the pavement, where the debonding process continues. Application can be much more precise than with traditional spinner spreaders, which cast as much as 40 percent of the deicing material beyond the targeted travel lanes. Cost savings of 30 percent to 50 percent resulting from the reduction of wasted material have been reported (Wald 1996). This more efficient application results in an environmental benefit as well, as less salt, sand, or other deicing and abrasive material is introduced into the environment than would otherwise be the case.

Ground-Speed Oriented Spreaders

Ground-speed oriented spreaders are designed to adjust for a truck's velocity and dispense material at a constant rate at any speed. As a result, less abrasive or deicing material is used than with traditional spreaders. Anoka County, Minnesota reports that with the use of ground-oriented spreaders, the number of loads of material per storm was reduced by half. Thus, an efficiency benefit was realized from reduced time spent for reloading. An environmental benefit from reduced sand, salt or other deicing materials introduced to the environment was realized as well (Transportation Technology Transfer Center 1996).

Snow Fences

Snow fences are natural or manmade barriers that control the accumulation of windborne snow. Snow fences are used in a number of diverse settings, including mountain passes,

FIGURE 4 Zero-velocity spreader.

farming areas, and plains. Design guidelines provided by the Strategic Highway Research Program (SHRP) specify that fence sections should be 20 times greater in length than in height and there should be a gap at the foot of the fence equaling 15 to 20 percent of the height. The length of the area to be protected should be 35 times the height (Kuemmel 1994).

Blowers

Snow blowers are used to cut deep snow accumulations, especially in mountainous terrain or high snow drifts, that exceed the height of the snow plow blade by blowing snow off the road or into dump trucks. Blowers come in a variety of sizes and designs for different needs and in various mount configurations (Kuemmel 1994).

Information

In its manual of anti-icing practices, FHWA describes a decisionmaking toolbox that provides information on weather and pavement conditions and a means for evaluating treatment effectiveness. This information helps maintenance personnel determine if and when to initiate treatment, which treatment operations are most effective for the conditions at hand, proper rates of application, etc.

- *Weather forecasts*—provide information on the timing, form, and extent of precipitation, and wind direction and speed for distinct geographic areas.
- *Pavement road information*—includes information on wet or dry conditions, air temperature, and pavement temperature. While pavement sensors can be used to forecast temperature trends, some also measure chemical concentrations and can help the maintenance engineer decide whether additional treatment is necessary.
- *Road weather information systems*—are roadside–based networks of data gathering systems, involving pavement sensors and weather stations with communication links. These systems provide information on weather and pavement conditions that can be processed and analyzed at a central site (Figure 5). Maintenance engineers can track changing weather conditions and allocate materials, equipment, and manpower where most needed. More advanced systems can incorporate current road conditions and maintenance activities several times each day. By 1994, over 750 RWIS atmospheric sensor sites were in use, with over 2,100 pavement sensors in more than 30 states. The New Jersey Department of Transportation (NJDOT) reported in the best practices survey that their system has the potential to reduce snow and ice control costs by 10 to 25 percent.
- *Thermal mapping*—uses infrared technology to measure pavement surface temperature patterns under a variety of weather conditions. Once recorded via a truck-mounted sensor, this information can be used to predict a pavement section's reaction to changes in temperature. The information can also be used to develop estimates of thermal profiles for other pavement sections.

Equipment and Operator Safety

Snow and ice control operations are normally performed during extreme weather conditions. The danger of collision with other vehicles or obstacles obscured by snowfall is greatly increased during such conditions. Some jurisdictions, such as Washington County, Minnesota, have taken steps to maximize operator safety. Enhancements include:

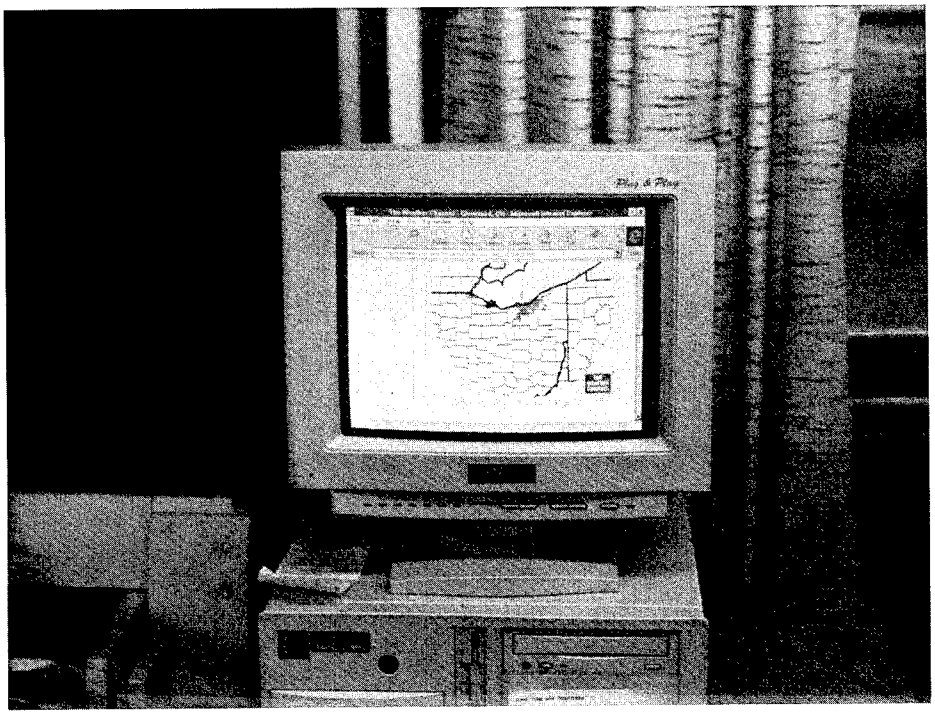


FIGURE 5 Roadway weather information system.

- Placement of hazard markers or metal sign posts for guidance near curbs, manholes, and cable guardrails and grass medians;
- High-output window defoggers and heated outside mirrors, strobe lights and extra reflective markings on snowplow trucks, and fender-mounted mirrors to increase visibility;
- Joy sticks to increase the ease and maneuverability of the plow and spreader controls;
- Application of flat black paint to the truck body in order to reduce glare;
- Blade and frame designs to reduce snow cloud;
- Use of zero-velocity spreaders to reduce the speed differential between snowplows and surrounding traffic (Transportation Technology Transfer Center 1996); and
- Installation of two-way radios or cellular phones.

Storage

According to the literature review, deicing materials should be stored in shelters away from exposure to the elements such that runoff is controlled (Figure 6). Concrete floors and covered loading areas also minimize the potential for contamination of water supplies. Some storage sheds are outfitted with salt detention basins or lagoons that retain salt for future recycling.

Selected Practices From Survey

Alternatives to Traditional Practices

Five respondents considered their use of alternatives to traditional salt application a best practice. New Jersey reported a reduction in the use of abrasives. The likely reason for this response rate is that use of CMA and other alternatives is considered more a common practice than a best practice in many areas of the country.

Use of new technologies was considered a best practice by seven respondents. Pre-wetting systems, roadway weather information systems, in-ground pavement sensors and truck-mounted temperature sensors and zero velocity spreaders were among the technologies mentioned.

Virginia

VDOT has produced an unpublished draft of best practices on snow and ice control. This document provides detailed procedural guidelines to district engineers on winter operations. The document sets out overall goals and objectives, training requirements and procedures for hiring outside services. The document establishes separate procedures for so-called "bare pavement routes" according to which snow and ice are cleared within 24 hours and promotes, although does not dictate, the use of anti-icing materials. The manual also provides suggested application rates for salt, other chemicals and abrasives in various conditions and locations. On-board supplies, equipment calibration, maintenance, communication and cleanup protocol are other areas covered. Although the manual was not officially released for this synthesis, it received high praise from other maintenance agencies.

New Hampshire

NHDOT has published a more limited snow policy document, setting out basic guidelines for spreading practices including materials and application rates. State highways are

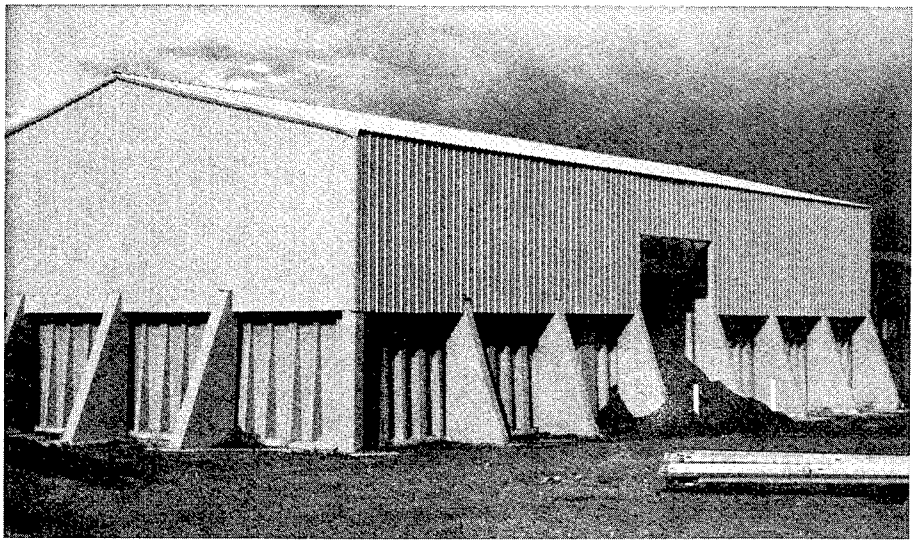


FIGURE 6 Covered sand storage area.

designated by treatment priority and a color-coded map with the classifications is included. Salt is the primary deicing agent used.

Massachusetts

The Massachusetts Turnpike Authority's snow and ice control program document outlines general policies for the general public. In this, it is different from other documents reviewed, which impart operations-level information. The Department relies heavily on salt as a deicing agent, and has been incorporating new materials and technology to reduce salt usage. In 1970, the typical application rate of salt was 329 kg/km (450 lbs/lane mile). By 1993, through the use of ground speed controllers, calibrated spreaders, onboard computers for dispensing deicing materials and the establishment of reduced salt areas, that rate had been reduced to 139-175 kg/km (190-240 lbs/lane mile). The Authority maintains a chemical use reporting system that accumulates data on the type and location of material used; this information is now entered electronically and is maintained in a computer database. The Authority has had a salt storage shed program in place since 1969; currently all deicing materials are covered. Lastly, the Authority conducts training programs each year for each of its employees on snow and ice control. Manufacturers of ground speed automatic control units are invited to present seminars on equipment calibration and repair.

Public drinking water supplies located along the Massachusetts Turnpike and other sensitive areas are protected and designated as restricted salt application areas. These areas are clearly identified by large signs visible to both plow operators and the motoring public. The established application rate of salt is 139 kg/km (190 lbs/lane mile); no mention is made of salt alternatives. The Authority collects and evaluates sodium and chloride data from each water supply on an annual basis to determine whether changes in concentrations of these chemicals have occurred.

New York State

New York State's highway maintenance guidelines on snow and ice control cover all principal operational aspects of winter maintenance. Topics include stockpiling, snow stake installation, maintaining the capability of drainage features and passive snow control (use of snow fences), and application rates. Salt is the principal deicing agent used. Stockpiling guidelines state that all salt should be stored on an impermeable pad in an acceptable structure, or covered and secured with tarpaulins.

North Carolina DOT

NCDOT's BMP manual covers general principles concerning the timing and extent of salt applications and a justification for the use of calcium chloride. The document's language implies that district highway engineers are responsible for identifying sensitive areas that will receive reduced application rates of deicing material. Lastly, it is DOT policy to ensure that spreaders are properly calibrated.

Practices in Severe-Snow Regions

Alaska

The DOT recommends that accumulated snow be placed so that the melt water will be routed to stormwater detention basins, where particles can settle out before being discharged to receiving waters. Accumulations of sand in urban areas and sensitive aquatic environments are collected via sweeping or vacuuming.

Minnesota

Mn/DOT reports the use of living snowfences. These prevent snow from drifting onto roadways and can also provide

wildlife habitat. SHRP has produced guidelines on the design of snow fences.

Alternative Salting Strategies

Vermont

The Vermont Agency of Transportation has developed a salt-reduction strategy called "smart salting." The program consists of measuring roadway temperatures during storms with infrared sensors and tailoring the application rate to the measured temperature, in order to minimize application, while achieving the desired result. The reductions are made possible due to these facts: 1) most winter storms occur when temperatures are around -2.2°C (high 20°F) when considerably less salt is needed and; 2) only four to six percent of the weight of salt needed to melt the total thickness of the snowpack or ice is needed to debond the snowpack or ice from the pavement. The average weight per cubic foot of snowpack and ice was first determined empirically; once combined with data on temperatures from infrared sensors, relationships among temperature and snow or ice thickness and salt application rates were developed. Since the inception of the program, the average salt application rate has declined from 362 kg/two-lane km (495 lbs/two-lane mile) to 270.8 kg/two-lane km (370 lbs/ two-mile lane). The procedure has received attention in trade journals and the news media. The transportation departments of Maine, New Hampshire, Connecticut, Missouri, and South Dakota have acquired pavement sensors to apply this technique as a result of their communication with Vermont transportation officials.

New Technologies

Minnesota

Mn/DOT is experimenting with a number of technologies in the winter maintenance arena. Some of these efforts include:

- Testing of snow shields designed by Mn/DOT staff. These shields are designed to reduce the amount of snow blowing over the plow.
- Automated liquid bridge deicers. These systems automatically dispense a deicing fluid on bridges from spray systems mounted on bridge guardrails with imbedded pop-up nozzles. Storage tanks and pumps are located at one end of the bridge. The deicing operation is triggered by a signal sent from an RWIS. Current policies for bridges call for frequent salt applications, and there is very little space for snow storage near bridges. It is hoped that the automatic system will reduce salt application and chemical costs. Automated salt spreaders are also being tested on bridge decks. The salt system is equipped with a vehicle detection system to prevent direct spraying on passing vehicles.
- Anti-icing from wash-water recycling. EPA regulations prohibit the discharge of wash water or floor drain effluent into drainage fields. Mn/DOT uses recycled wash water for its prewetting. It is also testing the use of wash water as an additive to salt brine.
- Mn/DOT is experimenting with the use of herbicide sprayer attachments to apply anti-icing agents. The Department expects this will decrease salt usage by increasing its anti-icing capabilities.

VEGETATION MANAGEMENT

A primary objective of vegetation management is to provide a safe, unobstructed roadway corridor and preserve the integrity of highway infrastructure. Left uncontrolled, roadside vegetation can impede normal maintenance operations, obstruct motorists' line of vision and cause damage to structures such as rail ballast and guard posts that are partially buried under the soil line. Other objectives may include development of an aesthetically pleasing roadside, pest control, provision of habitat, and stabilization of embankments and other areas prone to erosion. Mechanical mowing, the application of chemical herbicides, pesticides, and fertilizers, and the introduction of native vegetation are the primary tools of vegetation management. Increasingly, alternatives to chemical application are being sought and implemented. Such alternatives include wildflower growth and other competitive plantings, allowing natural growth and regeneration, increased use of mowing, and biological control agents such as flies, mites, midges, and weevils.

Typical goals of well-planned vegetation management strategies are:

- Naturalize the right-of-way to form a desirable transition with adjacent land areas;
- Encourage the regeneration of acceptable vegetation indigenous to the area;
- Integrate the right-of-way to visually harmonize the ecology with adjacent landscapes;
- Minimize maintenance costs;
- Provide undisturbed areas for wildlife and its habitat, including protected crossings, and
- Yield a pleasing and aesthetic appearance (Auburn University 1992).

Living organisms combine with the physical attributes of a travel corridor to form a highway ecosystem. For example, plants stabilize roadside soils against erosion and sediment production, provide a visible boundary at the pavement edge, and offer a pleasant and colorful driving experience. Insects recycle plant residues, generate channels within the soil profile for aeration and water movement, and pollinate flowers. Birds and mammals use the roadside for food, cover, and crossings for migratory species.

When plants or other organisms threaten the safety and comfort of the traveling public or maintenance personnel, jeopardize the capital investment in the transportation infrastructure, or endanger environmental quality, then pest management procedures may be initiated.

Available Management Methods (McCully 1997)

Roadside managers have mechanical, chemical, biological, cultural, and pyric methods available for treating pests. A

single treatment cannot be used in all situations; treatment selection should be based on the pest encountered, the environment in which the pest is found, safety of humans and other organisms, and effectiveness of the proposed treatment. Most of the treatment methods have regulatory oversight that should be accommodated. Provision should be made for systematic training in safe and effective use of the method(s) to be utilized.

Mechanical Treatment

Mechanical control techniques include cutting or trimming herbaceous and woody plants and the occasional cultivation of soils to reduce or eliminate undesirable vegetative growth. Mechanical methods include: operation of tractor-mounted flail, sickle, or rotary mowers; other powered machines that chop, cut, mow, grab, blade, or cultivate; and the manual techniques of grubbing, pulling, cutting, sawing, and mulching. Manual techniques employ both powered and non-powered hand tools.

Mowing is considered the most expensive vegetation management treatment. The need for periodic treatment, the variable growth stages of different vegetative components, and contrasting plant architecture contribute to variable responses to mowing.

Mechanical treatments are most hazardous to workers, and insurance costs are a significant budget item. Regulatory requirements are administered by the Office of Safety and Health Administration. Property damage is also a significant outlay, particularly for mower-thrown objects.

In 1994, the Massachusetts Turnpike Authority instituted a limited-use herbicides policy due to worker safety issues associated with mechanical methods of control, which included exposure to high-speed traffic and noise generated by mechanical equipment. Previously, the Authority had adopted a mowing-only policy by which the control of nuisance vegetation was achieved solely by mowing, weed-whacking and handcutting.

Chemical Treatment

Chemicals for pest management (pesticides) include herbicides for treating vegetation and insecticides for treating insects. Herbicides offer a versatile treatment arsenal because of the array of chemicals available and the variable responses of plants to individual compounds. Insecticides are the treatment of choice for controlling insects.

Pesticides undergo rigorous testing to determine their toxic nature to forms of life other than the target species, as well as the timing and rate of application for target and other species. The toxic nature refers not only to lethal characteristics, but includes any measured tendency to cause blindness or skin irritation, or to induce cancer, gene or birth responses. On conclusion of testing and approval of a pesticide for registration, the material is labeled for use. Materials applied in conformance with label directions should not pose a risk to applicators or others coming in contact. Registration and use are approved by the U.S. Environmental Protection Agency (EPA), the U.S. Department of Agriculture (USDA), and the Food and Drug Administration (FDA). Use is monitored by EPA and designated state agencies for compliance with label directions.

The Texas Department of Transportation employs a toxicity classification system to illustrate the relative toxicity of the herbicides it uses. The ratings are tied to the Oral LD-50 which is a statistical expression of the concentration of a particular substance needed to kill 50 percent of an exposed population of test animals. As illustrated in Table 1, the products used by the Department have oral toxicity ratings that compare favorably with common household chemicals, salt and aspirin. When applied according to label directions, pesticides should not be hazardous to humans or animals eating various food crops or forages with pesticide residues.

Selected pesticides are designed as selective for treatment of a single or narrow array of target pests; nonselective materials control a broader set of pests. Pesticides may be classified for restricted or general use. Restricted materials are those that must be applied by certified applicators. Many state DOTs certify their applicators with training and licensing for treatment of right-of-way with general use pesticides. Records of application specifics may be required.

Pesticides are formulated for dry or liquid application. Liquid application usually is the preferred method of treatment because the material is easier to restrict to the target area. Materials applied as insect baits are applied dry, however.

Herbicidal response may be topical from contact spray or systemic from absorption and translocation within the plant. Systemic materials may enter the plant by absorption through foliage or use other green tissue, freshly-cut stumps, bark, or roots. Applications to plant foliage should be made at or before flowering. Soil applications for root absorption should be made in late fall or very early spring.

Readily available and common-sense precautions vastly reduce the potential for contamination from chemical pest control. Chemicals should not be applied directly to flowing streams or impounded waters. Other measures include ensuring the proper application (rate, method, and timing) and choice of chemical treatment best suited for prevailing conditions. A certification process for herbicide and pesticide applicators is an effective means of ensuring that proper safety and application measures are taken. Most states have implemented certification processes that include training programs and a certification exam. Choosing an herbicide that will be least likely to produce toxic effects in receiving waters while producing the desired effects is best achieved through the assistance of knowledgeable personnel. Such knowledge can certainly be found in state and local departments of environmental protection, agricultural extension or in the private sector, if no in-house expertise exists. Measures that reduce waste include use of surfactants, that promote adherence to the leaf surface of the pest plant, and anti-drift agents and special applicators, that increase the precision of herbicide application. Herbicides are most successfully applied under conditions of low wind and low probability of precipitation. They should not be applied to waterways, wetlands, or other

TABLE 1

TOXICITY RATINGS OF HERBICIDES USED BY THE TEXAS DEPARTMENT OF TRANSPORTATION

Common Name	Common Trade Name	Oral LD-50 (mg/kg)	Oral Toxicity Rating
Aspirin	for comparison	1,240	4
Table salt	for comparison	3,320	4
Glyphosate	Roundup Pro	>5,000	4
Sulfometuron methyl	Oust	>5,000	5
Metsulfuron methyl	Escort	>5,000	5
Triclopyr	Pathfinder II	4,464	4
Clopyralid	Transline	5,000	5

Source: Texas Department of Transportation

drainage areas unless specifically labeled for that purpose (Kramme 1985).

The primary environmental issue in the area of vegetation management concerns the application of chemical pesticides and herbicides. The risk of such exposure at the levels necessary to cause threats to human health is linked to the excessive, improper, or careless application of chemical materials. Also, a very small number of individuals may react to very small quantities of a chemical in an exaggerated manner. The reason for this hypersensitivity is often unknown, but may be due to genetic, nutritional, or other factors.

The EPA is a rich source of information on the impacts of exposure to herbicides and pesticides. For example, the Pesticide Handler Exposure Database (PHED) is used to determine whether particular pesticides pose an unreasonable risk to workers. The Ecological Effects Pesticide Toxicity Database contains the results of over 9,100 studies on pesticide effects on plants, insects, amphibians, fish, birds, reptiles, and mammals; the database covers over 410 active ingredients. The Pesticide Information Network is another on-line collection of information including current regulations status, a training bibliography, and an ecological incident information system.

Cultural Treatments

This method of treatment involves the selection and use of management practices that encourage the competitive dominance of desirable plants. Such management practices include but are not limited to:

- Selection and installation of native grasses and wildflowers;
- Use of a mixture of planting materials to initiate biodiversity following reconstruction or maintenance;
- Utilization of soil materials free of seeds and/or rhizomes of undesirable plants;
- Employment of site preparation, seed placement, and surface mulch to encourage plant establishment; and
- Interseeding areas that have only thin plant cover.

Right-of-ways supporting desirable plant communities are considered to be resistant to erosion, invasion by undesirable plants, and damage from disease and insects. Preferred vegetation generally possesses the following characteristics:

- Perennial growth and habit;
- Absence of invasive roots;
- Drought resistance;
- Disease resistance;
- Ability to control erosion;
- Ability to maintain dominance over invading species;
- Compatible wildlife habitat;
- Attractiveness; and
- Growth habit to satisfy management needs of the roadside management zone in which the plant is located.

The competitive action of desirable plants can be enhanced by preventing pest establishment on the right-of-way through such practices as: specification of seed materials free of pest plants; minimizing the use of sand, gravel, or topsoil from infested sources; using thick mulch for transplanted ornamentals in landscape plantings; and cleaning maintenance equipment thoroughly after use in pest-infested areas. Cultural methods to establish desirable vegetation involves any or all of the following: site preparation, seeding, surface mulching, reseeding after reconstruction or maintenance, and interseeding areas of thin cover.

Native plant species have been introduced into roadside vegetation in many areas of the country. A key benefit of native species, according to practitioners in Iowa, is that native plants form an extensive root system, which inhibits weed growth. In general, they require very little maintenance. In addition, native species are more tolerant of temperature and climate extremes than other grasses (Shelquist 1994). Roadside managers incorporating the use of native species in their vegetation management practices report that the practice requires knowledge of roadside conditions and knowledge of which plant species can succeed in particular environments. Public support for the establishment of a fund for the introduction of native species along roadsides in Iowa came as a result of public concern over general environmental impacts, including groundwater contamination, decreasing wildlife habitat, and a reduction in prairieland. Johnson County, Iowa has banned the use of herbicides altogether, which impelled the maintenance agency toward the adoption of a native-

species planting policy. Mn/DOT staff have reported significant labor cost savings due to decreased maintenance needs that in part offset the increased expense of introducing natural grasses to particular areas under their care.

The technique and timing of other treatment methods (such as mowing and herbicide spraying) and plant susceptibility can be used to enhance plant competition when applied specifically to favor desirable plants and penalize aggressive invaders. Mowing heights may be set to favor certain species, or mowing may be postponed until after desirable plants set seed, for example. Selective herbicides may be used to affect only annual, invasive plants in a stand of stable, perennial vegetation. While cultural considerations in the application of mechanical and chemical methods is an essential component in a pest management program, the delineation between mechanical and chemical methods that could be used to enhance growth and those that would not is extremely difficult.

Biological Treatments

This treatment strategy is based on a predator-prey relationship that would interfere with reproduction or normal functioning of the targeted plants or insects. If the prey organisms do not succumb directly, they would survive as poor competitors or possibly be more susceptible to other treatment methodology.

A biological method must be specific for a particular pest, free of any possible predator organisms, self-perpetuating, and offer a high degree of environmental safety. The most successful biological controls usually involve natural control agents imported from the home territory of the imported pest. A biological control used to promote vegetation in California is the organisium *Bacillus thuringiensis*. By spraying the organism on vegetation, caterpillars that would consume the leaves of the vegetation are reduced or eliminated (Personal communication with Earl Shirley (Calif.), 9/98).

Pyric Treatment

Prescribed burning can be used to remove excessive growth, control noxious weeds, and encourage turf density. Burning should be done when desirable plants are dormant, the soil surface is damp, air temperatures are moderate, and wind speeds are low. Preferred atmospheric conditions for a prescribed burn in fine fuels are relative humidity of 25 percent to 40 percent, air temperature of 21 degrees C (70°F) to 27 degrees C, (81°F), and winds of 13 km/h (8 mph) to 24 km/h (15 mph).

Grasses are classed as fine fuels that ignite easily and burn quickly. A biomass of 660 to 1,100 kg/h (2,420 lbs/hr) is desired for ignition. Proper controls, such as safety strips and suppression equipment, should be in place. Prescribed burning has not been used widely, but has been practiced by Minnesota DOT.

Most Common Approaches to Vegetation Management

Auburn University identified the most common means of management among several states interviewed in its study (Auburn University 1992). Application of herbicides is the most frequently used method, although many states are more vigorously exploring alternatives such as those discussed above. States indicated that herbicide application for roadside vegetation control is permitted provided the application is in conformity with applicable regulations. Public notice is required in several states. Some of the options are a visible and important facet of many maintenance agencies' vegetation management plans as they provide aesthetic benefits in addition to their potential for reducing maintenance costs and enhancing roadside wildlife. Table 2 displays various approaches to vegetation management among states interviewed in the Auburn study.

TABLE 2

VEGETATION MANAGEMENT PRACTICES IDENTIFIED IN AUBURN STUDY

State	Acceptable Roadside Herbicides
New Jersey	Roundup only
Kentucky	Roundup, Arsenal, Oust, Garlon, Krenite
Vermont	Herbicides approved for use by Agriculture Department, which use criteria based on risk of carcinogenicity, groundwater contamination, danger to health, match to intended use
Utah	2-4-D, Atraxine, Dicamba, Diuran/ Bromacil, Glyphosphate, Picloram
Pennsylvania	Roundup, Surflan, Velpar, Oust, Garlon
California	Herbicides registered for use are approved by Caltrans. Pesticide laws and regulations more restrictive than EPA's.
Hawaii	Roundup, Velpar, Oust

State	Public Notice
New Jersey, Florida, Vermont, Pennsylvania, California, Colorado	Public notification of herbicide application
New Jersey, Florida, Vermont, Pennsylvania, California	Certification training

State	Herbicide Application
New Jersey	Minimize drift by specialized spray nozzles, low pressure sprays, low drift additives
Florida	Minimize drift through use of brooms with controlled droplet applicator
Vermont	Minimize drift with low-volume spray, large droplets rather than mist spray and use of anti-drift additives
Pennsylvania	Minimize drift through use of thickening agents and "invert" sprays

Integrated Vegetation Management

Mn/DOT and other state maintenance agencies have developed Integrated Roadside Vegetation Management Plans

(IRVMPs) to guide the practice of vegetation management in their states. IRVMPs, adapted from corporate management principles, describe the processes by which problems and issues are identified, personnel and material resources are marshaled, responsibilities assigned and results measured. A key component of the process is the active involvement of maintenance agency management with regulatory agencies and with staff in planning and operations-level decisionmaking. Reduced long-term maintenance costs, enhanced environmental stewardship, and improvement of roadside safety are the expected benefits of this planning process.

Knowledge and data gathering are central themes in an IRVMP. In a typical program, an inventory of all roadsides will be taken, with information on the prevailing type of vegetation, terrain, highway conditions, and current maintenance practices included. Research identifying which treatment promotes the goals of the program will follow.

The National Roadside Vegetation Management Association (NRVMA) is the central repository of information and exchange of ideas on IRVMPs. While no single formula for vegetation management can be produced, the Association has developed guidelines for developing an IRVMP (Arnebeck 1996).

NRVMA cites five procedures associated with an IRVMP Plan (National Roadside Vegetation Management Association 1997):

- An annual work plan, which identifies actions to implement the goals and objectives of the IRVMP for the current year;
- Method identification and application, which specifies the mix and timing of available methods, such as mechanical, cultural, chemical, "hands-off," and preservation and conservation;
- Training of district staff in methods of weed and pest control, employee safety and record keeping, and public relations;
- Recordkeeping to maintain timely information on the nature, timing, and location of actions taken, including project location, weather conditions, miles completed, amount of materials used, worker and equipment hours devoted to the project, and persons responsible for activity and follow-up evaluation; and
- Program evaluation, which provides an assessment of the successes and failures of the actions taken over a given time period.

A properly designed plan will identify locations and conditions for which particular procedures are appropriate.

Selected Practices From Survey

Connecticut DOT

ConnDOT's herbicide program is contracted out to two private companies. This practice reportedly saves money in application equipment, storage, and washing facilities and maintaining a workforce trained in herbicide application. The Department requires that an herbicide spray report be completed and submitted daily; these are kept on file for 5 years. Herbicides and application rates are specified in the Pest Control Management Plan. A particular herbicide is licensed for use in watershed areas and approved by the department for use in areas not adjacent to reservoirs. The Pest Control Plan cites two programs that were evaluated and later rejected. The first, broadcast foliar application of herbicide to control brush along highways, was rejected due to its potential for adverse environmental impacts. Manual and mechanical control under guardrails was rejected due to cost considerations, and out of concerns for safety of the maintenance crew.

Nebraska DOT

The Nebraska Forage and Grassland Council recommended, and the Nebraska DOT adopted, a policy of reduced mowing. This policy was initiated to provide undisturbed habitat and nesting cover for pheasants, quail, and other wildlife. Studies had shown that 25 percent or more of all pheasant chicks were hatched in roadside cover. A mowed strip is maintained along the shoulder, and has been found not to damage wildlife. This policy has been in place since 1970, when it was estimated that a half-million dollars in reduced costs would result. Another facet of the mowing standards has been the restriction of mowing in areas where native grasses have been sown. The National Audubon Society recognized Nebraska's efforts with an award in 1970.

Texas DOT

The Texas Department of Transportation has developed source documents describing their vegetation management practices. The Herbicides Operations Manual provides application procedures in detail, with complete descriptions of equipment, weed and herbicide characteristics, and precautions to be taken—a list of do's and don'ts when applying herbicides. The manual also contains a quick reference table containing herbicides, application rates, and optimum treatment periods. One particular policy that should be noted is that the department does not recommend bare ground control around guardrails and sign supports.

TxDOT has produced an informative and attractive public information document entitled "Give Nature a Hand." The document describes and explains the state's management policy. These policies include:

- Reduction of full-width mowing to create wildlife habitat, and encouragement of native plant succession;
- Incorporating landscaping based on water conservation;
- Individual vegetation management plans for each district, and
- Computerized record-keeping of all herbicide applications.

In 1996, the TxDOT unveiled an herbicide spray vehicle it had developed. The vehicle incorporated state-of-the-art components with a design process that included collaboration with

engineers from its districts. The vehicle is outfitted with a variable sprayer controller that adjusts the rate at which herbicides are applied in response to changing vehicle speeds so that a consistent flow rate is achieved regardless of speed. TxDOT estimates that this innovation could save between 25 and 30 percent in application expenses.

Alaska

The Alaska Department of Transportation and Public Facilities BMPs for vegetation management states that manual or mechanical mowing is the preferred method of control for vegetation. This policy will remain in place until a statewide integrated vegetation control program is in place. Regional environmental coordinators are consulted to determine whether permits are required before any vegetation control activities in wetland areas are initiated. Grasses that serve as natural filter strips are not mowed.

Arkansas

Arkansas is one of several states involved in a reforestation program. In addition to the environmental benefits of right-of-ways reforestation, the state saves the money it would otherwise have to spend on mowing or herbicide application, at $4.10 and $2.80 per hectare ($10.10 and $6.90 per acre) respectively. Arkansas' "Plant the Future" campaign has resulted in the planting of 355,000 seedlings since its inception in 1991.

Massachusetts

MassPike's Integrated Pest Management System employs vegetative controls in lieu of mechanical and chemical controls wherever practicable, and promotes establishment of a largely self-sustaining vegetation. This requires a soil analysis, which is amended as appropriate. Other features include the development of turf seed specifications that maximize cover and minimize cultural requirements; timely seeding of any disturbed soils to inhibit germination of weeds; reduced mowing to foster establishment of native wildflowers and grasses; and woodland thinning and pruning to favor "first-growth" specimens. Herbicides are used on a limited basis. Proper training of personnel is essential to guarantee success of the program. MassPike's expectation is that the program will be cheaper in the long-run, despite greater up-front costs.

North Carolina

In 1997 NCDOT used a commercial wet blade technology to cut test plots in North Carolina. The wet blade enables the user to cut growth and apply herbicide simultaneously. The wet blade operates like a bush-hog and can be used to cut ditches, banks, etc. The blade cuts the growth and applies the herbicide directly to the open wounds (caused by the cutting). It can be modified to fit almost any tractor, since it operates as a boom arm.

NCDOT expected to use the machine to control brush. They tried several high concentrate, low volume herbicides with the blade; the apparatus does not require any special herbicide. NCDOT achieved mixed results with the wet blade. An advantage of the wet blade is that the herbicide application is discreet. However, the same location must be treated several times to achieve good results. Sporadic wet blade use results in brush thinning, but does not provide complete brush control. NCDOT does not have plans to purchase additional machines, but will continue to use the blade they own. (Personal communication with David King of NCDOT Roadside Maintenance Division, September 1998).

A few states reported returning to the practice of controlled burns to limit the potential for wildfires. Several highly publicized wildfires in areas where controlled burns had been banned have brought some agencies to reconsider the need for periodic clearing of dead, dry brush and timber, potential fuel for large-scale fires.

PAVEMENT AND SHOULDER WORK

Maintenance organizations perform, or are responsible for, a wide variety of pavement and shoulder work. Among these activities are pothole repairs, joint and crack sealing, various types of surface treatments (slurry surfacing, chip seals, fog seals) as well as resurfacing, restoration, rehabilitation, and reconstruction. Shoulder work includes blading, leveling, stabilizing, widening, and resurfacing. Pavement and shoulder work may also involve recycling—hot plant mix, hot in-place, and cold in-place.

Guidance

Specific guidance in carrying out these activities, including procedures for minimizing environmental impacts, can be obtained from a variety of organizations such as the Federal Highway Administration, Transportation Research Board, and various associations, namely, the American Association of State Highway and Transportation Officials, the National Asphalt Pavement Association, the Asphalt Institute, the Asphalt Recycling and Reclaiming Association, the Asphalt Emulsion Manufacturers Association, the International Slurry Surfacing Association, the Portland Cement Association, the American Concrete Paving Association, the Concrete Sawing and Drilling Association, and the International Grooving and Grinding Association. Certain programs can also be the source of valuable information, such as the Strategic Highway Research Program and the Local Technical Assistance Program.

Suggested BMPs regarding pavement and shoulder work generally appear in other sections of this report. See, for example, discussions concerning vehicle maintenance, hazardous wastes, water quality, noise, air quality, and worker safety.

The remainder of this section briefly describes alternative methods for recycling materials into pavements and shoulders, where the materials have originated or been collected as a result of maintenance activities.

Recyclable Materials

Transportation agencies have historically incorporated waste materials from a variety of sources into projects involving pavement rehabilitation, restoration, and resurfacing. The materials in use are cheaper to incorporate than the virgin materials they replace, and often have been shown to perform to engineering and environmental specifications. Use of such materials will increase as research continues into the characteristics, cost, and performance of prospective materials.

Uses of recycled materials in activities involving low- and high-cost pavement and shoulder maintenance projects include (Collins 1994a):

- *Scrap tires*—Used maintenance vehicle tires or pieces of tires collected from the roadside are recyclable. Rubber from recycled tires has been used in crack/joint sealants, surface/interlayer treatments, hot-mix asphalt mixtures, and as a lightweight fill material for soil reinforcement. USDOT has written extensively on Florida's, Arizona's, and California's use of crumb rubber in asphalt pavement, in particular for functional and structural overlays. Federally sponsored research is continuing into the use of recycled tires.
- *Re-use of concrete*—Old concrete pavement has been used as coarse aggregate for new concrete pavements, for various types of bases and subbases, and has been recycled into asphalt paving mixtures. Over 20 states have used recycled concrete for any of these purposes. Recycled concrete is rarely used as a surface course, although it has been used successfully in a 10-yr old demonstration project at the Atlantic City International Airport in New Jersey. (Collins 1994b)
- *Asphalt recycling*—Asphalt paving materials are perhaps the most widely recycled and reused material in highway maintenance. The use of reclaimed paving materials has proven to be generally acceptable. Reclaimed asphalt pavement (RAP) can be used in hot mixes, cold mixes, or recycled in place. It may also be used in bases and sub-bases. In Colorado, asphalt manufacturers are allowed to supplement their product with up to 20 percent of RAP. This reduces the amount of material that would otherwise be buried in landfills and also reduces the amount of aggregates mined from quarries. The RAP can also be used to stabilize roadside shoulders.

A variety of machines are typically used to mill and plane the existing pavement in place, pulverize the material to the correct size, add a binding agent, and spread the recycled material back over the roadway section to form a new base layer. Both hot in-place and cold in-place recycling have been used. The main benefit of in-place pavement recycling is that it is frequently cheaper to reuse layers of old pavement than to import new materials, aside from benefits of conserving resources. Such reclamation can produce base material for a fraction of the cost of virgin material.

Approximately 80 percent of removed asphalt concrete surface is recycled in highway applications, with the result that more than 70 million tonnes (77 million tons) of asphalt pavement debris is kept out of landfills. The majority of states allow contractors to retain ownership of reclaimed asphalt pavement as incentive to using recyclable materials, to reduce costs, and to help manage equipment capacities and material inventories (Horvath 1998).

A key environmental concern regarding recyclable materials, especially asphalt pavement, is whether they contain constituents that warrant classification of asphalt paving materials as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) (see chapter 4, Section on Hazardous Wastes). The National Asphalt Pavement Association reports that numerous states have tested asphalt pavements in landfills using the toxicity characteristic leaching procedure (TCLP) and did not identify them as a hazardous waste; neither did they identify appreciable quantities of toxic materials (Horvath 1998).

The Texas Department of Transportation conducted tests on asphaltic materials used in different types of pavement related activities to determine if such materials posed a hazard to the environment. TxDOT uses a variety of different types of asphalt materials in its maintenance operations that may contain volatiles, semivolatiles, and trace metals (see Table 3). The department stockpiles quantities of these materials throughout Texas. Samples of the following asphalt materials were tested using the synthetic precipitation leaching procedure (SPLP), which is similar to the TCLP method described in the hazardous materials section of chapter 4:

- Hot-mix cold-laid asphaltic concrete pavement (HMCL);
- Untreated reclaimed asphalt pavement (URAP);
- Treated reclaimed asphalt pavement (TRAP);
- Patching mix (PM); and
- Precoated aggregate (PA).

Results of the test were designed to simulate the cumulative lifetime effect of rain on stockpiled asphalt material and be as conservative as possible. Results of the analysis of the synthetic leachate were compared to Texas Water Commission drinking standards, which are even more stringent than the U.S EPA's. Two conclusions were reached:

1. Trace metals, volatile organic, and semivolatile organic constituents in the synthetic precipitation leachate of the asphalt materials are not a significant concern. Expected runoff from similar stockpiles is not expected to release environmentally significant amounts.
2. There is no pattern of constituent presence based on the location of materials stored in Texas. However, the HMCL is more likely to contain organic compounds that may be leachable in trace quantities (Texas Department of Transportation 1993).

TABLE 3
POSSIBLE CONTAMINANTS OF ROAD MATERIALS

Group	Volatiles	Semivolatiles	Trace Metals
U-RAP	No, because the reclaimed road material would normally be several years old and would not be likely to have the volatile organics present in the material after several years of weathering.	Yes, because the asphalt and oil dripping and other leakage on pavement may contain semivolatile organics.	Yes, because the oil drippings onto the pavement may contain wear-metals. The metals of concern are As, Cd, Cr, and Pb. These have been identified by EPA as the most likely to be present in used oils. We will also include Ba because this compound was detected in some types of asphalt in previous research.
Precoated Aggregate	No, because this material is rocky substrate coated with asphalt through a heat treating process. Will not be expected to contain volatiles.	Yes, because the asphalt may contain semivolatile constituents.	No, trace metals are not a concern because there is no used oil or other source of trace metals.
TRAP, HMCL, PM	Yes, because cutback asphalt is sometimes used to prepare these mixes. Cutback is a mixture of asphalt and volatile hydrocarbon cutter stock.	Yes, because the asphalt may contain semivolatiles.	No, because there is no used oil or other source for HMCL, or PM. The T-RAP may contain used oil, but the testing of the U-RAP samples will be sufficient.

Source: TxDOT

Selected Practices From Survey

Massachusetts

MassPike, the Massachusetts Turnpike Authority, is working with a Massachusetts firm to develop a cold patch product made from roadway millings. As of 1994, the cold patch product was still in the experimental stage. The Authority also requires that 10 percent of its asphalt operations consist of recycled asphalt. Street sweepings, asphalt, and concrete demolition materials and suitable petroleum-contaminated soils are brought to an asphalt batch plant for recycling. Other products containing wholly or partially recycled products include traffic panels and guard rail spacers.

Vermont

Vermont DOT reports savings of $50,000 annually through its use of recycled asphalt concrete pavement for shoulders.

Texas

The recommendations of TxDOT's Environmental Maintenance Task Force Report included the following:

- In regard to overlay operations, cold mix, with cutback asphalts, should be used only when hot mix is not feasible or available. Care should be taken to avoid wasting materials on the roadside or ditch.
- In regard to liquid asphalt operations, the use of cutback asphalt should be limited. Asphalt cements and emulsions should be used wherever possible. Spraying cutbacks on the roadside or ditches should be prohibited.

Missouri

MODOT also recycles tires as tire-derived fuel at a University of Missouri power plant.

BRIDGE MAINTENANCE

Standard bridge maintenance activities include cleaning, painting, and scour protection, as well as repairing, rehabilitating, and replacing various bridge elements, including decks, railings, abutments, and bearings. Oil, dust from brake linings, sediments, deicing chemicals, paint chips, paint dust, broken asphalt, and bird droppings are among the materials that accumulate on bridge surfaces. The removal of lead-based paints from bridges is an acute concern. Unless somehow contained, these or other materials used or removed in maintenance operations will wash into water or soil beneath the structure with the potential for contamination.

Runoff and Wash Waters

An effective approach to controlling runoff and wash waters from entering surface waters is in the design of the bridge itself. Design features should allow wash water to run off where it can be treated on land before it is discharged to surface waters. DOTs can implement BMPs to minimize runoff of untreated discharge into surface waters where pretreatment on land is not possible (Young 1996).

The following practices can minimize runoff impacts (Young 1996):

- Avoid paving during rain;

- Collect maintenance wastes and keep from entering storm drains;
- Shovel or vacuum sawed-out slurry and broken asphalt to remove from site, while minimizing dust;
- Block or cover storm drains to divert to a collection area when saw cutting, liquid cleaning, or wash down is performed on a bridge deck;
- Keep drip pans or absorbent materials on site and use below leaking or dripping pavement equipment and vehicles or other potential spill areas;
- Use non-toxic cleaning solutions without chlorine or solvents;
- Hang tarps to trap, contain, and collect wash water as well as construction and maintenance debris on the bridge deck;
- Use booms in underlying surface waters to trap and remove floating substances; and
- Train workers on the methods and need to reduce water quality impacts.

Other desirable practices are to:

- Routinely inspect drain protection devices to ensure they are performing properly;
- Handle any wastes collected in a manner consistent with applicable laws and regulations;
- Empty drip pans to avoid overflow or accidental spills;
- Inspect tarps and enclosures for rips and tears and repair and resecure as required; and
- Routinely clean and remove debris and sediment from scupper drains.

Lead Paint

One of the greatest environmental concerns regarding bridge maintenance is the introduction of lead (from lead paint) into the environment. Applicable laws and regulations define lead content and permissible levels of lead in paint, the breathing zone, waste, air, water, and the blood stream (Appleman 1997). Both lead paint and abrasives used in removing lead-based paints may be considered hazardous under RCRA. Lead paint removal falls under OSHA regulations for worker protection as well. Many states require special equipment and procedures for the containment, storage, transportation and treatment of such materials (Figure 7). Great variations in costs bid by private contractors for lead paint removal on bridge structures underscore the gaps in knowledge and uncertainties surrounding the procedures and regulations. Lead paint removal procedures include:

- Open blast cleaning with expendable abrasives
- Open abrasive blast cleaning with recyclable abrasives
- Closed abrasive blast cleaning with vacuum
- Wet abrasive blast cleaning
- High/ultrahigh pressure water jetting
- High/ultrahigh pressure water jetting with abrasive injection
- Hand tool cleaning
- Power tool cleaning
- Power tool cleaning to bare metal
- Power cleaning to bare metal with vacuum attachment
- Chemical stripping
- Sponge jetting
- Sodium bicarbonate blast cleaning (Appleman 1997).

To prevent release into the environment, paint, dust, or abrasives used in paint sanding and stripping are contained in variously elaborate enclosed or semi-enclosed temporary structures. Of the methods listed above, the open abrasive blasting method requires the most stringent containment because of the high amount of dust and debris produced.

There are a number of containment and recovery techniques to prevent debris from being introduced into surface waters. The method of paint removal partially dictates the containment and recovery method, as do bridge design, size, and condition. Containment procedures include:

- Free-hanging sheets, which generally are capable of collecting no more than 50 percent of debris generated (Young 1996);
- Partial or total enclosures of rigid or flexible materials, supported by rigid framing. Working space, visibility, and interior air quality must be considered in the design (Figure 8); and
- Filtering systems, which remove particles produced in the process of removing paint before releasing the air outside of the enclosure. Although expensive and difficult to operate properly, these systems effectively remove paint dust and abrasives and improve air quality for workers.

Recovery techniques include:

- Vacuuming at the point of surface preparation. Typically, surface preparation tools are outfitted with vacuum nozzles that capture dust and debris as they are generated. Dust removed in this way is channeled to a container or a reclamation system that can separate the various particles for disposal or recycling;
- Removal of accumulated debris through manual or mechanical means. These include shoveling, sweeping, or vacuuming to collect debris;
- Use of barges or containment booms to collect falling debris; and
- Funneling wastes into a disposal container (Young 1996).

The most recent NCHRP synthesis on lead paint removal offers information on many additional practices that are worth consideration (Appleman 1997). One of these is adding calcium silicate additive to the abrasive in an amount equal to 15 to 20 percent of the volume of the abrasive. This is done before the blasting operations, to do so after the waste generated is considereed treatment of a hazardous waste and is restricted. Under RCRA, the waste would be hazardous if tested over 5 mg/l (6.7×10^{-4} oz/gal.) leachable under the TCLP, but in most instances it has tested non-hazardous. Consequently, the additive eliminates the generation of hazardous waste, thereby

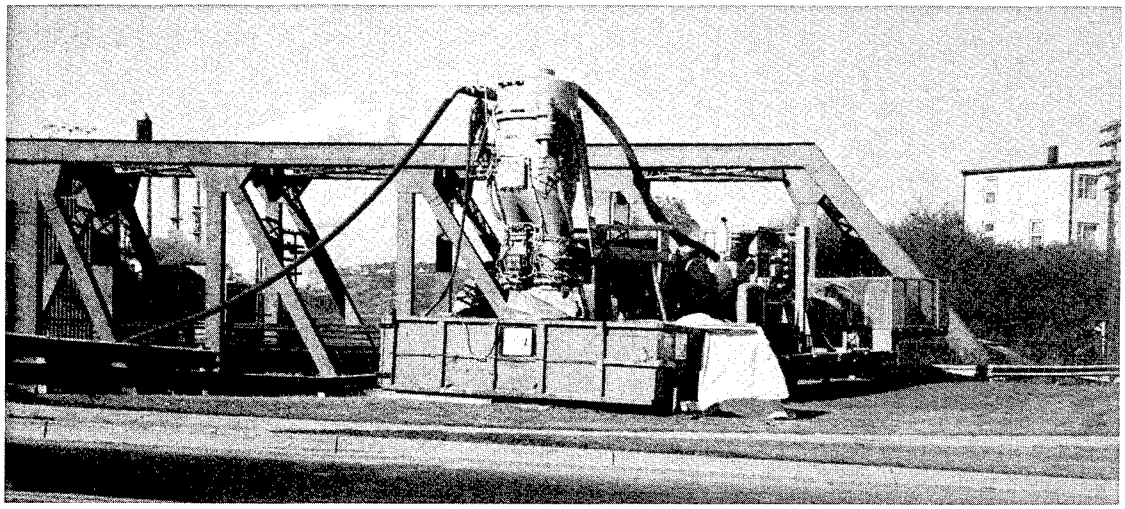


FIGURE 7 Full enclosure vacuum system.

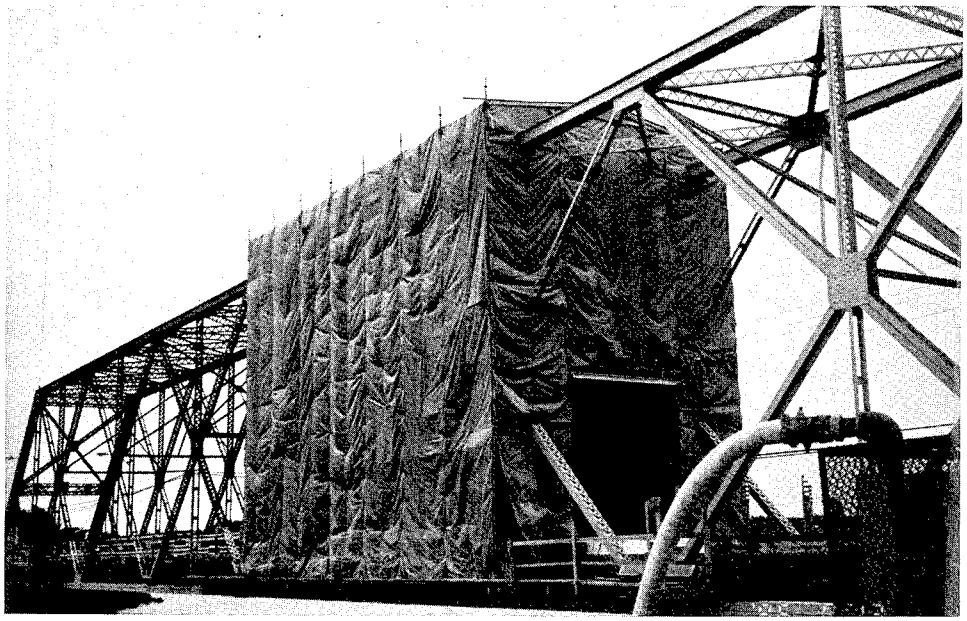


FIGURE 8 Full enclosure.

greatly reducing disposal costs and is not classified as a hazardous waste under RCRA. However, the long-term effects on coating and adhesion are unknown, and abrasive costs are increased $18 per tonne ($20 per ton).

Bridge maintenance costs have increased as a result of lead paint removal practices intended to protect the environment. While one study refers to a doubling or trebling of costs, another has estimated that total costs have increased by 20 to 35 percent for containment and disposal (Appleman 1992). The 1997 NCHRP Synthesis report on lead paint removal noted that costs have increased substantially since the previous synthesis was published in 1990 but have stabilized in the last 2 years for full removal and containment (Appleman 1997). Some state maintenance agencies have stated that deferral of bridge maintenance or diversion of funds from other maintenance activities has been the only recourse in light of the need to remove lead-based paints as mandated by applicable laws and regulations.

Overcoatings

An alternative to lead paint removal is to apply an overcoating especially if less than 20 percent of the protective coating system has failed. Overcoating involves: 1) cleaning the bridge with pressurized water to remove salts, soils, and other contaminants; and 2) spot priming areas where paint and corrosion have been removed, and applying coats of paint over the entire surface. Overcoating has the following advantages in comparison to full removal with containment:

- Minimizes the disturbance of existing paint;

- Reduces the generation of (possibly hazardous) wastes, and the need for disposal and accompanying precautions and requirements;
- Reduces worker exposure to lead;
- Avoids the need for expensive enclosures;
- Substantially lowers cost in comparison to full removal with containment; and
- Substantially increases service life (often 15 years or more).

However, there is significant risk of short-term failure of the complete painting system if the original coating does not have sufficient adhesion or the right mechanical properties, or if the overcoat is incompatible with the original paint system (Bernecki 1995).

Non-leaded paints

Non-leaded paints have been developed for use on bridges. The Steel Structures Painting Council provides guidance on different types of paint systems. The choice of paint system depends on the type of environmental zone, the type of preparation, the nature of the primer or undercoating, and whether the paint is intended for brush or spray application.

Monitoring and Testing

Many states monitor or test air, water, and soil for lead. Monitoring of visible emissions external to a containment structure and monitoring for occupational exposure of workers is common. Testing of wastes collected from containments and any potentially contaminated soil is often necessary. The desirability of monitoring depends on the nature of the wastes, regulatory requirements, impacts on the environment and worker safety, potential liability, and costs.

Worker Protection and Certification

OSHA promulgated a major new rule requiring contractors (as well as transportation agencies) to observe stringent requirements for protecting individuals removing lead or others who might be exposed. EPA is expected to issue a final rule (Title X) requiring certification of contractors, supervisors and workers engaged in lead paint activity (Appleman 1997). Issuance is expected in 1998 or 1999 with implementation to probably occur in 1999 or 2000.

Paints with Low VOCs

Paints with high volatile organic carbons (VOC), should be avoided and are subject to regulation under federal and state laws. The Steel Structures Painting Council publishes a guide on VOC content requirements. This guide describes procedures for preparing specifications for protective coatings conforming with VOC coating requirements, and is intended to be used by specifiers, end users, and others who select, test, or specify coatings to meet VOC regulations (Steel Structures Painting Council 1994).

Other BMPs for Painting

Additional BMPs for painting are as follows:

- Store wastes in compliance with applicable regulations;
- Mix and move paints at secure contained locations off the bridge and far from water;
- Prepare a plan for responding to accidental spills, provide training, and maintain the necessary equipment at the site for immediate mobilization;
- Do not clean painting equipment in surface waters or allow cleaning runoff to enter surface waters;
- Limit paint in pails to 7.57 liters (two gallons);
- Inspect the surrounding area for paint spills or debris, and remove and clean up debris, paint residue, paint, and waste on completion of the project; and
- Properly and mechanically maintain paint removal tools and vacuum/suction systems (Federal Highway Administration 1996).

Selected Practices from Survey

Minnesota

Mn/DOT has conducted research in several areas of bridge maintenance, including alternative methods of paint removal (e.g., recyclable abrasives), dry ice blasting, high-efficiency particulate air (HEPA) vacuums, needle scalars, and peel-away paint removers. Many of these have proven unsuccessful because the methods were either very slow, left paint, or required additional preparation work before repainting could begin. As a result, dry blasting is the paint removal method presently used in Minnesota (Personal communication with John Allen, Mn/DOT Bridge Design Unit, 9/98).

New York

In 1995, The New York State Department of Transportation submitted specifications for a lead paint removal containment enclosure. This action was prompted by the implementation of strict EPA regulations involving the removal of existing paint to control the emissions of dust, as well as dust-containing lead paint debris. Tarps and covers previously used contained only 40 to 60 percent of the paint debris generated. The enclosure for which design specifications were described would allow abrasive blast cleaning and paint removal work to take place with 99.9 percent efficiency against the passage of dust and particles two microns in size.

Washington

Bridge cleaning and painting operations are contracted out by WSDOT, which issues specifications for these operations. Specific instructions to the contractor include:

- After abrasives blasting, all loose rust, dirt, abrasive and paint residue, and dust shall be thoroughly removed before paint is applied.
- Enclosures may be constructed of flexible material, will cover the area below the blasting area, and extend up the sides.
- A minimum of three samples of blasting wastes are tested for arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc. If the average of the samples is at or above limits set by state regulations, the waste is designated as hazardous, and disposed at a permitted hazardous waste facility.
- A detailed description of methods used for removal of accidental spills or drips must be provided.

Vermont

The Vermont Agency of Transportation has applied automotive rustproofing materials to bridges for more than 20 years. It has been successfully applied over alkyd paint systems and bare steel, and is currently being tested over low VOC paint systems. According to the agency, the rustproofing material substantially extends the life of a bridge paint coating. Experience has shown that coatings can last as long as 20 years and in many cases much longer. First used as a solution to rusting of beam and girder ends at expansion joints, the approach is used by the agency as an alternative to total lead removal on bridge coatings. For spot applications, the material is applied after washing, vacuum scraping or sanding, priming, and top-coating. The rustproofing material is applied at a rate of roughly 408.6 kg per 45.35 tonne (900 lbs. per 50 tons) of structural steel. Use of vacuum-shrouded power tools and application of low-VOC coatings and a tinted automobile grease undercoating costs $226.8 per tonne ($250 per ton) of substructure steel as compared to total paint removal at $1,814 per tonne ($2,000 per ton), according to the Vermont DOT.

Texas

In its draft best practices manual, TxDOT states that its standard practice for disposing of blast material recovered from painting operations is encapsulation in concrete or clay bricks.

Arkansas

The Arkansas State Highway & Transportation Department (AHTD) applies calcium sulfonate paint to its bridges. According to the AHTD, this paint requires very little surface preparation, usually limited to removal of paint scales only.

Missouri

Missouri is known as the "lead capital of the world." Due to the number of lead smelting plants that process lead into lead ingots in the state, it is in the unique position of being able to recycle lead blast residues from bridge painting operations that would otherwise be considered hazardous waste under RCRA. The blast residues can be used to substitute for a raw ingredient in the lead smelting process. Used in this way, the state is exempt from RCRA waste regulations and the threat of long-term liability associated with disposal of lead in a sanitary or hazardous waste landfill is greatly reduced, according to the department.

The Missouri DOT uses abrasive recyclers in the removal of lead based paint from steel bridge structures. The steel shot used as an abrasive recycler reduces the volume of lead-contaminated blast residue generated by a factor of about 8-to-1, in comparison to routine sandblasting. The steel shot is collected and cleaned through a series of magnetic and air separators, removing the lead particles from the blast media. The abrasive steel shot is used numerous times.

Connecticut

The Connecticut DOT suspended the necessary practice of bridge washing because of concerns about lead contamination and the high costs of lead paint containment. While the action helps avoid lead paint contamination of water and soils, the department regards the suspension as a major problem.

SIGNS, STRIPING, AND PAVEMENT MARKERS

Paints and pavement markings are used to delineate travel lanes, medians, shoulders, and centerlines. Maintenance engineers can choose from several types of marking products and materials, each with distinct characteristics and qualities. It is estimated that nearly $353 million was spent in 1993 for marking programs in the United States (Russell 1993).

Retroreflectivity and durability are two fundamental performance characteristics associated with pavement marking materials. Retroreflectivity refers to the reflection of light back to the driver from the marking surface. Glass beads, premixed in the paint or applied during application provide this quality. Retroreflectivity ratings for adequate pavement marking visibility during nighttime or adverse weather conditions have been established (Henry 1990; Attaway 1990; Graham 1991; Ethan 1986). A suggested minimum standard is 100 millicandelas per lux per square meter (Andrady 1997). Durability refers to the resistance to wear of a pavement marking, and is generally equated with service life. Factors affecting durability include traffic demand, weather, the condition of the underlying pavement, as well as the quality of the material itself. Durability has been expressed as a rating between 0 and 10, directly correlated to the percentage of the marking remaining 12 months after its application. Cost and ease of application

are additional factors to consider in the choice of pavement markings.

Environmental and Health Considerations

Pavement marking materials may produce adverse environmental impacts through the release of VOCs and hazardous air pollutants (HAPs) into the atmosphere. Coatings including various types of paints and marking materials are estimated to account for nine percent of the VOC emissions from consumer and commercial product sources (Andrady 1997). HAPs present in high levels in pavement markings include certain VOCs, toluene, methanol, xylene, methyl ethyl ketone, and aromatics. Lead chromate, a toxic substance, is found in yellow paint used in highway striping. The presence of these substances during striping operations poses a potential health risk to workers.

The United States Environmental Protection Agency has published a draft rule to regulate the VOC content level for 55 categories of architectural coatings. In 1996, the EPA estimated that this proposed regulation would reduce VOC emissions by 96,142 tonnes (106,000 tons) per year, a 20 percent reduction from 1996 levels (U.S. Environmental Protection Agency 1996a). The final version of this rule was not implemented in January of 1998 as anticipated, and it is unknown when it will take effect. The draft rule bans the use of traffic marking coatings containing over 150 g/L of VOCs. Many state departments of transportation, anticipating the eventual establishment of this rule, have already adopted the use of so-called compliant markings.

Solvent-Based Paints

Solvents are used to reduce the viscosity of pigments, fillers, and other paint additives to allow application by spraying, brushing, or rolling. The amount and type of solvent used influences the drying time of the paint. While solvent-based paints rate high in retroreflectivity, they contain relatively high levels of VOCs, and pose relatively higher risks to workers than other marking materials.

Water-Based Paints

Solvents are replaced by water in these formulations, and different types of additives are used to form a paint film, maintain consistency, and perform other functions. Water-based paints are relatively inexpensive and produce far lower VOCs than solvent-based paints, and are compliant with proposed EPA regulations. Tests conducted by Snohomish County, Washington showed inconclusive results regarding performance of water-based paints compared to that of solvent-based paints. Based on the results presented, acrylic emulsion paints appear to perform best on clean, new pavements, and perform least well where the pavement is rough and dirty. Overall, the study found that the paint could be applied under a variety of temperature and humidity conditions, and was less expensive to apply (Snohomish County Public Works Department 1995). In order to apply the new paint, most existing striping machines must be retrofitted with new equipment. Retrofitting requirements may include the replacement of all reactive surfaces with non-reactive materials and replacement of gear pumps with diaphragm pumps. The costs of retrofitting range from $30,000 to $45,000, depending on the size of machine (Cinoman 1996).

Thermoplastics

Thermoplastic coatings are prepared by melting the material at around 200° C (340 °F) and applied by coating, spraying, or hot extruding. Thermoplastics exhibit good durability and retroreflectivity characteristics. With no measurable VOCs, they are compliant with proposed EPA regulations. In addition, they are moderate in cost. For these reasons they are considered an excellent replacement for the non-compliant materials.

Tape

Similar in composition to thermoplastics, tapes are preformed into ribbons at the factory and are glued into place on the surface to be marked. The initial cost of tapes is relatively high, and although they are not as durable as thermoplastic material, they have excellent retroreflectivity when first applied. While the material itself contains no VOCs, the glues used in its application may be very high in VOCs.

Raised Pavement Markers

Raised pavement markers are generally made of epoxy, metal, or ceramic and generally are glued into place with a strong epoxy adhesive. They are considered very good lane delineators because they are sensed both through sight and the gentle bump produced when traversed. Drawbacks include the relatively high cost of initial installation, vulnerability to grime build-up with subsequent loss of reflectivity, and damage from snowplow operations. Their use is generally limited to placement along major highway systems. The adhesives used are the only VOCs produced, and these are generally low.

LITTER, DEBRIS CONTROL, AND SWEEPING

Highway maintenance personnel collect litter and debris from roadways, rest areas, and other facilities for reasons of safety and aesthetics. Sources of small-scale litter and debris include littering, highway vehicles, construction and agricultural runoff, plant decomposition, eroded land, other surface runoff, atmospheric deposits, and wind-blown debris. These deposits are a significant source of contamination of stormwater runoff. This runoff also complicates stormwater facility

maintenance, as accumulations of debris, sediment, and other matter must be removed periodically. Culverts and drainage systems require periodic cleaning as well. In rest areas, and on roadways and shoulders large debris, such as car parts, tires, pieces of metal and construction materials can be found that require proper disposal.

Roadway sweeping and vacuuming, manual and automated refuse collection, and stormwater inlet and ditch cleaning are the primary means of litter control. Generally speaking, removal of litter and debris require extensive manual labor; agencies frequently rely on volunteer programs such as the adopt-a-road programs, prison labor, and contractors. This section focuses on litter, debris and street sweeping as specific maintenance activities. Further information on relevant BMPs is found in the sections of chapter 4 that address hazardous materials and water quality.

Litter and Debris

NCHRP Synthesis 184, *Disposal of Roadside Litter Mixtures,* provides a review of practices throughout the United States for managing litter and debris. The synthesis discusses collection, separation, recycling, and disposal practices as well as various deterrents to highway litter, such as law enforcement, state bottle bills, and laws mandating recycling. The synthesis also addresses education and beautification programs in addition to the widespread and highly effective volunteer Adopt-a-Highway programs. The synthesis noted that a number of states were involved in mandated or voluntary recycling operations. Connecticut, Indiana, New Jersey, New York, Massachusetts, and Pennsylvania reported separating glass, aluminum, and metal beverage containers. Colorado, Delaware, Missouri, and Virginia encouraged Adopt-a-Highway groups to separate and recycle.

Landfilling is the primary means of disposal for litter and debris. Diminishing landfill space and greater control over the types of debris acceptable for landfilling are emerging challenges. Tires and dry cell batteries, for example, are not permitted in some landfills. Other states sort materials collected on site, sending non-toxic materials to landfills and stockpiling others for testing and classification as hazardous or non-hazardous material. A few states with mandatory recycling programs separate glass, aluminum, and other trash collected. On-site stockpiles of recyclable materials include equipment parts, road building materials, signs, posts, and culverts. Some states provide separated containers for recycling cans and bottles at rest areas and welcome areas.

NCHRP Synthesis 184 found significant variation among DOTs in the fiscal resources devoted to litter and debris collection. As a percentage of total maintenance, litter costs range from under one percent to 14 percent, in New Jersey, with an overall average of 3.3 percent among all agencies. Other findings from the 1993 synthesis study include (Andres 1993):

- Formal waste management practices for maintenance operations are not in general use;
- Current and potential limits to landfill areas are not recognized by some highway maintenance organizations;
- A general lack of communication between highway maintenance and state environmental agencies impedes progress and cooperation;
- State beverage container deposit laws are considered very effective as roadside litter deterrents; and
- Adopt-A-Highway programs are the most effective volunteer programs benefiting maintenance operations.

Street Sweepings and Vactor Waste

Street sweeping is most effective in intensively developed areas such as central business districts (CBDs) (Young 1996). Other areas that can benefit from sweeping include rest stop areas, weigh stations, and maintenance facilities.

The effectiveness of material removal is directly proportional to the frequency of sweeping. Two passes have generally been found to be sufficient to remove most debris. Broom sweepers are generally more effective at removing larger debris, and are less effective at removing the finer particles associated with most pollutants. Street sweeping has an aesthetic benefit as well, especially in CBD areas. Mechanical and vacuum street sweepers are not effective in removing oil deposits. While vacuum sweepers are more effective at removing fine particles, they are currently too slow for practical and safe operation in high-speed facilities (Dye 1996).

Powerful vacuum sweepers/cleaners are increasingly used in the collection of dust and larger debris. Removal of dust and debris in preparation of streets for crack sealing, which is typically accomplished by blowing compressed air into the roadway surface or flushing with water, can be more effectively accomplished with the vacuum device. Outfitted with a water tank, the vacuum action can be reversed to clean catch basins and excavate around pipes, performing tasks that are more time consuming and injury-prone when done manually.

Street sweepings may be tested for contaminants such as total petroleum hydrocarbons (TPH), polynuclear aromatic hydrocarbons (PAH), and metals such as lead, chromium, and cadmium (Table 4). Sources likely to contribute to TPH concentrations in street waste include organic materials, automobile and truck tires, asphalt paving materials and motor oil and lubricants from cars and trucks. Heavy oils, truck tires, and asphalt paving materials are potential sources of PAH (London Associates, Inc. 1995).

The preferred means of road sweeping disposal is landfilling. Among the recycling uses of disposed sweepings are snow and ice abrasives, fill (e.g., for shoulders, borrow pits),

TABLE 4

TPH CONCENTRATIONS OF VARIOUS WASTE SOURCES

Type of Waste	Concentration (ppm)
Road sweeping	50–4600
Vacuum cleanout sludges	500–7800
Ditch spoils	200–2500

Reference: Andres 1993

TABLE 5
COSTS OF DISPOSAL AND REUSE OPTIONS FOR BROOMING AND SWEEPING

Cost	Landfill ($)	Thermo-Treatment		Bio-Treatment ($)	Land Applied ($)
		Onsite ($)	Offsite ($)		
Treatment cost	25 to 50 per ton	70 per ton	50 per ton	55 per ton	15 per ton approx.
Transport cost	7 to 0 per ton	N/A	0.30 per ton	N/A	7 to 10 per ton
Total cost	32 to 60 per ton	70 per ton	95 per ton	55 per ton	22 to 25 per ton
Analytical cost	600 per site	1,200 per site		2,400 per site	1,200 per site
Overage cost per site	7,000 to 12,600	15,200	20,200	13,400	5,600 to 6,200

Source: Iowa Department of Transportation, *Brooming and Sweeping*, Environmental Maintenance Committee Report, June 1996.

planting borrow, and repairing eroded areas. Table 5 presents costs for various disposal options compiled by the Iowa Department of Transportation. Land-applied, or recycled street sweepings, is the most inexpensive option, followed by landfilling.

Recycling of Street Wastes

Several public works agencies use catch basin sludge and highway sweepings as backfill or as landfill cover. Sand is sometimes collected after storms and recycled. Recycled street sweepings must be screened to remove large particles. In some states, such material must be tested for concentrations of toxic chemicals before such uses, or before permission is granted for their disposal in landfills. Concern over the use of such materials centers around the degree to which they are contaminated with heavy metals, carcinogenic polycyclic aromatic hydrocarbons (CPAH) or other materials (Collins 1998).

The characterization of street wastes as solid waste or hazardous waste can significantly increase disposal costs and limit recycling options. In 1995, the Road Maintenance Division, Publics Works Department, Snohomish County, Washington was faced with a four- to five-fold increase in disposal costs when mandated lab tests revealed that street wastes contained higher-than-permitted levels of total petroleum hydrocarbons. The county initiated a study to validate the testing methods used and to devise a simple means of composting street wastes. The study found that the presence of organic materials can interfere with the accurate detection of TPH levels in street wastes and catch basin solids. The study led to requests for changes to street waste policy to the Washington State Department of Ecology (DOE) (Perla 1996).

The Snohomish County Public Works Department also conducted an assessment of the cancer risks associated with reuse of its street waste in various settings. The study concluded that reuse would not be acceptable in residential settings, but may be acceptable in commercial, recreational, and industrial settings (Landau Associates, Inc. 1995). The study also found that composting leads to a decrease in TPH concentrations.

As a result of these studies, the Washington Department of Ecology re-evaluated its regulatory position regarding street wastes and developed guidelines for management of street waste. Under the guidelines, agencies generally do not need to test street sweepings and vactor wastes since enough data had previously been gathered to characterize it. Highlights from guidelines include the following:

- A recommended practice is to discharge street waste liquids to a municipal sanitary sewer;
- A suggested practice is to test street waste solids where the final reuse location is unregulated or not controlled by the generator; and
- Options for reuse of street waste include using it for roadgrade or other road fill, controlled density fill, and soil for use at industrial sites, roadway medians, and airport infields.

Washington Department of Transportation (WSDOT) joined a number of intergovernmental workgroups to develop better approaches to disposing wastes from streets and catch basins. WSDOT alone generates 8,300 cubic meters of catch basin sludge, 37,000 cubic meters of street sweepings and 1,700,000 liters of decant water. To help provide an effective solution to managing these types of wastes, WSDOT provided funds for the development of joint use dewatering facilities for catch basin sludge (vactor grit). As a result of this funding and of the DOE no longer characterizing street wastes as hazardous, there have been a been a number of accomplishments:

- WSDOT and local government generators of street and vactor wastes avoid costly landfill disposal;
- Local government is constructing dewatering facilities and using the dewatered waste materials for soil enhancement, shoulder rebuilding, median crossover construction, and high-density fills; and
- There is more accountability of WSDOT street maintenance activities (Pierce 1998).

The Oregon Department of Transportation commissioned a report on options and recommended procedures for handling street sweepings and vactor wastes. The report evaluates various alternatives from the standpoint of cost, environmental protection, environmental liability, feasibility, and other factors and proposes interim guidelines. The following are the recommended interim ODOT guidelines for sweepings and vactor wastes:

Sweepings

- Identify hot loads (i.e., potentially hazardous wastes) and manage separately from normal sweepings.

- Screen sweepings and dispose all trash and litter at permitted landfills.
- Store sweepings so that rainfall runoff will not carry them into wetlands or surface waters.
- Store sweepings to minimize the potential for site impacts from roadwaste contaminants by using berms and by placing on an impermeable surface with leachate collection and/or protection from heavy rainfall.
- If collecting and screening and reusing sand, wash it in a manner that prevents runoff, minimizes site impacts, and allows for the collecting of fine particles. Do not allow fines to become airborne.
- Consider using as construction fill sweeping materials from which trash has been screened and removed and which are known to have low impacts.
- Sidecast minimally contaminated sweepings on shoulders if appropriate, provided roadsides are not adjacent to surface waters, wetlands, or stormwater management systems with discharge to surface waters, wetlands, or subsurfaces.

Vactor Wastes

- Identify potentially hazardous wastes and manage separately from normal vactor wastes.
- Do not dispose liquid fractions back into stormwater catch basins or collection systems that discharge to surface waters, wetlands, or subsurface. Instead dispose these liquids, after approval is obtained, to the sanitary system. Sanitary sewers often require placement of vactor decant only into high-flow sewers or only into detention systems that allow 24 hours to settle out suspended solids.
- Where sanitary sewers are not available, the agency may identify areas with limited public access for field decanting of vactor liquids. Choose sites that minimize the chance of stormwater runoff and that will hold petroleum contaminants in the top layer of soil to provide the best chance for treatment in that oxygen rich environment. Avoid overuse of these sites because contaminants sorbed to fine particles suspended in liquid may lead to concern over site contamination.
- Consider disposing vactor wastes in landfill since they are harder to screen for trash and have fewer ready reuse options than sweepings, especially vactor solids generated from cleaning sumps.
- Consider options for dewatering including partnering with agencies that have already invested in dewatering facilities (Collins 1998).

Selected Practices From Survey

Texas

The state's anti-litter "Don't mess with Texas" campaign has been widely applauded by the news media. The $1.5-$2.0 million public education campaign includes public appeals by music and sports celebrities to reduce littering. The campaign succeeded in reducing litter by 29 percent statewide in its first year.

Colorado

The city of Colorado Springs designed and built a dewatering facility to separate solids from liquids collected from catch basin cleaning operations. The city's DOT had learned that liquids collected from these operations could no longer be deposited in a permitted disposal site without approval from the state Department of Public Health and Environment. The DOT built the facility out of a sense of environmental responsibility. Catch basin liquids, periodically tested for toxicity, are pumped to compost piles to add moisture, while solids are screened and composted, thus completely recycling catch basin wastes (King 1996).

Minnesota

Ramsey County, which encompasses the city of St. Paul, Minnesota, initiated a street sweepings recycling project in coordination with neighboring municipalities in the county. The parties involved developed a joint powers agreement to coordinate recycling activities. Previously, each community worked separately in collecting and disposing street sweepings, seal coat aggregate and other wastes. These materials were disposed of at a landfill at a cost of $68 per tonne ($75 per ton). The County was responsible for the purchase of a portable screener and conveyor, which cost almost $100,000. Currently the equipment is capable of screening up to 1,361 tonnes (1,500 tons) of material per 8-hour day, with costs in 1996 expected to be between $0.77—$0.96 per m^3 ($1.00 and $1.25/yd^3$). Screening stockpiles before weed growth develops and during optimal conditions, when the material is slightly damp, increases the efficiency of their operations. Note also that Ramsey County, Minnesota claims cost savings, from $3.6 per tonne to $1.1 per tonne, from recycling sand from sweeping operations.

Washington

As mentioned above, Snohomish County, Washington and other transportation agencies demonstrated that an EPA method for testing the toxicity of catch basin sludge and street sweepings was flawed. A more reliable method revealed that the waste very nearly met the standard for permissible TPH concentrations. The Washington State DOT successfully petitioned the Environmental Department of Ecology, local health officials, and solid waste officials to permit the reuse of this waste as a soil amendment. Monitoring of water quality has determined that no adverse impacts have occurred. The Department collects 8,415 m^3 (11,000 yd^3) of catch basin sludge and 36,720 m^3 (48,000 yd^3) of street sweeping material annually, which had previously been buried at WSDOT sites. This material will be excavated, screened, and recycled. The Department is encouraging local governments to adopt the same strategy. Washington DOT reports that its recycling of catch basin sludge saves it $2 million in annual disposal fees.

The County's Environmental Health Division has published guidelines for the use of street waste. Street waste may be used in any manner that would not cause a threat to human health or the environment if it can be demonstrated that:

- The collected or processed solids consist only of soils, sands, gravels, or sediments, and that garbage, refuse, vegetative debris, and other solid contaminants have been removed;

- Free liquids have been removed and appropriately treated or disposed of; and
- Concentrations of chemical contaminants do not exceed cleanup values identified in the Model Toxics Control Act regulation.

Potential uses for street waste solids, provided they will not result in contamination of surface or ground water, are as follows:

- Road subgrade, parking lot subgrade, or other road construction fill;
- Reuse as street traction sand;
- Pipe bedding;
- Utility trench backfill;
- Controlled density fill; and
- Fill in commercial or industrial zones.

Other appropriate uses for wastes, depending on chemical concentrations, are 1) portland cement concrete and asphalt concrete manufacturing; 2) treatment in a contaminated soil treatment facility; and 3) daily cover or fill in permitted solid waste landfills. Ditch cleanings not associated with a stormwater retention/detention system, or biofilter systems, and cleanings uncontaminated by spills are not considered solid waste.

Iowa

The Environmental Maintenance Committee of the Iowa Department of Transportation conducted an environmental review of the agency's maintenance standard for "Brooming or Sweeping." The committee researched a variety of disposal and reuse options for wastes generated by brooming or sweeping in metropolitan areas of the state. Recommendations of the committee were: 1) dispose of existing stockpiles in the short run, which would eliminate the stockpiles and eliminate the need to identify land application locations; 2) when possible, locate land suitable for land applications; 3) whether the material is landfilled or land applied, take it directly to the location instead of stockpiling at the garage; and 4) modify the maintenance standard to direct users to the Iowa DOT Waste Manual for handling and disposal methods.

BUILDINGS, GROUNDS, AND VEHICLE MAINTENANCE

Various maintenance related activities occurring on the buildings and grounds of maintenance organizations generate significant quantities of waste requiring some form of disposal. The various types of waste include waste water, solid waste, and hazardous wastes. These activities include washing, repair and maintenance of vehicles and equipment, and maintenance of the facility itself. Other activities include bulk storage of debris, litter, pesticides, asphalt, salt, and sand. Because these activities are confined within the perimeters of maintenance facilities and often occur inside garages, relatively few factors control the choice of practice regarding maintenance activities for buildings, grounds, and vehicle maintenance. Consequently, as mentioned in chapter 1, BMPs for activities occurring on a shop floor or on the grounds of maintenance facilities tend to be more universally applicable, although state, provincial, and local laws and regulations can dictate specific management practices. It is worth mentioning that applicable local and federal environmental laws, such as RCRA and the Clean Water Act, impose sanctions and penalties as a deterrent to lax controls on the handling of wastes and practices that have a negative impact on water quality. This section provides an overview of BMPs for buildings, grounds, and vehicle maintenance. Additional information concerning BMPs for specific environmental areas—hazardous wastes and water quality—appear in chapter 4. Note that additional guidance regarding buildings and grounds can be found in related literature regarding mass transit and the railroad industry (Schiavone 1995; Abrams 1994; Lowell 1995; U.S. Environmental Protection Agency, Federal Highway Administration 1996).

Storage

Most highway maintenance facilities store stockpiles of materials, sometimes in large quantities, needed to undertake various maintenance activities. Among the materials stockpiled are salt, sand, asphalt, pesticides, herbicides, creosote treated signposts, paints, cleaning agents, and litter and other debris collected from the roadside. Many of these materials, if disposed of improperly or discharged into the environment, may cause adverse impacts.

An important impact to guard against is stormwater or wash water carrying chemicals in stored materials into ground or surface water. General guidance for maintenance areas includes the following (Young 1996):

- Covering loading docks and storage and handling facilities with overhangs or door skirts that overhang docked trailers, designed to prevent contact by rainfall;
- Informing personnel of methods and requirements for avoiding and cleaning leaks and spills, and proper handling, storage and waste disposal practices, the use of oil and grease traps, absorbents, and cleaning compounds;
- Installing storage areas underlain by concrete, free of cracks and gaps;
- Designing and implementing spill prevention and pollution control plans outlining emergency containment and cleanup procedures, and methods of inventorying hazardous materials;
- Installing secondary containment systems constructed of berms surrounding chemical storage areas to contain potential spills;
- Implementing waste reduction, recycling, and reuse programs;
- Implementing storage inspection programs to identify potential sources of contaminant runoff; and

• Storing solid materials such as gravel and topsoil, concrete and metal objects in a covered area, on impervious surfaces, with drainage designed to prevent runoff.

Vehicle Maintenance

Maintenance departments are generally responsible for the upkeep of their vehicle fleet. Staff carrying out vehicle maintenance handle and come into contact with many substances that can contaminate watercourses and endanger worker health. BMPs concerning vehicle maintenance include (Young 1996):

• Performing fluid removal and changes on paved surfaces and indoors under cover;
• Refraining from spill area hose-downs;
• Using absorbents and dry cleanup methods;
• Immediately cleaning up spills;
• Recycling of waste gasoline, antifreeze, oil, oil filters, and lead-acid batteries;
• Establishing inspection and maintenance practices to minimize leaking of fluids;
• Protecting drains and stormwater drains with temporary berms or barriers;
• Using secondary containment, prompt draining of vehicle fluid drip pans;
• Providing covered fueling areas on concrete pavement;
• Providing perimeter drainage and/or sloping pavement inward to a dead-end sump or sanitary sewer;
• Avoiding the use of mobile fueling equipment, and using a designated and managed fueling area; and
• Using the least toxic alternatives to standard cleaning solutions, paints, and other materials, such as:
• Vegetable or citrus-based soaps;
• Water-based paints, wood preservatives, stains, and finishes;
• Alternative vehicle polishes, degreasers, and windshield washer solutions, and
• Re-refined, recycled oil.

Other practices include the following:

• Temporary fuel tanks should be located on impermeable surfaces, and bermed with an interior area of sufficient size to contain potential tank spills;
• Vehicles and equipment should be washed only in areas specifically designed to collect, contain, and convey wash water to a sanitary sewer or other treatment system, or a dead-end sump or other storage tank for removal and disposal at an off-site treatment facility. Wash areas should be located on pavement, with enclosures to contain spray and eliminate precipitation from contacting the area;
• Eliminate fueling at maintenance facilities in favor of off-site fueling stations; and
• Oil/water separators installed as a spill prevention/collection safeguard in areas of heavy use of petroleum fluids.

Oil/Water Separators

Oil/water separators are containment systems that use a series of pipes or baffles to remove oil and some solids from water. Among the basic types of oil/water separators (Figure 9), all of which use various mechanisms to allow the lighter oil to float to the surface, are the following (Richardson 1995):

• The SC-separator is a simple underground containment system effective for small spills. This separator cannot remove diluted oil droplets dispersed in waste water.
• The American Petroleum Institute (API) separator consists of a long basin with baffles. This separator can remove dispersed oil.

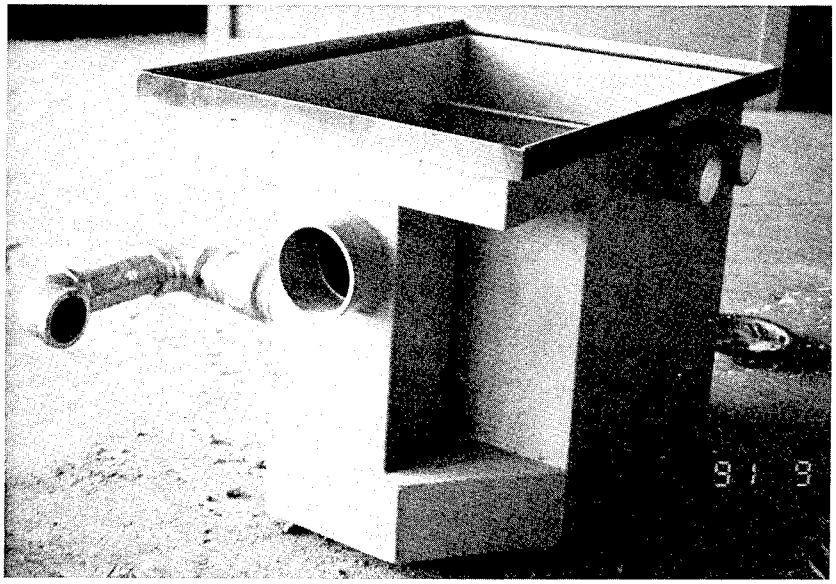


FIGURE 9 Oil/water separator.

- The CPS-separator uses a bundle of closely spaced plates made of fiberglass or polypropylene to remove oil with efficiency equal to the API separator, in one-fifth to one-half the space.

The presence of soaps and solvents reduces the effectiveness of oil/water separators. Such substances, used to clean vehicle components, emulsifies the oil. In addition, the separators require periodic maintenance. Washington DOT reports that its oil/water separators require two to four hours of maintenance each per year.

Proper personnel training and awareness is a prerequisite for success in preventing maintenance materials from introduction into the environment.

Other Mitigation Strategies

Automated fleet washing facilities are capable of reclaiming greywater and maintaining clean vehicles more cheaply than by manual methods. In 1995, the city of San Diego, California installed three automated brushless washing systems for its fleet of trucks and cars, of which 47 percent are maintenance vehicles and other heavy-duty trucks. The estimated cost per wash is $1.56 over a 10-year period, including the cost of a design-build contract ($220,000 per site), operation and staffing (*Public Works* 1995b).

Fleet maintenance software systems increase the efficiency of vehicle maintenance operations, providing a less direct, though real environmental benefit by reducing waste, and providing for more timely and effective diagnostic information and repairs.

Features of such systems include:

- Automated scheduled maintenance reporting;
- Fluid consumption tracking;
- Equipment inventory tracking; and
- Automated billing, cost and quantity transaction entry.

Vehicle Maintenance Product Substitution is possible as safer and less toxic automobile chemicals are showing up in the marketplace. Propylene glycol, an engine coolant, is less toxic than the ethylene glycol it replaces, and has chemical properties that protect water pumps and cylinder walls of diesel engines.

Selected Practices From Survey

Washington

WSDOT connects its oil/water separators to interior floor drains and exterior catch basins. Oil, anti-freeze, and solvents are among the most common substances spilled in the WSDOT maintenance facilities. WSDOT has established a number of BMPs designed to optimize the operation of its oil/water separators. Among the BMPs are:

- *Spill control measures*—These include the installation of temporary berms around stationary fluid dispenser systems and the placement of absorbent pads on top of containers used to dispense vehicle fluids. Absorbent pads placed beneath trench drain covers is another measure recommended to control small spills. The guidelines recommend use of absorbent material to prevent contaminants from entering the drain.
- *Emergency spill BMPs*—Specify the minimum contents of emergency kits, which include an oil absorbent boom, oil absorbent pads and granular sorbent. One kit for each two bays is recommended.
- *Heavy degreasing BMPs*—These state that drainage systems should be covered with oil absorbent pads or filter fabric to prevent contaminated solids from entering the oil/water separator. Guidelines recommend eliminating the practice of treating heavily soiled parts with solvent prior to treatment in wash bays.
- *Equipment prewash BMPs*—Prewashing loosens and removes heavy deposits of sand, salt and snow. Prewashing is allowed, with the following conditions: 1) use of cold water; 2) no detergents, solvents or antifreeze are used; 3) prewashing occurs upstream of any drain system to allow separation of the solids in the effluent; and 4) sediment is shoveled and mixed with sand piles.
- *Maintenance of oil/water separators*—The guidelines further specify monitoring and maintenance practices for oil/water separators. Bi-annual inspections include measurements of solid and oil accumulations and problems with performance. The Environmental Support branch within the Department maintains documentation of the chemical components of the waste stream.

Michigan, Iowa and Minnesota

As summarized in chapter 2, Michigan DOT performs waste stream analysis and conducts environmental audits of its waste facilities that generate wash. Iowa DOT conducts similar waste stream analysis and site reviews.

Minnesota

The Minnesota Department of Transportation has adopted a variety of waste reduction strategies. The process begins by identifying the size of the waste stream, possible environmental impacts, cost, liability, and potential impending legislation. Other procedures include:

- Development of performance criteria and evaluation of current products, involving product users and waste management coordinators;
- Alternative product testing and evaluation on a host of criteria, including safety, effectiveness, and other criteria previously determined, and potential recycle and reuse options;
- Consideration of total costs of purchase, application, and waste disposal; and
- Recommendations for product alternatives.

Much of this analysis applies to activities occurring in maintenance garages and other buildings and grounds of Mn/DOT. In anticipation of changes to state policies pertaining to sorbent disposal in late 1995, Mn/DOT conducted tests of various sorbent materials and developed recommendations for their use in maintenance operations. The policy changes were precipitated by the introduction of new regulations from EPA (40 FR 291.10c; Materials Containing or Otherwise Contaminated with Used Oil), and stated that used sorbent material would not be permitted to be disposed of as solid waste without testing to demonstrate that it is non-hazardous. The department evaluated various products using several criteria, including flammability, traction, ability to stay in place, oil retention, pick-up capabilities, residue left, speed of pick-up, and propensity to adhere to footwear (tracking). The recommendations resulting from the analysis include the following:

- Polypropylene and specified cellulose are the most user friendly and cost-effective options for Mn/DOT operations;
- Sorbent material should be used to maximum capacity to receive optimal performance and cost savings; and
- Burning sorbents for energy recovery is the preferred disposal method for the following reasons: 1) it is environmentally friendly and cost-effective; 2) it reduces future environmental liability; and 3) state-wide implementation is feasible.

In another research effort, Mn/DOT tested the effectiveness of asphalt release agents under a variety of conditions. Asphalt release agents are used to clean hot bituminous material from patching and paving equipment. An FHWA advisory dated 1988 stated that diesel fuel should not be used as an asphalt release agent. The primary concern behind the advisory related to the fuel's potential to degrade the integrity of asphalt. This advisory prompted Mn/DOT to develop guidelines for the use of asphalt release agents in general and alternatives to diesel fuel in particular. The evaluation did not endorse the use of any particular product, but did evaluate 10 agents according to criteria developed by product users. The recommendations for use are similar to those for any potentially toxic substance:

- Asphalt release agents should not be overused or spilled;
- Agents should be applied through a Hudson-type sprayer or other similar applicator;
- Agents should be applied while the truck is on a concrete pad;
- Reporting and cleanup requirements must be followed if spilling occurs;
- Any waste bituminous solids should be placed on a bituminous stock pile for recycling; and
- Any excess agent should be containerized for reuse. When no longer usable, waste material must be disposed of properly and should not be allowed to contact the soil.

North Carolina DOT

NCDOT lists five facility-specific BMPs, mostly related to storage of toxic chemicals on-site. They may be summarized as follows: 1) storage containment must be provided for liquid asphalt tanks; 2) pesticides must be safely and securely stored; 3) measures to prevent runoff from deicing chemicals must be taken; and 4) oil/water separators are required for any discharge from service or wash bays.

In 1995, NCDOT purchased 134 parts washers outfitted with paper filtration units. By 1996, virtually no solvent had been added to the cleaning units since the purchase. The paper filters, costing $0.80, must be replaced when dirty, and residue must be removed from the bottom of the filter housing regularly. The units were purchased at a cost of $751 each.

Massachusetts

MassPike has made significant efforts to recycle materials used in vehicle maintenance. Recycled products include antifreeze, freon, and used batteries. Waste oil is burned in space heaters, once determined to meet specifications for use. Used oil filters are drained and crushed. Empty containers are reused or returned to the manufacturer.

Vermont

The Agency of Transportation conducts an annual contest among its maintenance facilities as a means of encouraging an awareness of, and commitment to, the use of best practices around the maintenance site. The Best Overall Maintenance Site Contest (BOMS) consists of two evaluations. A team of District inspectors submits the supporting documentation for its selection of the best-maintained site. A panel of judges reviews the information and conducts an on-site evaluation of its own. The winning site receives $300 for each employee. The runners-up receive $100 for each employee. District winners get $50 apiece. The sites are evaluated on exterior and interior appearance, and environmental compliance.

Others

Nine respondents indicated that they have constructed some facilities to handle runoff of their stored bulk materials. Mn/DOT has produced a report on salt brine runoff. Mn/DOT reports that all sand and salt mixing and loading is performed on bituminous pads. Trucks are frequently washed to minimize brine runoff as well.

CHAPTER FOUR

ENVIRONMENTAL AREAS

INTRODUCTION

BMPs applicable to specific maintenance activities reflect fundamental environmental concerns with hazardous wastes, water quality, air quality, sound levels, wildlife and habitat preservation, and energy use. Indeed, regulatory agencies responsible for different environmental media and protection programs routinely require or encourage BMPs, often through regulations. In many cases, responsibility for compliance with federal laws and any regulations mandating BMPs is delegated to state environmental agencies. These agencies in turn work with public and private organizations to foster the best possible management practices to achieve regulatory compliance and make progress toward long-term environmental goals.

Managers responsible for roadway maintenance and environmental protection in many state and local transportation agencies are becoming increasingly proactive and aggressive in adopting BMPs. In the spirit of environmental stewardship as well as "being safe instead of sorry," they are adopting a number of approaches calculated to reduce or minimize the risk of contaminants spreading through the environment. They are also actively taking steps to preserve or enhance wildlife habitat, thus helping to maintain or increase biodiversity.

These proactive managers are insisting on scientifically defensible assessments using such tests as the TCLP and bioassays to ensure plants, animals, human beings, and other living organisms are protected from harmful or toxic substances. A key to developing this scientific approach is to distinguish between the different types of environmental media, such as water and air, and be aware of the potential problems and interaction effects. While environmental specialists are gaining knowledge and scientific data about many problems, much is not known. For example, herbicides and insecticides may affect the immune system in ways not fully understood. Also, the application of different pesticides in the same general location in subsequent years may be a problem, as residuals interact with one another. There is a need for an improved understanding of the environmental fate of individual chemicals and chemical mixtures, as well as their transport mechanisms, pathways, and toxic effects.

While there are large gaps in our knowledge, there are BMPs state transportation agencies can adopt that have evolved as a result of concern with specific environmental issues. This chapter focuses on BMPs applicable to specific environmental areas. Because all maintenance activities encounter different environmental media, BMPs in this chapter have broad applicability to different types of maintenance.

There is no neat dividing line to separate BMPs pertinent to specific maintenance activities and environmental issues. The previous chapter concluded with a discussion of removal of litter and debris, street sweeping, and activities occurring in and around maintenance facilities, including cleaning and maintenance of vehicles. Many of the BMPs in the concluding sections of chapter 3 are important because of concerns about hazardous materials and water pollution. Chapter 4 begins with sections discussing hazardous wastes and water quality.

HAZARDOUS WASTES

Generally speaking, a hazardous waste is any material that may . . ."cause or significantly contribute to an increase in mortality or serious or irreversible or incapacitating illness; or pose a substantial existing or potential hazard to public health or the environment when improperly treated, stored, transported, disposed of or otherwise managed" (Auburn University 1992). Materials identified as hazardous are known to have adverse environmental and health effects at specific concentrations. In addition to exposing workers to potentially unhealthy levels of chemical contaminants, improper hazardous waste handling can cause contamination of surface water, groundwater, and soil.

Hazardous waste has a specific meaning under the 1976 Resource Conservation and Recovery Act (RCRA) and is subject to specific handling and disposal requirements. The reader desiring specific details should refer to the regulations, since the description of the rules in this section is incomplete (CFR 260-299). Civil and criminal penalties for noncompliance with RCRA are strict. Responsibility for enforcement may lie with either the federal or state environmental protection agency. Maximum criminal penalties are 2 year's imprisonment and a penalty of $50,000 per day for each incident. Local and state regulations may impose more harsh penalties. It is important to note that state requirements for hazardous materials vary greatly under both the RCRA and the Comprehensive Environmental Response Compensation and Liability Act (CERCLA). Under CERCLA, parties that have been identified as responsible for the cleanup of contaminated surface water, groundwater or soil are under ". . . strict, joint, several and retroactive liability."[1]

Under RCRA a hazardous waste is any solid waste that is included in a regulatory listing of hazardous wastes or is a characteristic of hazardous wastes as listed under 40 CFR

[1] "Strict" means liability without fault. "Joint and several" means that one potentially responsible party can be held liable for all cleanup costs even though other parties are also responsible for the contamination. "Retroactive liability" means that a company is still liable for cleanup even if no law prohibited the burial of a substance at the time of disposal.

TABLE 6

HAZARDOUS WASTES GENERATED FROM THE USE OF MAINTENANCE MATERIALS

Process/Operation	Materials Used	Typical Material Ingredient	General Types of Waste Generated
Degreasing	Degreasers (gunk), carburetor and engine cleaners, solvents, acids, alkali, cleaning fluids	Petroleum naphtha, and distillates, benzene, toluene, aromatic hydrocarbons, mineral spirits	Acid/alkaline wastes, spent solvents, toxic wastes, ignitable wastes
Rust removal	Naval jelly, strong acids and alkali	Phosphoric acid, hydrochloric and hydrofluoric acids, sodium hydroxide	Acid/alkaline wastes
Paint preparation	Paint thinners, enamel reducers, white spirits	Alcohols, ketones, petroleum distillates, oxygenated solvents, mineral spirits	Paint wastes, spent solvents, toxic wastes, ignitable wastes
Painting	Enamels, lacquers, epoxies, alkyds, acrylics, primers, solvents	Acetone, toluene, benzene, epoxy ester resins, methylene chloride, xylene, naphtha, methyl isobutyl, ketones, aromatic hydrocarbons	Paint wastes, spent solvents, ignitable wastes toxic wastes
Spray booth, spray guns, and brush cleaning	Paint thinners, enamel reducers, solvents, white spirits	Ketones, alcohols, toluene, acetone, isopropyl alcohol, petroleum distillates, mineral spirits	Paint wastes, spent solvents, toxic wastes
Paint removal	Solvents, paint thinners, enamel reducers, white spirits	Acetone, toluene, methanol, alcohols, ketones, mineral spirits, isopropyl alcohol, methylene chloride, petroleum distillates	Paint wastes, spent solvents, toxic wastes
Tank clean-out	Solvents, cleaners, residues	Solvents, petroleum products	Tank draws, toxic residues
Installing lead acid batteries	Used car and truck batteries	Lead dross	Acid/alkaline wastes, lead acid batteries

Source: Auburn University, Impacts of Environmental, Health, and Safety Regulations on Highway Maintenance, p. 148.

261.31-33. Listed hazardous wastes fall into the following categories:

- Non-specific source waste generated by operations not specified to a single industry (e.g., degreasing and painting);
- Specific source wastes arising from processes of specific industries; and
- A chemical product slated for disposal because it 1) does not meet specifications, 2) is a spill residue, 3) is a container residue, or simply a product that is being discarded.

If a waste has any of the following characteristics as defined by regulations and determined through testing, it is also considered a hazardous waste: ignitable, corrosive, reactive, or toxic.

The Toxicity Characteristic Leaching Procedure (TCLP), a method specified by U.S. EPA to test the potential of wastes to leach eight heavy metals, and certain pesticides and common organic solvents.

Typical hazardous wastes resulting from the use of maintenance materials appear in Table 6. Other commonly used materials that may be considered hazardous include asphalt emulsions, antifreeze, cutbacks, herbicides, tar waste, paint booth filters, oil and other lubricants, and sorbents.

Hazardous materials generation sites are subject to different requirements depending on the category as defined by EPA:

- Conditionally Exempt Small-quantity Generators (CESQG) produce no more than 100 kg (220 lbs) of hazardous waste or 1 kg (2.2 lbs) of acutely hazardous waste in a single month and accumulate no more than 1000 kg (2,200 lbs) of hazardous waste at any one time. (Note that 100 kg is roughly equivalent to half of a 55-gallon drum, and 1000 kg is equal roughly to five 55-gallon drums);
- Small-Quantity Generators (SQG) produce between 100 kg (220 lbs) and 1000 kg (2,200 lbs) of hazardous waste and not more than 1kg (2.2 lbs) of acutely hazardous waste in any 1-month period; and
- Large-Quantity Generators (LQG) produce more than 1000 kg (2,200 lbs) of waste per month and are subject to all hazardous waste management rules. If at any time an SQG exceeds 1000 kg (2,200 lbs) per month, it becomes an LQG until the wastes are disposed.

Each of these types of generators has different requirements for reporting, handling, and storage.

EPA regulations specify accounting procedures for waste generation. Not all hazardous materials must be counted in the inventory. For example, wastes stored and neutralized in tanks designed for storage and neutralization of corrosive wastes are exempt.

The EPA requires special disposal procedures for containers holding listed hazardous wastes. Triple rinsing with an effective solvent or other procedure that empties the container to the agency's specifications regulation is required. So treated, these containers may be disposed of according to the maintenance agencies' standard practices. Otherwise, the containers are considered hazardous wastes and must be handled in accordance with procedures set forth for such materials.

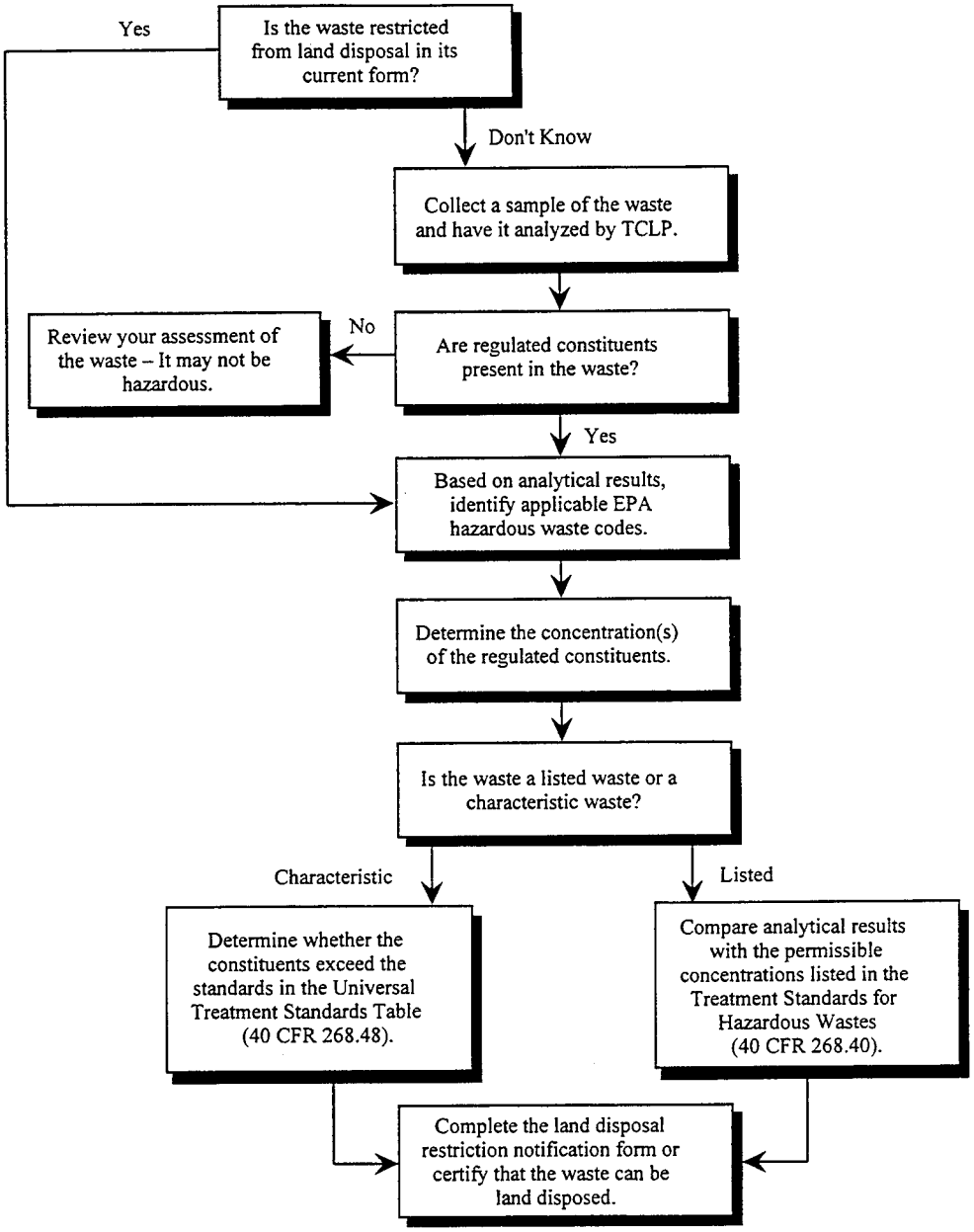


FIGURE 10 Waste handling procedures used by Ohio DOT.

Hazardous waste may be recycled on-site or may be shipped to an off-site facility. Haulers must be licensed, and have a RCRA Part B Permit. A solid waste is termed a "restricted waste" if it cannot be safely disposed of through land disposals such landfills, surface impoundments, waste piles, injection wells, and land treatment facilities. To determine whether a waste is subject to the land restriction, the generator must test a representative sample of the waste using the TCLP test or use his/her knowledge to determine if the waste is restricted from land disposal (See Figure 10 for a flow chart to determine whether wastes are restricted from land disposal). Off-site facilities must be authorized by the EPA or the state and meet the requirements of RCRA for treatment, storage, and disposal of the material. In order to ship the materials off-site, they must:

- Meet DOT regulations for packaging, labeling, and placarding; and
- Complete a hazardous waste manifest, a shipping document that allows for shipment tracking.

Shipments must be tracked from "cradle to grave," meaning from the point of waste generation to the point where the waste is disposed or is no longer hazardous. The responsibility for safe shipment of hazardous waste generally lies with the generator until the shipment is received. In some cases, there

may be coliability with the hauler. For this reason, selection of a licensed, reputable, and dependable hauler is paramount. Under RCRA, shipments of some hazardous wastes are exempt from most requirements in many states if they are being transported to a recycling or reclamation center.

Agencies must also maintain records of all transactions involving a hazardous waste, and thus keep on file all term contracts, manifests, waste analyses, land disposal certifications, or other communications or notices, unless exempt from certain record keeping requirements under RCRA and applicable state laws.

Proper storage procedures for hazardous waste include:

- Storing hazardous wastes in containers, 55-gallon (208.2 liters) drum tanks, etc. in very good condition;
- Not allowing waste constituents on the outside of a container;
- Not placing incompatible wastes in the same container;
- Separating containers of incompatible wastes from other materials or separated from those other materials by means of a wide berm, wall, or other device;
- Storing waste on a diked or concrete base capable of containing releases;
- Not storing hazardous waste in a tank if the waste may cause rupture, leaks, corrosion, or otherwise cause the tank to fail;
- Keeping a tank covered or providing at least 2 feet of space at the top of the tank;
- For continuous flow tanks, providing cutoff or bypass systems to stop the flow of waste if necessary;
- Providing safe buffer zones for reactive or flammable wastes;
- Storing materials a safe distance from drains to prevent contamination;
- Removing or treating wastes within a specified timeframe;
- Proper labeling of drums and containers;
- Posting signs to warn of potential dangers;
- Limiting the number of personnel authorized access to waste storage areas;
- Routine inspections of the waste storage area;
- Spill prevention, emergency response, and contingency plans;
- Providing Material Safety Data sheets as required by law;
- Providing appropriate personal protective clothing and equipment to prevent hazardous chemicals from entering bodies through inhalation, ingestion, absorption, or injection; and
- Providing appropriate training.

Much can be done to avoid the creation of hazardous wastes. Many of the high-level broad-based BMPS discussed in chapter 2 can play a major role in minimizing the generation of hazardous wastes. Waste stream analysis conducted as part of site reviews, development of pollution prevention plans and programs, and training are just a few of these effective management practices. Other desirable hazardous waste practices include reuse of materials, recycling of waste, waste treatment, and waste reduction. Waste reduction practices include not mixing hazardous and non-hazardous materials or different hazardous wastes, avoiding spills and leaks, using all of the product before discarding the container, and using no more of the substance than is needed to perform the task.

Non-hazardous waste generation is also subject to regulations under RCRA and other laws. Generation of non-hazardous wastes can result from facility maintenance, vehicle maintenance operations, highway litter and debris collection, and other highway maintenance activities.

It is important to emphasize that state and local laws and regulations concerning hazardous wastes may be more strict in certain parts of the country than federal law. In addition, Canadian and provincial requirements are different. Consequently, hazardous waste management programs need to be tailored to specific situations.

To provide guidance on hazardous materials, many states have developed hazardous waste manuals that are intended to ensure compliance with federal and their own state regulations. Tables in Appendix D provide information from the Ohio DOT's Waste Management Program Manual in regarding informational poster for staff on handling road waste, vehicle maintenance waste, general wastes, and lead wastes.

Storage Tanks

Underground and above ground storage tanks pose serious environmental risks, especially due to potential contamination by hazardous materials. Both above and below-ground tanks are subject to corrosion and leakage of tanks and connecting piping. However, underground tanks are a particular concern because of the danger of invisible tank corrosion and subsequent undetected leakage. In 1992, the EPA estimated that as many as 25 percent of underground tanks in the country could be leaking (Auburn University 1992). Leaking tanks contaminate surrounding soils where the substances can spread to water supplies and endanger human health and other living organisms.

Underground Storage Tanks (USTs)

The EPA defines an underground storage tank as any tank that has at least 10 percent of its total volume (including piping) buried underground. A number of laws and regulations govern the maintenance, operation, and monitoring of USTs. While the EPA sets guidelines for USTs, most states enforce their own requirements, with backing from federal law. Depending on the contents of the tank and other factors, the Clean Water Act, RCRA and CERCLA contain applicable provisions.

The EPA has established four major requirements for tanks installed after 1988 (Auburn University 1992):

1. Owners and operators must certify that the tanks and piping are installed according to industry codes;

2. Tanks must be equipped with apparatus to prevent spills and overfills;
3. Tanks must be protected against corrosion; and
4. Tanks and piping must be equipped with a leak detection system. They must be monitored and tested periodically.

Tanks installed prior to 1988 are subject to the leak detection and leakproofing requirements, overfill and spill prevention requirements. In addition, the EPA specifies reporting, clean up, and response procedures to be taken in the event of a leak.

Most tanks with a capacity greater than 378.5 liters (100 gallons) must be upgraded by December 22, 1998 to meet federal requirements for leak detection systems, corrosion protection, and spill/overfill protection.

The EPA has developed guidelines for compliance with federal law, and has allowed states to develop their own programs as long as they are in conformance. UST regulations vary by state.

Above-Ground Storage Tanks (ASTs)

A tank whose underground capacity plus underground piping does not exceed 10 percent of the tank's capacity is categorized as an AST. Figure 11 shows an above-ground storage tank. Care is required to manage and maintain these tanks to avoid spills and leaks and, in turn, environmental damage, liability, financial loss, and disruption of operations. Some states require registration of ASTs and yearly fee payments. Other states have AST regulations. In addition, stormwater regulations pertain to ASTs.

Some Desirable Practices

The following are desirable practices shortline railroads use to manage USTs and ASTs: (U.S. Environmental Protection Agency and Federal Railroad Administration 1996). Most are generally applicable to highway maintenance organizations.

- Use colorcoded fill ports for fuel storage tanks. In particular use the American Petroleum Institute's color and symbol codes;
- Verify that operating valves are on all gravity drained tanks;
- Use automatic shut-off valves to prevent leaks in case of pipe or hose failure (solenoid valves for gravity dispensing systems and shear valves for pumped dispensing systems); and
- Regularly check valves of tanks filled by pumping for backflow prevention.

Underground Storage Tanks

Monitor the inventory and keep records regarding use, deliveries, losses or gains, and bottom water levels;

- Report inventory losses in accordance with applicable regulatory requirements;
- Test for tightness in accordance with state and federal regulations; and
- Monitor corrosion resistant tanks and pipes in accordance with the manufacturer's recommended schedule, and frequently inspect leak detection systems and double-walled tanks.

Above-Ground Storage Tanks

- Label tanks to identify contents;
- Regularly inspect connected piping and associated pump equipment to prevent spills, leaks, or equipment failure;
- Provide secondary containment to prevent spilled material from entering surface or groundwater;
- Construct dikes and any flooring for tank farms on impermeable material; and
- Pressure test underground piping.

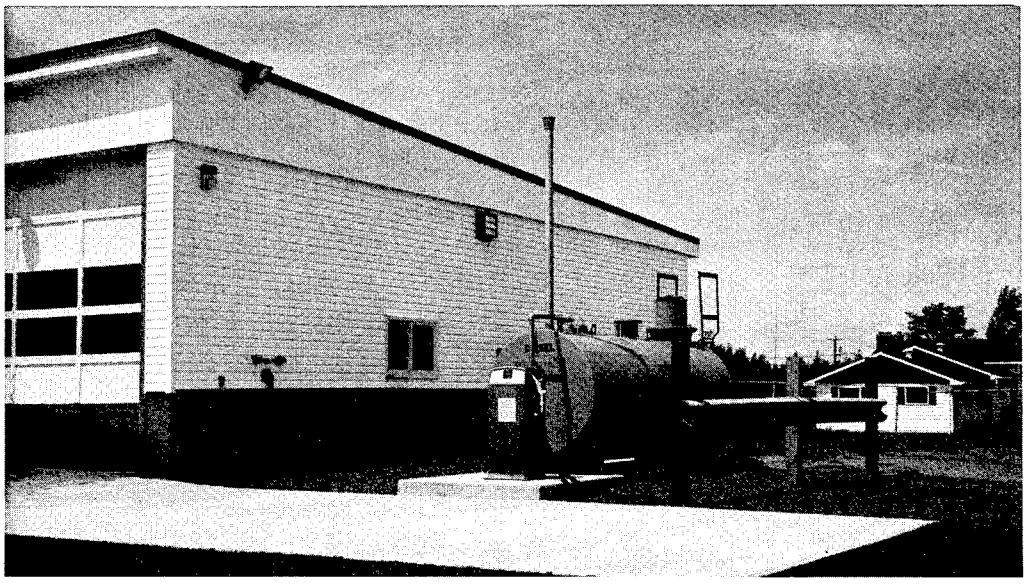


FIGURE 11 Above-ground fuel installation.

Remediation

Due to the potential for groundwater contamination, soil contaminated by tank leakage (or due to other spills or leakage of hazardous or potentially hazardous materials) must be treated so that the danger of infiltration is removed. The contaminant involved as well as the extent and degree of contamination partly determine the type of remediation required. Options include (Auburn University 1992):

- Excavation and removal to a landfill or hazardous waste facility. State regulations on acceptable levels of contaminants and agency policy dictate the degree to which landfills are used to dispose of such contaminated soil.
- Land farming (land treatment), in which contaminated soil is spread over the ground surface, and decomposed by the natural action of microorganisms in the soil.
- Bioremediation, in which microbes known to effectively decompose petroleum products or other contaminants are added to the soil. On-site bioremediation is an increasingly acceptable practice in the eyes of regulators.
- Thermal treatment, the use of heat to remove or vitrify (encapsulate) petroleum and other contaminants from soil. Most thermal treatments are conducted off-site, with excavated soil.
- Use of contaminated soil as a filler in asphalt mixes, or as a sub-base for new road surfaces. Unanswered questions about the potential for contaminants in the soil to leach out may limit the extent of this practice.

A number of techniques allow for in-situ (on-site) remediation, without excavation. Some techniques induce the vaporization of petroleum contaminants by boring wells or trenches either passively or through the use of pumps. Forcing oxygen and nutrients into contaminated soil, known as bioreclamation, induces microbiological breakdown of petroleum products. A common in-situ remediation technique is the liquid recovery well, in which free petroleum is separated from soil by forcing water through a contaminated area. This brings the contaminant to the surface of the water where it is skimmed away (Auburn University 1992).

National Cooperative Highway Research Program (NCHRP) Synthesis 226, *Remediation of Petroleum-Contaminated Soils* (1996), provides an in-depth examination of different practices, which are summarized in Table 7 (Friend 1996). The survey of state DOTs conducted as a part of that study found that landfill disposal remains the soil remediation technology most often chosen for state DOTs. DOTs reported using landfills (54 percent) most often, followed by land treatment (20 percent), thermal treatment (17 percent), and in-situ treatment (8 percent). On-site bioremediation is becoming an increasingly accepted practice by regulatory agencies and DOTs.

Handling of Hazardous Wastes and Other Dangerous Wastes

Medical waste, household garbage, and dangerous flammable or unflammable chemicals are sometimes found by

TABLE 7

DESCRIPTIONS OF PETROLEUM-CONTAMINATED SOIL TREATMENT TECHNOLOGIES

Type of Process	Alternate Technologies	Location of Application	General Description
Biological	Passive biodegradation (Natural attenuation)	In-situ	Passive biodegradation relies on naturally occurring microorganisms to slowly degrade the biodegradable petroleum contaminants in the soil. Microbes metabolize contaminants, leaving behind harmless by-products. Unlike other biological techniques, the biodegradation process is not enhanced by adding nutrients, some form of oxygen, and/or cultured microbes. Soils may be covered with plastic, however, to raise temperature and microbial activity.
	Bioventing	In-situ	In bioventing, oxygen is delivered to the subsurface to stimulate the biodegradation, but not volatilization, of contaminants by microbial activity. If necessary, the activity of indigenous microbes is also enhanced by adding nutrients. Like passive biodegradation, successful bioventing requires that suitable soil and contaminant conditions exist at a site.
	In-situ biodegradation	In-situ	In-situ biodegradation stimulates microbial activity and biodegradation by circulating water-based solutions through the contaminated soils.
	Biopiles	Ex-situ	Biomounting involves the excavation of contaminated soil and its placement in mounds (called biomounds) or piles (called biopiles) to which nutrients and/or other biological enhancements are added to stimulate contaminant degradation by microorganisms. Aeration pipes are usually installed in the mounds or piles to deliver oxygen and promote biodegradation of the hydrocarbons in the soil. Composting is a form of biomounding.
	Land treatment (Landfarming)	Ex-situ	Similar to biomounding, land treatment involves excavating contaminated soils and spreading them over a lined treatment area, or biocell. Volatilization and natural biodegradation is then enhanced by tilling, aerating, or watering, or by adding nutrients or microorganisms to the soil.
	Slurry biodegradation	Ex-situ	Petroleum-contaminated soils are excavated and treated in an aqueous or slurry solution within a bioreactor vessel that provides the nutrients or microbes necessary for successful biodegradation.

TABLE 7 *(Continued)*

Type of Process	Alternate Technologies	Location of Application	General Description
Physical	Soil venting	In-situ	Soil venting refers to the technique of removing residual hydrocarbons from the unsaturated zone by passing air through the contaminated area, volatilizing the hydrocarbons, and then capturing them for treatment. Hot air or steam may be injected under pressure or vacuum conditions into the subsurface in place of ambient air to accelerate the stripping of the volatile contaminants from the soil.
	Soil flushing	In-situ	Soil flushing refers to the process in which chemical surfactants or leaching agents are flushed through the contaminated area to separate contaminants from the soil. The aqueous solution is then recovered and treated.
	Soil washing	Ex-situ	Ex-situ soil washing involves the use of chemical surfactants or leaching agents combined with a mechanical agitation to separate contaminants from the soil.
	Coal tar agglomeration	Ex-situ	The coal tar agglomeration process is an extraction process that uses a solid sorbent rather than a liquid sorbent to remove contaminants. The process operates on the principle that oily waste constituents are strongly adsorbed on the surface of fine coal particles and that the coal-organic agglomeration that is formed can be separated from the soil in an aqueous slurry.
Chemical	Solvent extraction	Ex-situ	This technology involves the blending of a leaching agent (proprietary solvent or chemical reagents) with the contaminated soil to extract contaminants. The extraction fluid is then reclaimed for recycling, and the contaminant waste stream treated or otherwise disposed. Used primarily by the petroleum refining industry to treat refinery sludges and wastes.
Thermal	Radio frequency heating	In-situ	Radio frequency heating uses electromagnetic energy much like a microwave oven would to heat the subsurface soils and volatilize petroleum contaminants trapped there.
	Vitrification	In-situ or Ex-situ	In in-situ vitrification, electrodes or plasma torches are placed in the soil, the soil is heated, and some contaminants are volatilized while others are encased in glass. Effective for treating inorganic as well as organics. Problems with the off-gases, high energy and capital costs, and permitting issues have affected the widespread application of this technology.
	Thermal desorption	Ex-situ	Thermal desorption systems rely on the application of heat to the contaminated soil to promote the volatilization of VOCs and SVOCs. As the contaminants vaporize, they are desorbed and separated from the soil matrix. Depending on the specific technology employed, the volatile contaminants are either destroyed in a specific treatment chamber or captured, condensed and recovered, or incinerated.
Other	Stabilization/solidification	In-situ or Ex-situ	Stabilization and solidifaction technologies typically use lime, fly ash, or cement, and occasionally a cement/bentonite mixture, to bind the contaminants and oil in a matrix so that the contaminants do not leach into the environment. Because this technology simply contains the movement of contaminants, it is not considered a treatment technology.
	Capping	In-situ or Ex-situ	The area containing the contaminated soil is simply capped (e.g., under a road surface) or otherwise sealed to prevent the leaching of contaminants.
	Microcontainment by cold-mix asphalt	Ex-situ	In the cold-mix treatment of petroleum-contaminated soils, the soils are screened and used without thermal pretreatment as an aggregate in the asphalt mix.
	Land disposal (landfilling)	Ex-situ	The contaminated soils are excavated and transported off-site to a landfill that is permitted and willing to accept the soils for either disposal or use as landfill cover.

Source: (Friend 1996)

maintenance staff in the course of performing other activities. Other than the environmental hazards, there is an immediate threat to worker safety from exposure to such substances.

The establishment of formal policies and procedures regarding the handling of potentially unsafe materials can provide an overall benefit to worker safety. Hazardous material training and so-called "Right to Know" programs assist maintenance crews to gain a clear understanding of procedures to follow in the event of an emergency. The North Carolina Department of Transportation has written an extensive manual on worker safety, which includes a section clearly explaining which items to collect, which to avoid, as well as whom to contact in the event that a dangerous substance is encountered. Some agencies use, or have conducted, research on the use of automated equipment for debris and litter pickup to minimize the exposure of workers to traffic on high-volume, high-speed facilities. Such equipment will increase in use as their cost-effectiveness increases.

Selected Practices From Survey

Minnesota

Mn/DOT developed a bioremediation treatment that used fertilizer instead of manure as a food source for soil bacteria. Another source of experimentation was the use of taconite tailings instead of native soil. The experiment was conducted in June of 1996; results have not been published yet.

Missouri

The Missouri Department of Transportation burns used engine oil for supplemental heating in maintenance buildings. This practice is best suited for areas where the DOT must pay for the disposal of used oil. The pay-back period on the cost of the used oil heaters is 3 years based on current prices for propane and natural gas. Disposal costs dropped from $113.4 to $362.8/tonne to $72.6 to $81.6/tonne ($125–$400 per ton to $80–$90 per ton).

Pennsylvania

PennDOT has developed a hazardous waste substitution manual. The manual contains a listing of all inventoried materials used by the Department. The items are classified by type and usage, and then ranked according to their relative safety, health, and environmental hazards. The manual results in the use of more environmentally friendly products, and the elimination of the most harmful products.

PennDOT has researched the feasibility of using microbes to remediate soil moderately contaminated with motor-vehicle fuel. Commercially available microbes and nutrients are added to the soil, which is later used as backfill in the UST upgrade program. The technology offers the possibility of a mix-it and leave-it solution to moderately contaminated soils.

WATER QUALITY

Highway runoff is a significant source of water quality degradation. Highway maintenance activities and policies, in turn, can have a significant impact on water quality. Sources such as accumulated dust and grit, debris from natural and man-made sources, and deposits of highway vehicles through normal operations and wear can be channeled directly into sewer systems in urbanized areas. Practices such as roadway sweeping can mitigate these effects. In less built-up areas, permeable surfaces act to filter out harmful substances, yet some chemical pollutants may still find their way to surface water and groundwater through infiltration. An agency's own policies regarding storage, handling, and disposal of the large amounts of potentially harmful substances used in maintenance operations can have a bearing as well. Finally, maintenance facilities themselves are often large enough to require permits for stormwater discharges.

Pollutants in Highway Runoff

(Young 1996)

Kobringer identified more than 20 pollutant constituents found within highway rights-of-way, ranging from petroleum products to lead and copper (See Table 8). Barret has identified various solids, metals, and nutrients present in highway runoff. Particulate matter may transport other pollutants along to receiving waters. Heavy metals are known to adsorb to fine particles and other solids, where they may be released when exposed to water, and become a threat to aquatic life. Nutrients, such as nitrogen, may stimulate the growth of algae blooms and deplete levels of dissolved oxygen. Fine airborne particulate matter containing nitrogen, phosphorus, and metals generated from human activities, and other pollutants from vehicle emissions, may be transported to earth where they will be part of urban runoff during periods of precipitation. It is important to note that not all the pollutants in highway runoff can be attributed to transportation activities. Other sources of runoff may include particulate matter from industrial air pollution, and chemical runoff from agricultural activities.

Fine particles as well as larger litter and debris must be controlled to minimize the water quality impacts of stormwater runoff. Fine particles themselves account for 25 percent of the oxygen-depleting demands of stormwater runoff and 50 percent of the nutrient sources (Young 1996).

Several factors influence the composition and concentration of highway runoff, including:

- *Surrounding land use*—Areas with more impermeable surface and more human activity tend to accumulate greater pollutant constituents. Paved roadways with average daily traffic (ADT) greater than 30,000 produced runoff with two to five times the pollutant levels found in that from rural highways (Driscoll 1990; cited in Young 1996).
- *Presence of construction activities*—Construction activities are prone to erosion and will contribute sediment and nutrient loads to nearby streams if proper control measures are not installed prior to rainfall events.
- *Storm intensity and duration and days between storm events*—Generally, pollution concentrations are higher when storms are of higher intensity and shorter duration. They tend to be higher where storm events are infrequent, allowing buildup to occur. Pollutant concentrations are highest during the initial period of the storm. According to the "half inch" rule, 90 percent of the annual stormwater pollutants are transported in the first half-inch of runoff.
- *Traffic activity during a storm*—Vehicles during a storm (VDS) may be a stronger predictor of highway runoff concentration constituents than ADT (Racin 1982; cited in Young 1996).

To control and mitigate water quality degradation, qualified staff should collect site-specific data and apply procedures to accurately predict pollutant loadings and their potential impacts. The nature and extent of the impact assessment depends on many factors. One of the most important is the nature of the receiving waters and its uses.

TABLE 8
SOURCE OF POLLUTANT CONSTITUENTS IN HIGHWAY RUNOFF

Constituent	Primary Sources
Particulates	Pavement wear, vehicles, atmosphere, maintenance, snow/ice abrasives, sediment disturbance
Nitrogen, Phosphorous	Atmosphere, roadside fertilizer use, sediments
Lead	Leaded gasoline, tire wear, lubricating oil and grease, bearing wear, atmospheric fallout
Zinc	Tire wear, motor oil, grease
Iron	Auto body rust, steel highway structures, engine parts
Copper	Metal plating, bearing wear, engine parts, brake lining wear, fungicides and insecticides use
Cadmium	Tire wear, insecticide application
Chromium	Metal plating, engine parts, brake lining wear
Nickel	Diesel fuel and gasoline, lubricating oil, metal plating, bake lining wear, asphalt paving
Manganese	Engine parts
Bromide	Exhaust
Cyanide	Anticake compound used to keep deicing salt granular
Sodium, Calcium	Deicing salts, grease
Chrloride	Deicing salts
Sulfate	Roadway beds, fuel, deicing salts
Petroleum	Spills, leaks, blow-by motor lubricants, antifreeze, hydraulic fluids, asphalt surface leachate
PCBs, pesticides	Spraying of highway right-of-ways, atmospheric deposition, PCB catalyst in synthetic tires
Pthogenic bacteria	Soil litter, bird droppings, trucks hauling livestock/stockyard waste
Rubber	Tire wear
Asbestos*	Clutch and brake lining wear

Source: (Kobringer 1984)
*No mineral asbestos has been identified in runoff, however some break-down products of asbestos have been measured.

Clean Water Act

The Clean Water Act, first enacted in 1972, is the primary legislative vehicle for maintaining the integrity of the nation's waterways. This act regulates the discharge of solid and liquid pollutants from point sources and non-point sources. Compliance regulations at the federal level have been set by this law, but states and local governments are allowed to set their own stricter requirements as well. The National Pollutant Discharge Elimination System (NPDES), published in the *Federal Register* in 1990, sets forth permit requirements for pollution and for stormwater discharges directly into U.S. waters from industrial and other sources. NPDES permits:

- Require disclosure of volume and nature of pollutant discharges;
- Set limits on the quantity of certain pollutant discharges;
- Set certain monitoring requirements; and
- Require development and implementation of a pollution prevention plan.

Maintenance operations undertaken by most highway maintenance agencies are affected by the provisions of the Clean Water Act and the NPDES regulations. For example, vehicle maintenance and equipment cleaning operations are activities regulated by permit requirements. However, facilities that discharge wastewater to wastewater treatment facilities are not required to obtain a permit for pollution discharge. Moreover, a facility may not be required to obtain an NPDES permit if runoff enters a combined sewer system in which water enters a sewage treatment plant, or where no stormwater leaves the facility.

Stormwater permits require a variety of information, including:

- Site characterization, including maps;
- Discharge characterization including the volume and quality of discharge;
- Management Program Description, which includes strategies to control pollutants and emergency spill response systems (Young 1996); and
- The development and implementation of a pollution prevention plan.

Current NPDES regulations provide for three types of permit applications: individual, regional or group:

- Individual permits are for individual industrial facilities using data particular to an applicant;
- Regional permits are issued where the cumulative impacts among industrial facilities are minimal, or where duplication of effort among regulatory agencies would result; and

FIGURE 12 Detention pond.

• Group permits allow a group of industries that can demonstrate that their operations are similar to be treated as though each were applying for an individual permit, thereby reducing costs of compliance.

States that have pollution control and water quality management programs approved by the EPA can issue NPDES permits. Most state DOTs have applied for permits as co-applicants with the municipality responsible for overall stormwater management. In such a case, the municipality may have its own requirements on stormwater discharges from individual facilities.

Regulations for a second phase of stormwater discharges are scheduled to be published in final form by 1999. It is anticipated that these regulations will give states greater latitude to manage and control stormwater discharges.

The FHWA document, *Evaluation Management of Highway Runoff Water Quality* (1996) describes a number of structural and non-structural BMPs designed to mitigate the impacts of human activity on water quality. These are briefly described in the section below. The reader is referred to this document for more complete information on the appropriate measure for specific conditions. It should be noted that all these BMPs require proper maintenance to retain effectiveness. This maintenance may produce waste products that require proper disposal or recycling. Grass clippings from regular maintenance of swales or material dredged from a stormwater retention pond are examples of such waste products.

• Extended detention ponds are depressed basins that store water during a storm and are dry otherwise (Figure 12). The discharge of the stored stormwater may be accomplished by a control mechanism, or water may be allowed to evaporate or infiltrate groundwater. Nutrients, heavy metals, sediment and floating materials are among the substances removed from the stormwater. The extended detention ponds are typically designed to reduce runoff to pre-development levels.

• Wetponds perform a similar function to the dry ponds described above. The permanent presence of water allows for biological processes that can reduce the quantity of nutrients. Flood control and the opportunity to create an aesthetically pleasing site around the pond are two other benefits of wetponds.

• Infiltration trenches are underground basins lined with a filter and filled with stone and are designed for small drainage areas. Highway runoff is channeled to the trench where it filters into the soil or is piped away to another drainage system. Infiltration trenches have been employed in residential and commercial areas, parking lots, median strips, and near highway shoulders.

• Infiltration basins are ponds that capture stormwater and allow it to percolate through the soil, allowing pollutants to be trapped in the process. The basins more effectively remove soluble pollutants and sediment than do infiltration trenches, and in fact are typically intended for use for drainage areas larger than those appropriate for trenches. A variety of basin designs exist, each appropriate for the particular needs of the facility.

• Sand filters, which apply principles used by waste treatment facilities constructed at the turn of the 20th century, can be adapted to many situations, including those in which conventional filtration methods may not be effective. Sand filters are appropriately used in watersheds that are relatively small and where the proportion of impervious surface is relatively large, and in warmer climates, where the biological processes that improve water quality can be used to full effect. Sand filters are sometimes combined with settling basins, which are used to store and meter the flow of runoff to the filter.

• Water quality inlets, also known as oil and grit separators, employ chambers to trap oil and sediment. Water quality inlets are often used to treat runoff from roadside areas, parking lots, gas stations and other areas where vehicles generate pollutants. They are often integrated with an infiltration system or larger drainage system. Their storage capacity is limited in

comparison to some of the other BMPs, and are thus not as effective in removing pollutants. The inlets must be frequently cleaned to remove sediment and hydrocarbon deposits.

- Swales are channels of grass in which filtration and infiltration act to remove pollutants. They are sometimes used as pretreatment measures for other pollutant removal measures. The grasses in swales act as filters, increasing deposition in high-velocity areas or increasing infiltration into the soil. They are generally not as effective in removing pollutants as other BMPs. Suspended solids and adsorbed metals are the pollutants most effectively removed by swales.

Landscaping and Vegetative Practices

Vegetated surfaces interrupt and divert the flow of stormwater and help permeable surfaces perform a filtering function. By slowing down runoff velocity, vegetated surfaces also can remove nutrients and other pollutants through plant uptake and adsorption. Soil erosion is prevented or reduced as well. For these reasons, landscaping and vegetative practices are sometimes used for pretreatment purposes as part of a comprehensive system of stormwater treatment. Their use can reduce the overall cost of the system. After the first few years of care, maintenance is relatively minimal. They are not generally used as standalone pollution control systems. Specific practices and their benefits include the following:

- Urban forestry: Trees can stabilize soil and moderate air and water temperature. The areas around trees generally absorb more water than grassed areas and are more effective in removing runoff.
- Stormwater basin landscaping: Proper landscaping will stabilize the soil around the basin, and increase its pollutant removal capabilities.
- Xeriscape programs: More popular in arid regions, xeriscaping incorporates the use of drought-resistant plants and an efficient watering system. In this way, maintenance costs are reduced, and water conservation efforts are enhanced. Florida and California require xeriscaping for certain highway projects.
- Grass management: some BMP for grass management are: proper application of pesticides and fertilizers, conservation of water, incorporation of integrated pest management and xeriscaping concepts, use of trained and certified individuals for chemical applications, high-cut grass to reduce mowing needs, and recycling clippings to encourage decomposition and reduce fertilizer requirements.

Erosion

Erosion is the process of separating and transporting soil away from its base by water or wind. Although erosion control is a particular concern for new construction, maintenance activities can lead to erosion as well. Removal of vegetation, disturbance of topsoil, compaction, and increasing slopes are among the many causes of erosion. Also, wind can be a major contributor to erosion (Roberts 1995). Over 80 million tons of soil annually are deposited into bodies of water due to erosion (Auburn University 1992).

The American Association of State Highway and Transportation Officials (AASHTO) has published guidelines that address erosion and sediment control issues in federally funded highway projects. Every state agency using federal funds must comply with the guidelines, whose development was mandated by Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991. This is one instance of BMPs promulgated at the national level.

The environmental impacts of erosion are felt at both the source and the destination. Erosion removes fine particulate matter containing vital plant nutrients. The remaining soil can be hard and infertile, creating difficult conditions for the establishment of grass or other vegetation. Grading and sloping for highway drainage within rights-of-way should consider the effects of stormwater runoff, and the potential to carry sediment loads to streams and rivers. Erosion of these fine soil particles also carry attached nutrients and pesticides that are applied during maintenance activities, and contribute to the accelerated eutrophication (enrichment) of waters with the accompanying increases in algal vascular plant nuisances, foul odors, and water treatment problems. Temporary control measures include proper planning that includes silt fences, hay bales, gently sloping terraces, and temporary vegetative covers and/or fiber netting. Also, tracks of wheeled vehicles should not be left to initiate erosion activity. Runoff can carry soil into stormwater inlets, retention ponds, and other bodies of water, causing sediment build-up, which reduces storage and flow capacity. Costly dredging at regular intervals is the result. The soil particles generated by erosion may carry with them various chemicals that can damage water quality and aquatic and wildlife habitats. Excessive deposits of silt and sediment can also smother and kill aquatic vegetation, and destroy spawning areas (Auburn University 1992).

There are four major categories of erosion: 1) raindrop splash, the force of direct rainfall; 2) sheet erosion, the removal of soil from sloping layers in thin layers or sheets; 3) rill erosion, the creation of small defined channels typically a few centimeters deep; and 4) gully erosion, the creation of deep channels that require extensive earthwork to repair. Rills that are not repaired often create gullies in time.

Soil erosion is a function of climate, soil characteristics, topography, and vegetation:

- Climate: Adverse conditions in which growing grass and other plant cover is difficult, such as cold or arid conditions, increase the difficulty of preventing soil erosion. Areas with high-intensity rainfall are more subject to erosion as well.
- Soil characteristics: Soils vary in their susceptibility to erosion. Soils composed of silt and fine sand and low in clay and organic material tend to be the most susceptible, while those with a relatively high proportion of sand and rocky soils are the least. Loose, granular soils absorb water and resist erosion better than compacted or crusted soils. Generally speaking, loose, granular soils, particularly those rich in

organic matter, favor plant growth, which reduces the potential for erosion.

- Topography: The length, steepness, shape, and orientation of a slope are the critical factors determining the potential for erosion. Longer slopes increase the potential for erosion. Flatter slopes reduce the potential for sheet, rill, and gully erosion by reducing runoff velocity and maintaining smooth flow conditions (Roberts 1995).
- Vegetation: Vegetated surfaces are much less susceptible to erosion than those that are not.

Vegetation has the following beneficial effects:

- Reduces raindrop impact and runoff velocity;
- Provides structural integrity to the soil from the root system;
- Filters contaminants and sediment from runoff; and
- Increases infiltration (Roberts 1995).

Additional approaches to minimize erosion and maximize sediment control are as follows:

1. Fitting Development to the Terrain: The natural contours of a site should be carefully considered in planning and design so as to disturb the terrain as little as possible. Roads should parallel these contours, and buildings should be situated on the flattest part of the site.
2. Performing Timed Grading and Construction to Minimize Soil Exposure: Grading should be planned and staged to occur so that only areas being actively developed are exposed to erosion. Exposed areas should be seeded and mulched as soon as grading is completed. In addition, grading should be avoided during any wet seasons or thawing periods. Erosion and sediment control measures should be instituted if any chance of erosion exists.
3. Retain Existing Vegetation where Feasible: Studies have shown that it takes several years for the rate of erosion from a construction site to approximate the rate before construction. It is preferable, from an environmental standpoint, to clear only what is needed to gain access to a site and to perform the construction or maintenance work.
4. Maintaining the Fertility and Structure of the Soil: The presence or application of organic matter in soil promotes permeability, promotes a stable soil structure and improves cohesiveness. Such soils provide an effective medium for plant growth. Typical organic matter includes peat humus, straw, and manure.
5. Vegetating and Mulching Denuded Areas: Disturbed soils should be seeded and mulched as soon as possible. Once established, seedlings can help retain soil in place and resist erosion. Temporary vegetation can provide immediate ground cover until permanent landscaping is in place.
6. Diverting Runoff from Denuded Areas: Perimeter dikes or ditches may be constructed to collect and route runoff to a protected outlet before reaching a maintenance or construction site.
7. Minimize Length and Steepness of Slopes: The longer and steeper a slope, the greater the potential for erosion. Terraces, narrow, level plains placed at regular intervals, slow runoff and provide a place for sediment to settle. Benches and ditches are sometimes placed so as to intercept runoff and divert it to an outlet before erosion occurs. Channels are sometimes lined with fabric or other materials to prevent erosion inside the channel.
8. Keeping Runoff Velocities Low: By placing obstacles in the direction of the flow of water, the energy and erosion-producing potential of runoff can be reduced. Drainage channels may be lined with rough surfaces such as vegetation or riprap, or by placing check dams at regular intervals. On overland slopes, vegetation and minimizing slope length and steepness are effective means of interrupting the flow of water. On disturbed areas, construction operators sometimes drive equipment in a perpendicular direction to the flow of water to create trackmarks that interrupt the flow of water.
9. Keeping Erosive Wind Velocities Low: Stone walls, fences, and screens can provide shelter against wind erosion. Rows of trees and shrubs placed at right angles to susceptible areas, known as shelterbelts, reduce the wind velocities and break up the distances between uninterrupted open wind.
10. Preparing Drainageways and Outlets to Handle Concentrated or Increased Runoff: This can be done as follows: 1) calculate peak flows and velocities for all drainageways that drain a project site; 2) design drainageways to withstand peak flows without erosion; 3) select and install lining materials that are appropriate for peak flows; and 4) deenergize concentrated flows at outlets by constructing energy dissipaters such as riprap aprons.
11. Trapping Sediment On-Site: Sediment barriers can prevent eroded soil from leaving work sites. Typical barriers include straw bale dikes, and earth berms, which are sometimes used to channel stormwater into basins or traps downstream of a disturbed site. Bales and silt fences can also trap water temporarily, allowing the suspended particles to settle to the bottom where they can be disposed. Heavy nylon matting is capable of holding soil in place on steep slopes while providing sufficient open space for grass seed to become established. Figure 13 shows an example of good use of BMPs involving properly installed silt fences, grass waterways, and a gravel/rock access road (Auburn University 1992).

Maintenance of Drainage Structures

Drainage structures are similar to other environmentally related maintenance features, in their need for proper design and periodic maintenance. Lacking these, the capacity of drainage structures and their efficiency in reducing or removing pollutants is significantly less than optimal. The Florida Department of Transportation contracted to have guidelines developed for removal of sediment from retention/detention ponds. An excerpt from those guidelines follows:

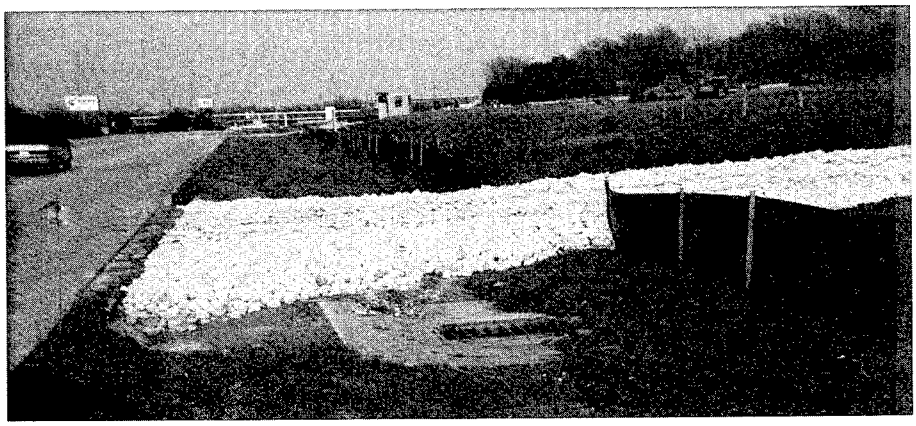


FIGURE 13 Good use of BMPs.

To keep a detention pond operating properly, a routine maintenance plan must be developed following the initial construction. Therefore, the design of the highway runoff ponds should provide for easily accessible and maintainable ponds. The factors that are considered important for future maintenance of the pond include: 1) accessibility of detention ponds for the equipment needed to service the pond; 2) the design of sufficient clearance for large machinery; 3) the design of stable banks and roadways along side of the pond; 4) geometry of the pond to reach mid width with available equipment, if possible; and 5) the design of a separate off-line containment area for disposal of accumulated bottom sediments if land area and/or topography permits. Maintenance functions include mowing, control of pond vegetation, removal of debris from all inflow and outflow structures, the upkeep of physical structures and removal of accumulated bottom sediments.

The most widely used method for the removal of accumulated bottom sediments is the use of a crawler crane and dragline. The cost of dredging the sediments may vary several orders of magnitude from one place to another. The cost includes mobilization of equipment, dredging, trucking to transport the sediment and their disposal cost. Generally, the use of sediment will be practical whenever some form of fill is required.

A complete and accurate record for ponds dug should be kept to show the location of the pond, accessibility, geometry, surface area, volume, construction data, inlets, outlets, vegetation, routine maintenance performed and drainage basin characteristics (Yosef 1991).

Selected Practices From Survey

Texas

TxDOT's guide to vegetative cover on highway rights-of-way is a highly user-friendly guide to seeding and watering. In addition to setting forth the erosion-reducing practices, the guide also includes information on monthly climate data in each district, planting dates, a description of seed species, and standard seed mixes and rates.

TxDOT has conducted extensive research into erosion control measures. Its erosion control field laboratory has tested the field performance of erosion control blankets and mulching materials. For its work in this area, the Department won a merit award from the American Society of Architects in 1994.

Alaska

The Alaska Department of Transportation and Public Facilities released a BMP for construction erosion and sediment control and maintenance operations in January of 1997. BMPs for drainage, structures, roadside management, and snow and ice control are described in the document. Drainage BMPs include the following:

- Ditches are inspected twice a year, and are cleaned once a year, to maintain the flow capabilities as originally constructed. A regional environmental coordinator is contacted before maintenance in fish streams is conducted, to determine whether any permits are necessary. Culverts are inspected regularly for signs of damage or blockage. Oil/water separators are similarly inspected; they are cleaned at least once each year.
- Grading on gravel roads is conducted to reestablish crowns in order to maintain proper drainage (sheet flow).
- All treated wood should conform to current standards for treatment practices and chemicals. Field treatment of wood should be minimized. When performed, it should be done at least 22.8 m (75 feet) away from any body of water above the high water mark, by trained personnel.

California

Alameda County's stormwater management plan for the clean water program includes performance standards for maintenance activities such as:

- Street cleaning,
- Storm drainage facilities and maintenance of watercourses,
- Litter control,
- Road upkeep and maintenance, and
- Upkeep for maintenance yards.

TABLE 9

SELECTED BMPs AND OTHER GUIDELINES FROM ALAMEDA COUNTY'S PERFORMANCE STANDARDS FOR MUNICIPAL MAINTENANCE

Maintenance Function	Practice
Street cleaning	• Clean streets so they look clean and no dirt tracks, trails, or debris are visible • Check that street cleaning equipment is in proper adjustment • Operate street cleaning equipment at the speed specified by the manufacturer • Check the proper weights on main and gutter brooms are used • Discourage residents from "opting out" of the municipalities street cleaning program • Assess ability to maximize pollutant removal of alternative equipment and new technologies when purchasing new sweepers • Maintain a consistent sweeping schedule • Take appropriate measures to keep curbed areas clear during street cleaning • Remove large accumulations of leaves prior to cleaning • Provide operators with adequate resources to report trees interfering with street cleaning • Keep records on miles swept, volume or weight removed each day • Require contractors to have backup street cleaning equipment in event of equipment failure • Ensure proper handling and disposal of removed material to prevent discharge into surface waters or groundwater
Drainage facilities	• Inspect and clean drainage facilities as necessary, preferably prior to the rainy season • Develop a storm drainage facility inspection and maintenance plan • Report and keep records on the amount of material removed • Document and track spill incidents • Track storm drain inlets which require more frequent cleaning than once or twice a year
Disposal of material	• Store material removed from drainage facilities on concrete pad or other type of impermeable material (during the rainy season cover with impermeable material) and drain wastewater to the sanitary sewer or allow to evaporate to prevent discharges to the storm drain system. • Agencies must dispose of material at an appropriate facility
Pesticide use	• Reduce to the maximum practical extent the use of algaecides containing copper as an active ingredient such as copper sulphate
Graffiti	• Protect storm inlets prior to removing graffiti from walls, signs, sidewalks or other structures • Never discharge debris, cleaning compound waste, paint waste, or wash water containing cleaning compounds to the storm drain • Direct runoff from all types of sand blasting and high pressure water (no cleaning agents) washing activities into landscaped or dirt areas; otherwise filter runoff through an appropriate filtering device (course sand bags or filter fabric) to keep sand, particles and debris out of storm drain. • Avoid conducting graffiti abatement activities during a rain storm. • Train employees and volunteers conducting graffiti abatement in using these performance standards

Source: (Alameda County 1977)

Performance standards were set to maximize removal of pollutants and minimize discharges into drainage lines. The plan won a U.S. EPA National Award for Excellence of Stormwater Program in 1994. Table 9 shows selected BMPs included in the Alameda County's Performance Standards for Municipal Maintenance (note: the county distinguishes between three tiers of practices, but Table 9 does not make such distinctions).

As a part of the Statewide Stormwater Permit and Management Plan, the California Department of Transportation has identified BMPs applicable to different maintenance activities. (See Table 10.) Caltrans also developed a "Maintenance Stormwater Pollution Prevention Program." The following are selected BMPs and pollution prevention actions pertinent to stormwater management:

• Prior to the wet weather season inspect inlets, culverts, pumping stations, ditches, gutters, stream channels, detention basins and infiltration devices to determine whether cleaning, repair, maintenance, removal of sediment and debris, or other actions are required. Inspect catch basins and drainage inlets that are known to clog during storms.

• Be alert for spills within the operating right-of-way, report any such spills, and follow procedures for dealing with spills in the department's maintenance manual. If an identified spill has the potential to enter the stormwater drainage system, containment must be undertaken immediately if it can be done without exposure to hazardous materials. Otherwise the spill must be cleaned up according to appropriate regulatory requirements.

TABLE 10

BMP MATRIX FOR MAINTENANCE ACTIVITIES

BMPs	Maintenance Activities																							
	Highway Maintenance Activities	Vegetation Control	Landscaping	Painting and Roadway Restriping	Graffiti Removal	Road Sweeping	Litter Removal	Storm Water Drainage System Facilities and Stream Channel Maintenance	Bridge and Road Surface Maintenance	Snow and Ice Control	Highway Storm Water Surveillance	Accident Spills	Illicit Connections	Illegal Discharge/Dumping	Highway Maintenance Stations	Shop-Type Activities at Maintenance Stations	Material Storage	Fueling of Vehicles	Vehicle Washing, Engine Cleaning, and Automotive Stream Cleaning	Facility Maintenance and Landscaping
Emergency Response and Cleanup Practices (MD1)												●									
Hazardous Material Spill Log (MD 1b)												●									
Public Reporting and Response Practices (MD2)			●									●	●	●							
Safer Alternative Products (MD5)		●		●	●				●	●						●					●
Above Ground Leak and Spill Control (MD7)																		●			
Illegal Dumping Control (MD8)														●							
Illicit Connection, Detection, and Removal (MD9)													●								
Highway and Freeway Cleaning (MD10)						●															
Storm Water Drainage System Facilities Inspection and Cleaning (MD11)								●													
Vegetation Controls (MD12)		●																			●
Bridge and Road Maintenance (MD 14)									●												
Detention/Infiltration Device Maintenance (MD15)								●													
Oil/Water Separators (MD16)																					●
Material Storage Controls (MD17)		●		●	●				●							●					
Housekeeping Practices (MD18)		●		●	●				●							●	●	●	●		
Used Oil Recycling (MD19)																●					
Non-Storm Water Discharges to Drains (MD20)																●			●		●
Vehicle Equipment Fueling (MD21)																		●			
Vehicle and Equipment Pressure Washing (MD22)																			●		
Vehicle and Equipment Maintenance and Repair (MD23)																●					
Outdoor Loading/Unloading of Materials (MD24)																	●				
Outdoor Container Storage of Liquids (Hazardous) (MD25)																	●				
Outdoor Storage of Raw Materials, Products, and By-Products (MD27)																	●				
Waste Minimization, Handling and Disposal (MD28)		●		●	●	●	●	●	●	●						●	●				●
Contaminated or Erodible Surface Area (MD29)		●	●																		●
Building and Grounds Maintenance (MD30)																					●
Pumping Station Cleaning (MD31)								●													
Anti-Litter Signs (MD34)							●														
Adopt-a-Highway/Adopt-a-Wall (M35)					●																
Snow and Ice Control (MD36)										●											

Source: (California Department of Transportation 1996c)

- Identify and report any illicit connections that may introduce stormwater from properties outside the rights-of-way.
- Identify and report any illicit discharges or dumping on highways, freeways, roadside rest areas, vista points, and park-and-ride lots.
- Make contractors responsible for roadside rest areas aware of potential problems that contribute to stormwater pollution. The contractor should ensure employees are aware of proper use of all cleaning agents, the possibility of hazardous material dumping, and proper notification procedures for cleanup.
- Regularly inspect and clean any oil/water separators that may exist at park-and-ride lots.
- Make the state highway patrol aware of the potential for stormwater pollution at weigh stations and their responsibility for ensuring their employees properly use cleaning agents. Also request the state highway patrol to inspect the area for illegal dumping, and make sure the state highway patrol knows whom to contact to ensure proper cleanup, especially if there are hazardous materials (California Department of Transportation 1996).

New Hampshire

New Hampshire DOT has developed sedimentation/erosion control measures for construction activities. Measures include use of cofferdams and settling basins for dewatering work areas. These practices have met with approval from permitting agencies, reducing the time involved in obtaining permits.

Arizona

Tucson, Arizona's interim watercourse maintenance guidelines establish procedures for minimum maintenance of naturally vegetated watercourses. The manual describes and defines a naturally vegetated watercourse and places limits on the type and amount of maintenance allowed for these areas. It also establishes a multidisciplinary team to resolve potential maintenance conflicts between public health, conveyance volume, and habitat preservation.

Nevada

The Nevada Department of Transportation has implemented BMPs for maintenance activities for environmentally sensitive areas. The BMPs were mandated by the Tahoe Regional Planning Commission for the Lake Tahoe area, a national tourist attraction. The Department has installed special detention basins, sand/oil separators and catch basins to prevent sediment and pollution from being discharged into the lake. The Department has taken other measures as well, including the installation of paved retaining pads to hold contaminated soil until disposal, obtaining special permits for many activities and refraining from any grading activities in the summer. The maintenance engineers at the agency have experienced delays in other routine activities due to the implementation of these mitigating measures and believe them to be less effective than the imposition of development limits in the area.

New Brunswick

The New Brunswick Department of Transportation has prepared a field guide on environmental practices for highway construction and maintenance. The guidelines reflect applicable Canadian and New Brunswick environmental laws and regulations, but have applicability elsewhere. The field guide contains suggested procedures to reduce erosion and sedimentation, including the following:

- Plan the work to fit the topography, soils, waterways, and natural vegetation at a site;
- Expose the smallest practical area of land for the shortest possible time;
- Apply soil erosion control practices such as special grading methods, diversion structures, and grade stabilization structures as a first line of defense against on-site damage; and
- Apply sediment control practices, such as diversion ditches, sediment traps, and sediment basins as perimeter protection to prevent off-site damage.

Oregon

Multnomah County, Oregon initiated the Portland Stormwater Program to comply with federal municipal NPDES regulations issued by the U.S. EPA in November 1990. A condition of the Portland NPDES permit is the adoption of BMPs. The BMPs, which consist of either source or treatment controls, are grouped into seven categories:

1. Public involvement and education,
2. Operations and maintenance,
3. Industrial/commercial controls,
4. Illicit discharges control,
5. New development standards,
6. Structural controls, and
7. Planning/system preservation and development.

One of the BMPs under Operations and Maintenance (O&M) was to evaluate the O&M plan for public stormwater quality structural controls and evaluate existing maintenance practices that affect water quality. Key tasks to carry out this BMP were to develop a maintenance manual describing procedures for routine inspection and maintenance of stormwater drainage facilities in the Portland NPDES permit area, develop recordkeeping logs and reports for use by field and office staff, and annually inspect the entire system and keep records. The maintenance manual that was developed includes procedures for inspecting, cleaning, and maintaining stormwater drainage facilities such as catchbasins, storm inlets, storm sewer lines, ditches, sumps, and outfalls. The manual places considerable

emphasis on regular reporting and record keeping. Also contained in the manual are guidelines for shoulder grading, roadside vegetation management, erosion control, sanding activities for snow and ice control, and truck hauling practices on county roads.

Minnesota

Mn/DOT has approved the use of sorbents to contain motor vehicle fluid spills at accident sites. According to Mn/DOT policies, workers are not allowed to handle large container and cargo spills. The sorbent materials are used to contain motor oil, fuel, coolants, and other liquids spilled in accidents. This practice prevents the fluids from entering waterways. Secondly, by allowing DOT staff to contain minor spills, the accident site can be cleared more quickly, thus reducing the possibility of secondary accidents.

Florida

FDOT was able to reduce the amount its spends on landfill tipping fees through reuse of dredged pond sediment. FDOT staff tested the toxicity of the sediment, and was able to demonstrate that the material was safe for recycling.

AIR QUALITY

Maintenance agencies engage in many activities that have a direct and measurable effect on air quality. In construction, road repair, and winter operations, maintenance agencies operate considerable numbers of heavy-duty trucks and machines. In painting, cleaning, and roadway maintenance, large quantities of chemical products containing VOCs are purchased and used. Particulate matter and more significantly, smaller particulate emissions, loom as potential issues in the application of abrasives and street sweeping.

Primary Emissions Produced by Mobile Sources

Ozone and Ozone Precursors

Ozone, or photochemical smog, is a secondary pollutant created in the atmosphere by the reactions of VOCs with nitrogen oxides (NOx) and other compounds. Manmade sources of NOx and VOCs include industrial processes, highway vehicles, and non-road engines. High ozone levels have been associated with respiratory problems, such as coughing and difficulty with breathing. Ozone exposure has also been linked to decreased lung capacity, increases in hospital admissions for respiratory ailments and asthma attacks (Federal Highway Administration 1992). Ambient ground level ozone can also damage agricultural crops, trees, and other vegetation. Ozone formation is associated with hot, dry weather and is a particular concern during the summer months. Hydrocarbons themselves are potentially cancer-causing toxins, while oxides of nitrogen contribute to the production of acid rain and the eutrophication (development of oxygen-depleting algae blooms) of coastal waters.

Carbon Monoxide (CO)

Carbon monoxide is an odorless and colorless gas whose primary manmade source is mobile emissions. CO remains near the source of pollution, accumulating in areas with high traffic densities. CO combines with hemoglobin in the blood, and inhibits the delivery of oxygen to the body's tissue. Asphyxia and shortness of breath are symptomatic of CO poisoning. Mobile sources account for 40 to 60 percent of CO emissions (Federal Highway Administration 1992).

Particulate Matter

PM-10 refers to suspended solid or liquid particulate matter less than 10 micrometers in diameter. Diesel vehicles, dust, and industrial processes are major sources of PM-10. Asthma attacks and respiratory irritation have been associated with exposure to PM-10, and research has associated increased mortality with high levels of PM-10. Particulate matter 2.5 microns (PM-2.5) in size is an increasing concern, due to its ability to become lodged deeply in lung tissue. Among mobile sources, diesel engines are a primary source of PM-2.5.

Regulations Affecting the Maintenance Community

The 1990 Federal Clean Air Act Amendments (CAAA) are the latest in a series of legislative initiatives designed to curb the harmful effects of air-borne pollutants. Under the CAAA, all transportation plans and projects must conform with state air quality implementation plans and contribute to the attainment of national ambient air quality standards (NAAQS). The 1990 Act increases controls on ozone, carbon monoxide, and particulate emissions from diesel engines and acid rain. The Environmental Protection Agency (EPA) sets emissions standards for harmful pollutants and has primary enforcement responsibilities. The 1990 CAAA directed EPA to consider non-road vehicles and equipment such as construction equipment for the first time.

Standards for metropolitan level emissions of selected pollutants are set by EPA. In 1996, the EPA proposed more stringent ambient emissions standards for ozone and particulate matter, covering both the intensity and duration of exposure. Under the proposed new rules, a standard for PM-2.5 would be established as well.

EPA is adopting new emissions standards for standard equipment used by the maintenance community. For heavy-duty trucks and buses, EPA has proposed a new combined emission standard for nitrogen oxides (NOx) and hydrocarbons (HC) for

the model year 2004 and later. This action is expected to result in a 50 percent reduction in NOx from the current standard. Currently, EPA regulates trucks over 8,500 lbs. GVWR (3.9 Mg) as heavy-duty vehicles, whose emissions standards and certification testing procedures are less stringent than for light-duty engines.

EPA issued emissions standards for small internal combustion engines (those at or below 19 kilowatts (kW), or 25 horsepower) for the first time in 1995. The first phase of these standards is targeted for the 1997 model year engines; a second is scheduled to be implemented between 2001 and 2005. Small non-road internal combustion engines include grass mowers, weed trimmers, and paint sprayers. According to EPA, these standards can be met with existing technologies. Each phase of the regulations is expected to reduce HC and NOx emissions from these engines by at least 30 percent. For both diesel and small internal combustion engines, the responsibility for compliance is with the manufacturer, who must certify that its products meet these standards through a formalized process sanctioned by EPA.

Vehicles meeting tighter emissions standards and mandated use of clean-burning fuels for centrally fueled fleets will be required of 22 metropolitan areas in 19 states in 1998. The percentage of new vehicle purchases in the most polluted areas in the country to which this regulation will apply increases to 70 percent by the year 2000 from 30 percent in 1998.

Alternative Fuel Vehicles

Increasingly, alternative fuel vehicles (AFVs) are being incorporated into public works fleets for compliance with environmental regulations and efficiency reasons (See Figure 14). The final rule for provisions of the 1992 Energy Policy Act stipulates that most state governments with urban areas greater than 250,000 population must incorporate AFVs into their vehicle fleets. By the year 2000, 50 percent of vehicle acquisitions are required to be capable of burning alternative fuels. Vehicles running under alternative fuels are generally cleaner-burning, thus providing an emissions benefit in addition to meeting the energy efficiency and sufficiency goals of the Act.

Heavy-duty vehicles that travel short, regular routes, consume large amounts of fuel and refuel at a central location are viable applications for natural gas vehicle conversions. The compressed natural gas (CNG) energy equivalent of one gallon of gasoline produces one-tenth the pollutants and costs less than 70 cents (*Public Works* 1995a).

Some evidence regarding the emissions characteristics of CNG-fueled heavy-duty trucks has been mixed. One test of New York City demonstration vehicles not optimized for emissions reductions conducted by West Virginia University showed a large statistical range of carbon monoxide, hydrocarbons, nitrogen oxide, and PM-10 emissions, with average rates for CO, HC and NOx higher than for comparable diesel engines, when run on a heavy-duty chassis dynamometer simulating urban stop and go driving (National Renewable Energy Laboratory, n.d.). However, PM-10 emissions from the CNG-fueled vehicles were reported to be near zero, significantly lower than those of the diesel-fueled vehicles. In addition, 90–95 percent of the hydrocarbon emissions from the CNG vehicles are composed of methane, which does not contribute to ozone formation. Tests on identical, emissions-optimized engines, conducted for EPA and California Air Resources Board-mandated emissions certification in 1993 and 1994, showed vastly lower emissions for all major pollutants for the CNG engines. Further research has identified causes for the highly variable emissions results reported in the West Virginia test. Similar, more recent tests with CNG engines show more reductions still, with sources of emissions variability better controlled.

The city of North Miami has converted or purchased more than 125 vehicles for use with CNG. The conversion has cost $5,500 per truck. A variety of vehicles have been converted, including rear-loader garbage trucks and dump trucks. These vehicles require less maintenance because of their cleaner

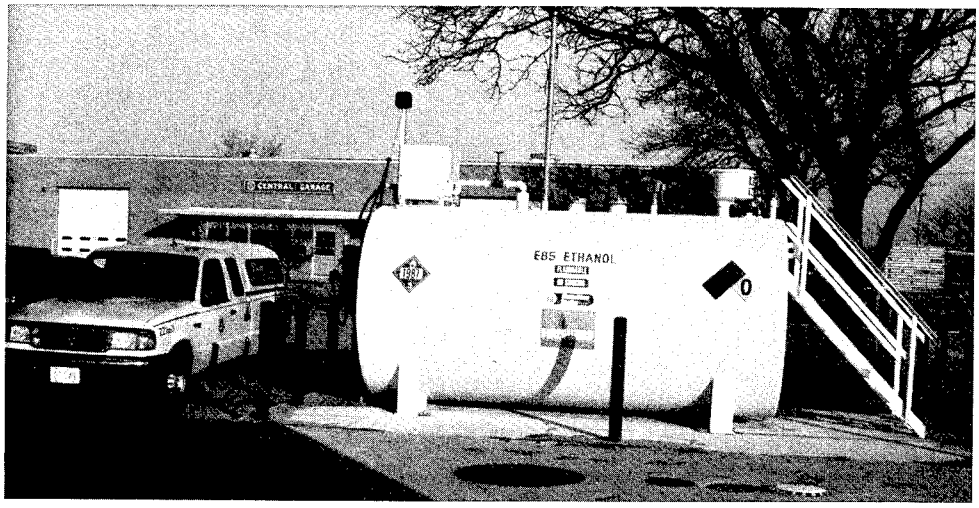


FIGURE 14 Alternative fuel vehicles.

burning characteristics; together with fuel cost savings, the city reported a total cost savings of $250,000 since the program's inception in 1982. Three CNG-fueled garbage trucks with an expected useful life of 3 to 5 years have been in operation for 14 years (National Renewable Energy Laboratory, n.d.).

Road Dust

Increasing attention is focused on accumulations of fine particles on roads. The action of vehicle tires passing over debris creates ever-smaller particles, which can eventually become airborne through contact with a moving vehicle's tires. Particles such as these, which are often less than 0.2 microns in size, are an increasing health concern because they can become lodged in lung tissue and cause respiratory problems. Of particular concern during road construction and maintenance of roadway side slopes and shoulders is the release of asbestos from the predominant serpentine rock formations. Although it may not pose a serious health concern, it has received a fair amount of recent media attention (personal communication with Earl Shirley (Calif.), September 1998).

In Los Angeles, dust accounts for roughly one-third of all airborne particulate matter, and one-half of that fraction is estimated to originate from paved roads. Standard street sweepers are regarded as generally ineffectual against these types of particles. In Los Angeles, where federal law requires the Air Quality Management District to reduce airborne dust, attention is being turned toward the purchase of vacuum sweepers. While these machines are roughly 25 percent more expensive to purchase, it is estimated that their use, combined with dust control measures on unpaved roads, will eliminate 25 percent of fugitive dust emissions (*Los Angeles Times*, unknown date).

Dust control agents suppress airborne dust in construction areas and unpaved roads by binding soil particles together. Concerns over worker safety and wildlife impacts have been raised about the application of dust suppressants made with petroleum oil, which is sometimes diluted with flammable solvents. Since 1992, the Pennsylvania Department of Transportation has used a dust suppressant free of these substances. The dust suppressant product, ". . . imposes neither a physical nor a health hazard and is non-toxic" (*Better Roads* 1995).

Selected Practices From Survey

Arizona, Arkansas, Florida

Transportation agencies in these states are among several agencies using both waterborne traffic paint and thermoplastic pavement markings, both of which produce little or no VOCs. FDOT was recognized by EPA for its use of lead-free, solvent-free pavement marking materials.

Arkansas

The Arkansas Highway Department has restricted the use of cutback asphalts to prime and winter tack coating. All other liquid asphalt applications are accomplished using emulsions. As a result, less fuel is used and heating emulsions and VOCs are reduced.

NOISE

Highways are a primary source of noise and have significant quality-of-life and health impacts. This is especially so in areas where residential development abuts high-speed highways. Between 1973 and 1993, more than 1,550 miles of noise barriers had been installed in the United States (Cohn 1993). Noise barriers are part of a growing environmental infrastructure whose maintenance and upkeep is the responsibility of maintenance forces.

According to federal statistics, over 70 percent of the U.S. population is exposed to noise levels at or above the annoyance level (55dBA) (U.S. Department of Transportation 1995). Over nine percent of the population is exposed to highway noise above 65dBA, the level at which interference with communication and sleep is possible. Heavy vehicles, whose vertical exhaust pipes often produce noise that cannot be attenuated effectively by many noise barrier installations, emit levels at 90dBA or above, far above the level at which physical responses to noise can be measured.

Federal Guidelines

The federal government recognized the importance of noise control with passage of the Noise Control Act of 1972. Under the legislation, the EPA is required to issue noise emission standards for motor vehicles used in Interstate commerce and requires the FHWA office of Motor Carrier Safety (OMCS) to enforce these standards. The FHWA regulations for mitigation of highway traffic noise in the planning and design of federally aided highways require the identification of traffic noise impacts, examination of potential mitigation measures, the incorporation of reasonable and feasible noise mitigation measures, and coordination with local officials (U.S. Department of Transportation 1995). Upper limits for highway traffic noise for different types of land uses and human activities are included as well.

Health Impacts

Highway noise has been associated with elevated levels of stress and nervousness in individuals. Noise damage is known to interfere with sleep, speech communication, and relaxation (Haling 1995). In extreme cases, highway noise may result in loss of sleep and a perceived loss of utility in use of the surrounding outdoor areas (Billera 1997). These factors may contribute to a reduction in the value of residential properties adjacent to high-speed facilities relative to similar structures located in more isolated areas.

Excessive noise emanating from maintenance operations can annoy inhabitants of surrounding residences and businesses

and lead to temporary or permanent hearing loss to maintenance personnel. Vehicles, loud machines, and equipment—jackhammers, drills, etc.—can increase noise to harmful or annoying levels.

Noise Abatement and Maintenance of Noise Barriers

Noise emissions by themselves are generally not enough to prevent construction or reconstruction of a highway. Abatement is generally achieved through the construction of noise barriers. While earthen berms are sometimes used as noise barriers, most barriers are high, solid walls made of precast concrete, held in place by vertical steel supports. The choice of barrier depends on a number of criteria, including visual appeal, durability and maintenance requirements, costs, and local preferences. The effectiveness of barriers is increased the closer they are placed to the source of noise, that is, as close to the roadway edge as possible. According to the FHWA, properly designed noise barriers can reduce noise levels by 10 to 15 dBA, cutting the loudness of traffic noise by one-quarter to one-half. Wooden slats or small panels used for noise attenuation may not be as effective as large solid panels, since any openings in noise walls significantly diminish their effectiveness.

Once constructed, noise barriers require maintenance. One common maintenance problem in dense urban areas is the need to remove graffiti from noise barriers. The water quality section includes a description of BMPs for graffiti removal (Table 9).

Caltrans, in its highway design manual, specifies maintenance considerations in the design and installation of noise barriers. If maintenance of the area behind the barriers is the responsibility of Caltrans, access from the rear must be provided. Where there is a large area between the noise barrier and the right-of-way line, maintenance responsibilities for this area are negotiated with abutting property owners. Also, access panels are provided for entrance by emergency vehicles or to gain access to fire hose openings. The access panels are designed so that their sound-attenuating qualities and those of surrounding panels are not compromised.

Noise from Operations

The New York DOT's environmental handbook for transportation maintenance adopts a good neighbor policy and encourages maintenance personnel to consider noise when scheduling work in order to minimize noise impacts and annoyance to the public as much as possible. The handbook encourages the following noise abatement policies to reduce or eliminate complaints:

- Adjust schedules or equipment assignments to take affected residents into account;
- Ensure equipment with internal combustion engines have mufflers which are well maintained;
- Operate equipment at lower speeds and increase the spaces between equipment;
- Set up noise barriers or enclosures such as plywood sheets or lead-vinyl curtains for particularly noisy operations near very sensitive receptors; and
- Consult the regional Environmental Coordinator and the DOT's Environmental Analysis Bureau's Noise Section to obtain answers to questions about noise impacts to neighbors.

The New York Department of Transportation's (NYDOT's) environmental handbook for maintenance also says engineering controls should be used when feasible to prevent noise levels from exceeding OSHA limits for employee noise exposure. Employees are urged to consult the department's safety manual for information on noise exposure and the types of noise protection required in high-noise environments (New York State Department of Transportation 1997).

WILDLIFE AND HABITAT

Roadway systems have facilitated the connectedness and growth of human settlements. They have often had just the opposite effect on wildlife populations in the United States and abroad. Human settlement patterns and their transportation systems have reduced the amount of available habitat beyond that required to sustain certain populations of wildlife, driving some out entirely. Air, water, and noise pollution, undesirable by-products of 20th century technology, have decreased animal populations further still. Many species co-exist with human beings, although direct conflicts are inevitable and often tragic. Increasingly, roadway systems that are properly planned and maintained are being recognized for their potential to co-exist with wildlife. In the design, construction, and maintenance of roadways and bridges, the transportation community is increasingly sensitive to the importance of reducing the potential for conflicts between wildlife and automobiles, and providing for the survival needs of animals native to the particular region under its jurisdiction.

Transportation agencies frequently assess the impacts of transportation actions on biodiversity. According to the Office of Technology Assessment, biodiversity is "the variety and variability among living organisms and ecological complexes in which they occur" (Office of Technology Assessment 1987). Bardman, in a recent TRB paper, summarized various approaches states are using to assess biodiversity (Table 11) and proposed a process adaptable by state transportation agencies for biodiversity assessment (Figure15). If significant impacts are expected to occur, then mitigation actions should be developed (Bardman 1997).

Roadway Impacts on Wildlife

Threats to wildlife from conflicts with the transportation system result in several types of impacts. These can be characterized as follows (Woods 1996):

- Direct habitat loss: Roadways are built mainly in low-elevation areas, where the concentrations of wildlife are the

TABLE 11
SUMMARY OF METHODS STATES USE TO ASSESS BIODIVERSITY

Method	Positive Attributes	Negative Attributes
Gap Analysis	Powerful and efficient step toward setting land management priorities. Beneficial in that it identifies gaps in the representation of biodiversity in areas managed exclusively or primarily for long-term maintenance of populations of native specifies and natural ecosystems.	Coarse-filter approach to conservation evaluation and limitations related to the minimum mapping unit size. Failure to distinguish among several stages, failure to indicate gradual ecotone, other factors must be recognized as that it can be supplemented by more intensive inventories. Costs associated with the use of satellite data and GIS systems to perform the analysis may be limiting.
Rapid Assessment Methodology	Good tool. It uses a wider variety of taxonomies than usual inventories of vertebrates and flowering plants.	Still in the development stage and requires intensive training for use.
General State Methodology	Provides a good analysis of fragmentation issues which transportation projects most often pose because it analyzes each issue (threatened and endangered species, wetlands, aquatic resources, and terrestrial ecology) independently and on different geographic scales and then the method combines these analyses for a comparative assessment.	Does not take into consideration species richness aspects related to biodiversity. Becomes cumbersome because many individual analyses are required to establish a good comparative analysis.
West Virginia Department of Transportation Methodology	Analyzes areas for fragmentation, effects on landscape dependent species, and edge effects due to the highway construction. Analyzes secondary effects on biodiversity.	Developed for use in large forested areas. Modification would be necessary if areas such as prairies, farmlands or mixed land are involved.
Maine Department of Transportation Methodology	Assessment of biodiversity is made at a qualitative level with readily available information cutting down on the expense of the assessment. Basis to establish clearly measurable and obtainable goals to conserving biodiversity.	Qualitative assessment.
Methods of the Illinois Department of Transportation	Does analyze wildlife mortality and barrier to wildlife movement.	Does not address species richness impacts nor does it analyze the geographic scales of biodiversity.

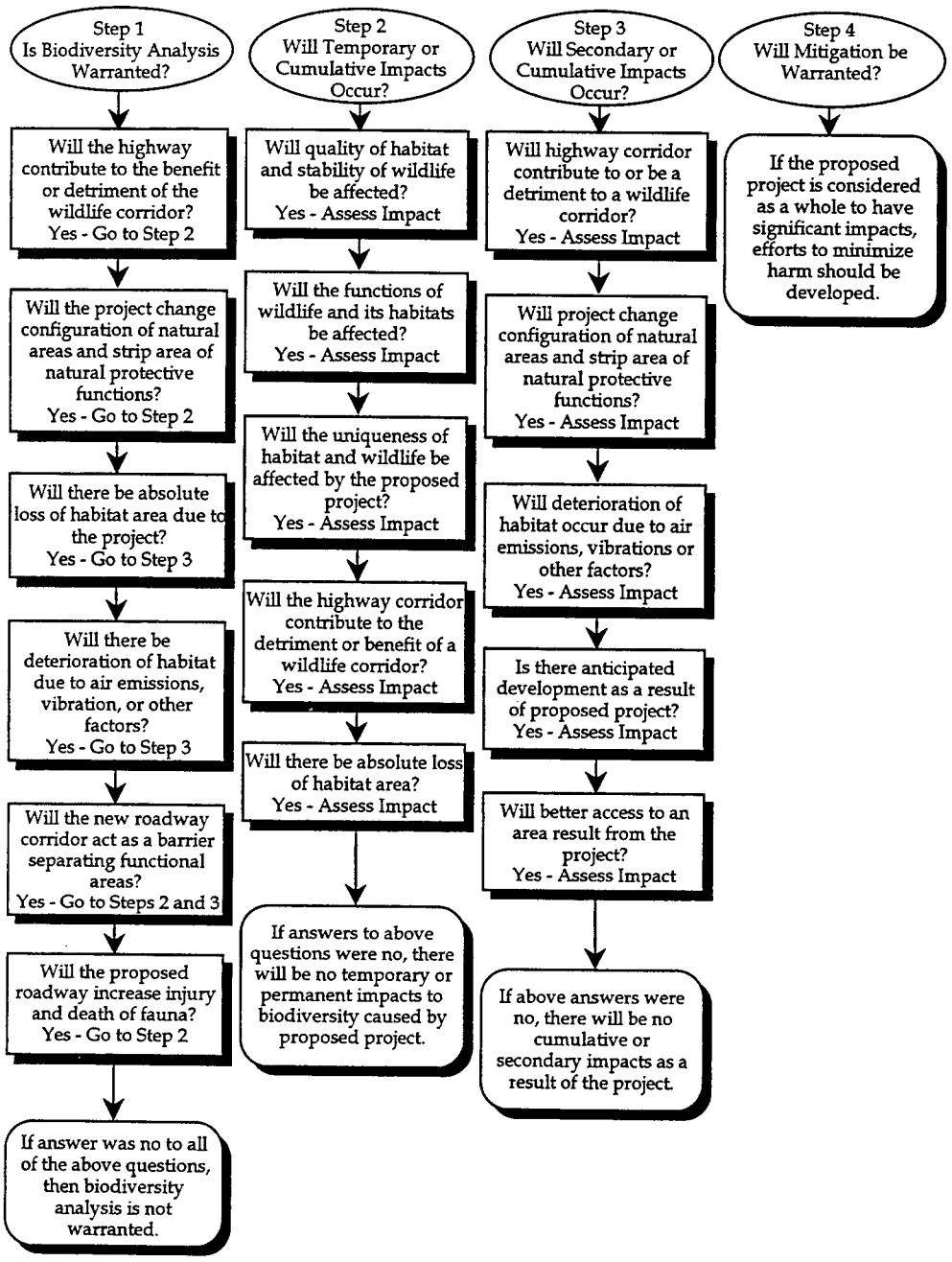
Source: (Bardman 1997)

greatest and opportunities for habitat loss the greatest. The area of the contiguous 48 states dedicated to roadways and their attendant rights-of-way is equivalent to the state of Georgia, and increases each year. Some animals shun contact with humans if at all possible; thus an "avoidance" zone grows in size as human settlements grow. For example, it is estimated that 136.2 hectares of bear habitat are lost for every kilometer of roadway built (209 acres for every mile) (Gilbert 1996).

- Indirect habitat loss: Roadways, through noise, vibration, and other sensory cues, act as a barrier to crossing, even where no physical barriers exist, and traffic densities are low.
- Habitat fragmentation: Fences, medians, roadway width and volume can effectively prevent migration and cut off animal populations from one another, reducing the opportunities for biodiversity and encouraging in-breeding.
- Direct wildlife mortality: The potential for roadkills can be exacerbated by highway design and maintenance practices. Wildlife may be attracted to a highway right-of-way by vegetative plantings used to stabilize slopes. Salt and abrasives used in winter maintenance can attract birds, deer, and moose.

The explosive growth of some animal populations has increased the potential for roadway-wildlife conflicts. It is estimated, for example, that the deer population has increased from 500,000 at the turn of the century to over 20 million in 1995. These increases have occurred as the boundary between feeding areas, park space, and backyards has blurred. One estimate places the total number of roadkill for deer alone at 750,000 per year. Although collisions with large animals cause the most damage, small animals such as dogs, cats, and squirrels are those most commonly killed by motorists. Cook and Dagget estimate that the number of such animals killed in motor vehicle collisions runs to the tens of millions annually, based on a 14-county study conducted in Virginia comparing accident rates for deer versus small animals. Motor vehicle collisions with endangered species are an acute concern as well. In Florida, for example, roadway collisions are a major cause of mortality among panther, black bear, and key deer populations, all endangered species (Cook et al. n.d.).

- Public safety and property damage: The potential for conflict with large mammals presents a public safety problem, especially in less populated areas. Driver efforts to avoid collisions are perhaps more likely to result in injury than actual collisions. Cook and Dagget estimate the total cost in human injury and property damage from such accidents to be $1.2 billion per year.



Source: Bardman, Transportation Research Record 1601

FIGURE 15 Biodiversity analysis.

Compensatory Strategies

Where roadways cause actual or potential conflicts with wildlife populations, avoidance, mitigation, and compensation strategies may be employed (Forman 1996). Roads severely impacting wildlife populations, and certainly those listed as endangered species, would not be built at all, or would be resited to a more appropriate location. The National Environmental Policy Act (NEPA) of 1969 and the Endangered Species Act provide for protection of threatened and endangered species. Ecological impacts may be mitigated through the construction of wildlife crossing areas or by the construction of barriers to prevent crossing altogether.

Compensation refers to the replacement of lost habitat or migration areas so that the overall ecology suffers no net loss. Replacement of wetlands, establishment of greenways, protected wildlife habitat, and migration corridors are examples of compensation. Greenways are linear corridors of restored or undisturbed natural land, set aside for habitat and migration. A small number of roads and urban development projects have been designed with the intention of extending, linking, or creating buffer zones for wildlife.

Each of these broad strategies requires knowledge of the ecology of the affected area, including the size and make-up of the wildlife population. Of these strategies, mitigation can directly relate to the maintenance function. This is so for two reasons: 1) mitigation actions can be retrofitted during reconstruction activities, or solely because of compelling environmental or ecological considerations; and 2) mitigation that results in the creation of additional structures including culverts or overpasses, etc., themselves require maintenance, perhaps of a relatively more frequent or higher intensity nature. Many of the mitigation measures described below have been installed after the original construction, as part of a reconstruction or retrofitting operation.

Mitigation

Tunnels, underpasses, and overpasses have been built to accommodate safe crossings for various types of animals, including amphibians and large mammals. Important considerations in the design of these underpasses and overpasses are the channeling devices, such as fences, that discourage use of the roadway as a crossing and direct the animals toward the grade-separated crossing. Equally important is the sizing of the crossing. In Florida, state ecologists stress the importance of establishing a clear line of sight to the habitat at the other end of the crossing. Animals are variously sensitive to the amount of light entering the crossing as well as its width and height.

In South Florida, nearly 30 underpasses were built for animals inhabiting the swamps and marshes of that area to cross a section of I-75 known as Alligator Alley (Forman 1996). Black bear, deer, bobcat, great blue heron, wild turkey and alligators have used the 30-meter wide by 2.5-meter (98.4-ft by 8.2-ft) high underpasses, which were also designed to increase the flow of water to the Florida Everglades. Roadway mortality of bear and panther have been reduced as a result of these efforts.

Tunnels, pipes, and culverts of various sorts have been constructed around the world to facilitate movement of small and medium-sized animals. European nations are at the forefront of these techniques, although tunnels for amphibians have been built in Massachusetts and Texas. In these locations, roadways have been retrofitted with commercially available polymer-concrete tunnels 30 cm by 30 cm (roughly 1 ft by 1 ft) whose slotted tops sit flush with the roadway and allow rainwater to provide needed moisture for amphibians. Larger tunnels, measuring up to 150 cm (59 in.) wide, are available as well. The state of Washington has redesigned box culverts to facilitate the movement of its fish population, particularly salmon.

Other mitigation strategies include (Cook n.d.):

- Initiatives designed to modify motorist behavior, such as education campaigns, signage or increased lighting, and reduced speed limits;
- Fences and other barriers to prevent crossing or to channel wildlife movement; and
- Installation of devices designed to scare off or warn crossing animals, such as reflectors directing headlight beams toward the roadside or the use of ultrasonic whistles. The results of tests studying the effectiveness of these reflectors has been mixed.

Geographic information systems (GIS) play a significant role in helping plan ways to mitigate or avoid roadway impacts to wildlife. Data on animal migration patterns, locations of habitat, and roadkill can be mapped and used to determine optimal settings for new roadways or mitigation measures for existing roadways. GIS are an integral part of Florida's efforts to reduce wildlife mortality due to automobile collisions.

Bridges, Culverts, Ditches, and Wildlife

Bridges provide a welcome roosting home for many species of birds, offering some shelter against rain and wind and releasing heat absorbed during the day. The bird droppings (guano) produced by nesting or roosting birds, however, can interfere with the functioning of bridges and can damage surface coatings. While scraping and collecting guano is labor intensive, the practice reduces or eliminates the introduction of the high-nitrogen substance from the water system below.

In the state of Texas, recent studies have shown that design modifications to bridges and culverts can provide roosting grounds for bats, to compensate for the loss of traditional roosts (Bat Conservation International 1998). In Texas, bats are extremely effective at controlling insect populations of concern to farmers and foresters. However, more than half of all U.S. species are listed as endangered or are candidates for such designation. The Texas Bats and Bridges Project, sponsored by the Texas Department of Transportation and Bat Conservation International, investigated the modifications necessary to accommodate ideal roosting areas for bats, and investigated whether such modifications were feasible. Among the studies' findings was that bridge crevices between 1.27 and 3.18 cm in width (0.5 and 1.25 in) and 30.5 cm (12 inches) in depth can provide ideal roosting grounds for the Mexican free-tailed bat, among the most valuable to farmers and foresters. The study also found large culverts designed with roughened ceilings would provide a suitable habitat as well. Several other state highway departments have shown interest in the results of this investigation.

In Austin, Texas, an inadvertent bridge-redesign ideally suited to the Mexican free-tailed bat has produced a rare bridge-animal tourist attraction. The Congress Avenue bridge is home to over 1.5 million bats, which are attracted to protected spaces conforming to their needs and the steady supply of insects below. Each evening at dusk, the creatures fly off in search of food en masse, providing the tens of thousands of tourists who visit the bridge with a spectacular sight. The bridge has been the subject of national media attention, and provided the impetus for further research into the use of bridges and culverts as bat habitat.

The New York State Department of Transportation has developed a handbook for transportation maintenance that addresses

wetlands and maintenance near water (New York State Department of Transportation 1997). Guidance pertinent to wetlands and maintenance near wildlife habitat includes the following:

- Beaver dams—Removal of beaver dams is not a part of routine maintenance. However, when water from a dam threatens to flood highways or railroads, or interferes with proper drainage or maintenance activities, it may be necessary to remove or modify beaver dams. Permits are required and affected property owners should be notified. Water levels should be lowered gradually to prevent downstream flooding and habitat damage from siltation. Dams should be removed in the morning to allow the impoundment to drain all day. Dam material should be removed from the site so the beaver will not return to repair it.

- Cleaning culverts/scour protection—NY State DOT requires that all planned culvert cleaning and scour protection projects be discussed with the Regional Environmental Coordinator to address any permitting or environmental issues. General guidance for cleaning culverts and scour protection include the following: BMPs to minimize impacts on water quality, fish and fish habitat, and recreation. Work during low flow periods and utilize temporary water diversions. Allow some stone and stream bed material to remain inside culverts to permit fish to swim through during high and low flow periods. Remove accumulated sediment, stones and trees only near the culvert; cleaned areas should not be more than 3.05 to 9.15 meters (10 to 30 feet) long. Isolate the work using gravel bags, pumps, dirt bags, turbidity curtains or similar material. Remove any sediment pumped behind a cofferdam before allowing the water to return to a stream by using temporary dewatering basins, dirt bags, or allow the water to slowly flow across a vegetated filter strip. Secure baffle pump outlet lines to reduce erosion and scour. Do not use any machinery in the stream channel unless essential and such use has been approved. When stones are placed below the water line for scour protection in the stream bed, do not put them more than 1.53 to 3.05 meters (5 to 10 feet) within a culvert's outlet. Do not fill in fishing pools. Do not straighten or widen stream channels, and do not remove "riparian" vegetation from the stream bank unless absolutely necessary, since it will take at least 15 years to recover. Especially, avoid removing large trees and undercut banks. Reseed and mulch any disturbed area.

- Cleaning and snagging stream channels—Remove in-stream bars, islands, and trees only immediately up- or down-stream from bridges and culverts and only when they threaten the structure. Work in streams only on dates that will not interfere with spawning fish, incubating eggs, and developing larval fish. Try to avoid operating machinery in streams, but if necessary use rubber-tired equipment whenever possible and get approval from the state environmental agency.

Vegetation Management and Wildlife

DOTs are adopting vegetative management practices to enhance wildlife habitat. These practices include protection and replacement of wetlands, and fostering edge effects through mowing and other strategies designed to provide feeding, nesting, protection from predators, and safe migration.

A recent issue of *Greener Roadsides*, the quarterly publication of roadside management issues, includes articles on wetland characterization, the national wetland reserve program, wetland mitigation banks, and "do's and don'ts of wetland planning (*Greener Roadsides* 1995).

Most transportation agencies limit or control access to highway rights-of-way by wildlife to prevent collisions with vehicles. Efforts to limit use of highway roadside by animals likely to be hit by cars or trucks include: (Cook n.d.)

- Use of vegetative plantings that will not attract large animals to roadsides. For example, avoiding plantings of crown vetch and white cedar, which deer favor;
- Clear-cutting of a fixed area beyond the highway shoulder, to reduce the potential for collisions and increase visibility; and
- Use of remote feeding areas away from highway rights-of-way to encourage movement away from the roadway.

Highway rights-of-way provide shelter and food for many species of smaller animals, such as birds and rabbits. Changing vegetation management policies have recognized that fact, and made accommodations where appropriate. Such accommodations include delayed mowing and spraying schedules, increased mowing height, and reduced mowing frequency. These measures are particularly important to promote bird nesting in highway rights-of-way. Occasionally, however, pressure exerted by farmers who are allowed to harvest roadside hay to mow sooner and more frequently, cause more damage to bird habitat than would otherwise be the case. The vegetation management section describes mowing and pesticide application practices in more detail.

Disposal of Roadkill

Consistent with AASHTO guidelines, animal carcasses are removed from highway rights-of-way as soon as possible after being reported, for health and aesthetic reasons. Andres reports that state maintenance personnel typically bury carcasses on-site or at a discrete location nearby, and that state regulations govern the disposal of animal carcasses in about half of all states (Andres 1995). In most states, disposal of the carcass is the responsibility of the maintenance agency. In other states it is the responsibility of the natural resource or environmental protection agency.

Other disposal methods include:

- Pulling the carcass off to an area not visible from the highway to decompose naturally or to function as carrion for other animals;
- Taking the carcass to a rendering plant;
- Disposing of the carcass at a landfill; and
- Salvaging the meat.

TABLE 12
SURVEY OF STATES: DISPOSAL OF ANIMAL CARCASSES

	Problem Activity	Regulations on Disposal	Methods of Disposal	Disposal Contracts
Alabama	Yes	No	Buried On Site, Render Plants	No
Alaska	No	No/Meat Salvaged	Pulled Back, Land Fills	No
Arizona	No	Yes	On Site, Off Site, Forest, Burning	Yes
Arkansas	Yes	No	Buried On Site, Land Fills	No
California	No	Yes/Fines	Buried On Site, Off Site	Yes Animal Control
Colorado	Yes	Yes	Pulled Back	No
Connecticut	Yes	N/A	Buried On Site, Off Site	No
Delaware	No	No	Buried On Site, Off Site, Landfill	No
Florida	Yes	No	Buried On Site, Off Site	No
Georgia	Yes	Yes	Buried On Site, Off Site, L.F.	No
Idaho	Yes	Yes/Burial Site	Buried On Site, Off Site	No
Illinois	No	No	Buried On Site, Off Site	No
Indiana	No	Yes	Buried On Site, Off Site	No
Iowa	Yes	Yes/Burial Site	Buried On Site	Yes Render Plant
Kansas	Yes	N/A		
Kentucky	No	No		
Louisiana	No	No		
Maryland	Yes	Yes/Burial Site	On Site, Off Site, L.F., Render	
Massachusetts	No	No	Buried Off Site	No
Michigan	Yes	Yes	Off Site, Forest, Render Plant	Yes Render Plant
Minnesota	Yes	Yes/Local Regs	On Site, Off Site, Forest, Render Plant	
Mississippi	No	No	Off Site, Forest, Landfill	No
Missouri	Yes	No	On Site	No
Nebraska	Yes	No	On Site, Forest	No
Nevada	Yes	Yes/I.D. Notice	Off Site, Landfill	No
New Hampshire	Yes	Yes/I.D. Notice	On Site/Off Site, Forest, L.F.	No
New Jersey	Yes	No	On Site, Rendering Plant	Yes Deer Pickup
New York	Yes	Yes	On Site, Off Site, Forest, L.F.	No
North Carolina	No	Yes-Large Animals	On Site, Landfill	No
North Dakota	Yes	No	Pulled Back, Rendering Plant	No
Ohio	Yes	Yes	Landfill, Rendering Plant	No
Oklahoma	Yes	No	Landfill	No
Oregon	No	Yes/No L.F.	On Site, Off Site, Render Plant	No
Pennsylvania	Yes	Yes	Off Site, Rendering Plant	Yes/SPCA
South Carolina	No	N/A	On Site, Off Site, Forest	No
South Dakota	No	No		No
Tennessee	No	No		No
Texas	Yes	Yes/L.F. Disposal	On Site, Off Site, Landfill	No
Utah	Yes	Yes Records	Landfill, Rendering Plant	Yes
Vermont	No	Yes-Deer, Moose	On Site	No
Virginia	Yes	No	On Site, Off Site	No
Washington	Yes	Yes/Burial Site	On Site, Off Site, Forest	
West Virginia	Yes	Yes	On Site, Off Site, Forest, Landfill	
Wisconsin	Yes	Yes	Off Site, Rendering Plant	Yes/Natural Res.
Wyoming	Yes	Yes/Burial Sites	On Site, Off Site, Forest, Landfill	No

Source: Andres, 1993

Table 12 summarizes each state's approach to disposal of roadkill.

ENERGY

Transportation agencies devote a considerable portion of their budget to meet their energy needs. Purchasing new products and technologies that reduce energy usage can lower costs in the long run. Examples of potentially energy-saving practices already mentioned include the use of CNG-powered truck engines and using recycled oil or tires for heating. Other energy-saving actions are described below:

— Solar-powered traffic signals and signs are increasing in use, as photovoltaic (PV) technology decreases in cost and increases in efficiency. PV-powered signals require no cabling and generate their own electricity (Weiner 1995). Flashing amber school zone warning signals have been installed in more than 100 locations in the Dallas-Fort Worth area. The Texas Department of Transportation uses PV technology for programmable message boards along highways. Solar-powered portable message boards are in use in Maryland and other states. A reliable stand-alone traffic signal that operates on solar energy has yet to be developed, but advances in light-emitting diode (LED) and PV technology show promise in this area.

— Maryland SHA has entered into an agreement with a vendor to make improvements in energy efficiency at its headquarters. The vendor implements capital improvements and guarantees a cost saving, presumably through reduced energy consumption. The vendor receives in payment the amount of the cost savings for a specified period of time, after which the benefits revert to SHA.

— Ramsey County, Minnesota reports that each LED used to replace an incandescent bulb costs $300, as against the $2.00 previously spent for incandescent bulbs. However, the LEDs use 70 percent less energy and last far longer, resulting in less energy usage and generating dollar savings in the long run.

— Tucson's light abatement program is applauded by skywatchers. Tucson places shields over its low- and high-pressure sodium lights, to direct light downward. The public works department reports that there has been no net increase in light pollution observed, despite population growth. The city is ringed on three sides by mountains that contain observatories, including Kitt Peak National Observatory, the Smithsonian Observatory, and the University of Arizona's Mt. Lemmon Observatory. The International Dark Sky Association's headquarters is located in Tucson, and has recognized the city's efforts.

CHAPTER FIVE

CONCLUSIONS

Public concern about the environment, a commitment to environmental stewardship, environmental laws and regulations, and a desire for increased operational efficiency are prompting transportation agencies throughout the United States and Canada to mitigate, reduce, or eliminate the environmental impacts of highway and street maintenance. At the same time, transportation agencies must remain focused on their fundamental mission of providing safe driving conditions, offering the level of service customers desire, and preserving the highway infrastructure. Public accountability also requires transportation agencies to make cost-effective use of public funds.

This synthesis has yielded a series of findings and conclusions that indicate transportation agencies are pursuing with increasing vigor the development and adoption of BMPs for environmental issues related to maintenance. Overall, the effect appears to be beneficial from the standpoint of allowing maintenance agencies to deliver maintenance more cost-effectively while protecting, preserving, and enhancing the environment. The basic findings of this synthesis, based on the literature review and survey responses, are as follows:

- Environmental laws and regulations, and the potential sources of liability associated with them, are the main factors behind the adoption of more environmentally sensitive highway maintenance practices. State or local environmental protection agencies and health departments play key roles in designing and enforcing these regulations.
- The complexity of environmental issues related to maintenance pose major management challenges to transportation agencies.
- Agencies effective in introducing and fostering BMPs use an interdisciplinary approach. They carefully balance considerations of environmental issues, occupational health and safety, customer service, and maintenance cost-effectiveness while striving to ensure legal and regulatory compliance.
- BMPs that are developed with active input of regulatory agencies are most likely to ensure compliance and reduce the risks of liability and fines. Moreover, transportation agencies that develop in-house expertise in environmental areas report some success in negotiating with staff of regulatory agencies.
- Formal procedures for adopting new practices exist in few agencies. Such procedures include criteria for objectively evaluating prospective practices.
- Most states engage in training of some form but relatively few have developed a comprehensive training program that emphasizes practices that avoid or reduce environmental impacts.
- Very few regulatory agencies have developed BMPs that cover most or all maintenance areas, and where agencies have undertaken a comprehensive effort to do so, in only a few cases do the BMPs provide enough guidance to be useful to practitioners.
- Information on the costs and benefits of BMPs is lacking in most instances, partly due to the difficulty of quantification. However, there are clearly documented cases where BMPs have decreased costs and in other cases increased costs. Often cited is the expectation that a particular policy will produce cost savings in the long run.
- Knowledge of practices beneficial to the environment appear to be diffused throughout individual maintenance agencies. Previously there has not been an effective mechanism for sharing information regarding BMPs throughout the United States and Canada. Nor is there a national repository and means of dissemination.
- Some agencies are becoming highly proactive in addressing environmental issues related to maintenance. Among the steps they are taking are pollution prevention programs, site reviews, scientifically defensible testing and assessments, comprehensive training, and adoption of BMPs.

There are compelling reasons to adopt BMPs for environmental issues related to highway and street maintenance: the public's desire for enhanced environmental quality; environmental laws and regulations; potential liability and fines; increased commitment to environmental stewardship on the part of transportation managers at all levels of the organization; opportunities to reduce costs and environmental side effects; and, the need for some type of guidance given the complexity of environmental issues related to maintenance.

The drive for increased efficiency, safety, and environmental sensitivity is creating a market for technological innovation in many maintenance areas. Rapid technology advances in materials, equipment, sensors, software, hardware, and telecommunications are providing remarkable opportunities to continually improve maintenance. Indeed, the development of BMPs can be part and parcel of an agency's program of continuous quality improvement.

Practices that are adapted for their efficiency or safety-enhancing characteristics often consume less resources, thus providing an environmental benefit. Based on available cost information, BMPs appear to reduce both costs and environmental impacts more often than not. However, there are important instances where adoption of BMPs to ensure conformance with regulatory requirements have increased costs, sometimes substantially.

BMPs, while having a connotation of "best" and universal applicability, are typically site-specific due to local and regional variations in laws and regulations, climate, ecology, and factors that affect the cost-effectiveness of maintenance.

High-level, broad-based management practices that address environmental issues related to maintenance are most

likely to have universal applicability to state, provincial, and local transportation agencies. Such management practices do not pertain to specific types of maintenance activities or environmental issues. Rather, they involve developing overall department policy and strategic plans, preparing pollution prevention programs, conducting environmental analysis, conducting environmental reviews, etc.

Knowledge of policies and practices and an instilled sense of environmental stewardship among line workers is one of the most important factors in successfully promoting environmentally sensitive maintenance practices. Effective internal communication and training programs are essential to achieving this success.

Due to the complexity of the issues involved, further work is needed to refine and develop additional information on BMPs. Research problem statements developed by the Environmental Maintenance Task Force and other indications of future research needs suggest additional resources will be required to develop BMPs for the maintenance community.

In addition to this synthesis report, transportation agencies would benefit from additional efforts to collect, store and disseminate information on BMPs. Possibilities include follow-up research to examine more fully specific environmental and maintenance issues in more depth, expansion and increased circulation of existing newsletters, integration of BMPs' studies into benchmarking studies, and use of various electronic means—including the internet—to share information. Other possible actions are as follows:

- Develop criteria for evaluating alternative practices that can serve as BMPs;
- Collect better information on the costs and benefits of alternative practices;
- Perform research to develop BMPs regarding maintenance activities and environmental issues for which BMPs do not currently exist;
- Develop a database of practices, pertinent laws and regulations, costs, dollar savings, and impacts. An internet site could serve as the repository of such information and enable discussion among practitioners about particular practices;
- Undertake research on how to increase the cooperation and collaboration by transportation and environmental agencies, especially in regard to the development and implementation of BMPs;
- Encourage the practice of conducting site reviews and expand their scope to include all facets of maintenance of consequence to environmental quality;
- Establish a core curriculum for environmental training, coordinate with other types of maintenance worker training, and make training programs available on interactive CD; and
- Undertake research to determine the role of pool-funded efforts, cooperative agreements, and public/private partnerships in developing and implementing BMPs.

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APPENDIX A

Selected Findings of Best Practices Survey

This section presents results of the survey conducted as part of the synthesis project. The questionnaire was sent to state transportation agencies in each of the 50 states, the District of Columbia, and numerous counties, municipalities, and Canadian provinces. The responses to the best practices survey reveal a considerable range of reactions to environmental concerns and mandates in the area of highway maintenance. This variety is a function of geographic, political, and economic factors, with each maintenance district facing a unique set of challenges that are approached in a different manner.

SURVEY STRUCTURE

The best management practices survey is composed of two sections. In the first section, respondents were presented a list of 15 maintenance activities (e.g., vegetation control), nine environmental issues (e.g., air quality) and 19 management practices (e.g., training, automation) and were asked to indicate any that might be considered a best practice. Respondents were encouraged to describe any practices that might provide an overall benefit to the environment, within the constraints under which the respondent's agency operates. The intention was to encourage as large a response as possible. Following this, respondents were asked to provide a brief description of the practice and any evidence of: 1) impacts to maintenance costs; 2) environmental impacts; and 3) any form of recognition for the practice. Lastly, they were asked for any documentation of practices noted as BMPs.

The second section, *Factors Affecting Practices and Costs,* presented multiple choice questions on the agency's approach to maintenance in light of changing environmental concerns and regulations. Respondents were asked to rank contributing factors changing maintenance practices today, as well as factors that influence an "environmentally sensitive" approach to highway maintenance. Lastly, respondents were asked to identify, from a list of choices, how the particular agency has adapted or responded to changes in mandates and practices. Additional space was provided for a general response or reaction to any of the questions asked.

The best practices survey was sent to 296 agencies. In total, 77 responses were received. Thirty-three states responded, with several agencies returning multiple surveys from various divisions, for a total of 50 state responses. This may underscore the fact that in many state agencies, knowledge of maintenance practices relating to environmental impacts is likely to be dispersed among units responsible for a particular practice area, rather than stored or maintained in a centralized location. The response rate from state DOTs was equivalent to that of the Task Force's first survey. However, the response rate from counties and other agencies for this survey was much lower by comparison. In all, responses were received from 13 counties, 11 municipalities and three Canadian provinces. Table A.1 summarizes the response results.

TABLE A.1

RESPONSE RESULTS NCHRP 20-5 TOPIC 28-01

Results	Number
Completed Surveys Received	77
States Responding	33
Surveys from State DOTs, (including multiple responses)	50
Surveys from County Agencies	13
Surveys from Municipal Agencies	11
Surveys from Canadian Provinces	3

SECTION ONE—FINDINGS

Surveys Noting Best Practices

In each of the three areas for which information on best practices was collected, over half of the respondents indicated that their agency had instituted a BMP (Table A.2). While 62 percent of the respondents chose BMPs in maintenance, almost as many indicated the existence of a BMP in the environmental area and the management area. It should be noted that, due to the design of the survey, a particular BMP could have been noted in each of several areas, thus allowing some double counting. For example, installing secondary containment devices might be indicated under "buildings and grounds" as a maintenance area BMP, and as an environmental BMP under "stormwater runoff/water" quality.

TABLE A-2

SURVEY NOTING BEST PRACTICES

Practice Area	Number	Percentage
Maintenance	51	66
Environment	40	52
Management	39	51

Maintenance Area

Roadside vegetation and snow and ice control were the two most frequently cited maintenance area BMPs. This result is consistent with the distribution of literature on maintenance practices, if not the manpower and resources expended (see

Table A.3 below). It is unclear, however, whether these are the maintenance areas most affected by environmental legislation or whether these are the areas of highest effectiveness in terms of environmental impact for each dollar expended. Among the less frequently cited BMPs, roadway maintenance categories including shoulders, litter pickup and sweeping, and signs and striping predominate.

TABLE A.3

DISTRIBUTION OF BEST PRACTICE AREAS: MAINTENANCE AREAS

Best Practice	Percentage
Roadway and shoulder surfaces	7
Roadside vegetation	11
Drainage	5
Litter pickup	7
Sweeping	6
Bridge maintenance (including cleaning and painting)	7
Snow and ice control	10
Signs, striping, and pavement markers	6
Other traffic control devices	2
Emergency maintenance (including spills, storms, accidents)	5
Care and cleaning of parks, rest areas, and weigh stations	2
Equipment (vehicles, maintenance equipment)	6
Materials and handling	3
Buildings and grounds	5
Other	4

Environmental Area

According to the best practices survey, water quality was the most frequently cited environmental area for BMPs. Of the surveys received, 14 percent cited BMPs in the area of storm water runoff/water quality. Four other categories whose percentages range between 6 and 10 percent—soil contamination, wetland and habitat preservation, hazardous waste and other waste disposal—are all closely related to water quality. The distribution of all environmental areas is displayed in Table A.4 below.

TABLE A.4

DISTRIBUTION OF BEST PRACTICE AREAS: ENVIRONMENTAL AREA

Best Practice	Percentage
Stormwater runoff/water quality	14
Air quality	5
Noise	3
Soil contamination	6
Wetland and habitat preservation	8
Hazardous waste/hazardous materials, non-toxic)	10
Other waste disposal (non-hazardous, non-toxic)	6
Worker health and safety	6
Other	3

Management Area

Nineteen percent of respondents indicated that their agencies had implemented a best practice in the area of technical guidance. Forty-four percent of respondents indicated implementation of a BMP in either this category or two related management areas: training/outreach and education/awareness. This underscores the importance of information exchange, in the forms of education, coordination, and outreach among staff, oversight agencies, and the general public.

The results of the survey by management area are broken out in Table A.5.

TABLE A.5

DISTRIBUTION OF BEST PRACTICE AREAS: MANAGEMENT AREA

Best Practice	Percentage
Broader management, planning and other ways of addressing environmental issues related to maintenance and operations.	5
Environmental planning and impact assessment	6
Research and development	13
New product testing evaluation and implementation	5
Organizational development	3
Innovative research agency coordination and permitting	6
Public/private partnerships	7
Policies	10
Procedures (including manuals)	2
Cost-effectiveness and productivity	9
Technical guidance (including manuals)	19
Training	11
Outreach, education and awareness	14
Automation (computer systems, decisions support systems, groupware, expert systems)	11
Strategic, policy or long-range planning	10
Programming and budgeting	2
Business planning and process re-engineering	11
Continuous improvement/total quality management	3
Other	0

TABLE A.6

FACTORS WHICH MOTIVATE AGENCIES ENVIRONMENTAL PROCEDURES

Factors	Score	Rank
Law and regulations	57	1
Economic cost savings and efficiencies that are sometimes positive side effects of environmental protection and enhancement	18	2
Pressure from public interest groups	12	4
Additional funds and resources being devoted to environmental compliance, protection and enhancement	10	5
Total quality management/continuous improvement	14	3
A corporate philosophy of environmental stewardship	14	3
Other	0	6

SECTION TWO—FINDINGS

Factors Motivating Environmental Procedures

The second section began by asking respondents to score the three most important factors motivating changes in maintenance practices. The results already indicate that laws and regulations are the most important factor influencing the implementation of environmentally sound maintenance practices (see Table A.6). There are many major environmental laws applicable to highway maintenance operations; among the federal laws are the Resource Conservation and Recovery Act (which regulates the handling of wastes and underground storage tanks), the Clean Water Act (which regulates the discharge of pollutants into the nation's waterways) and the Federal Insecticide, Fungicide and Rodenticide Act (which regulates the use of pest and plant control products).

Economic cost savings ranked a distant second as a motivating factor. The majority of respondents citing BMPs stated that the costs of the new practice were generally higher than the old. However, several respondents also cited maintenance practices that have proven to be cost-savers while providing a benefit to the environment.

Factors Influencing a Successful Program

Question 2 asked respondents to cite the three most important factors in creating a successful maintenance program. Two areas stood out: 1) understanding environmental impacts of maintenance practices; and 2) laws and their associated penalties. These responses are consistent with previous findings (Table A.7).

Staff understanding and laws and regulations tied for first among factors cited. This result underscores the recognized need for education, training, and awareness. An additional implication is that once policies and practices have been instituted, they must, through proper training, be embraced by the staff implementing them.

Impacts of Compliance

The last question in the survey addressed the ways in which maintenance agencies have adjusted to environmental mandates (see Table A.8). The results indicate that agencies are adjusting by being more efficient, purchasing more cost-effective products, and sharing costs in innovative ways. Eight percent of respondents indicated that they did less maintenance overall, while seven percent deferred low-priority maintenance and two percent deferred high-priority maintenance. This implies that, for the most part, maintenance departments are still able to carry out their primary maintenance functions. Forty-two percent of respondents stated they either made the business process more efficient (i.e., re-allocation of staff, implemented management reforms, etc.), used more cost-effective materials or entered into public/private partnerships to share costs.

TABLE A.7

FACTORS THAT INFLUENCE A SUCCESSFUL, ENVIRONMENTALLY SENSITIVE MAINTENANCE PROGRAM

Factors	Score	Rank
Staff understanding of the environmental impacts associated with maintenance practices	28	1
Existence of law and regulations regarding maintenance related environmental issues	28	1
Development of policy, procedure, and technical manuals for maintenance personnel to follow	9	5
Leadership from top management on environmental protection and enhancement	12	3
Penalties and tort liability associated with failure to comply with laws and regulations	22	2
Conviction of maintenance personnel in the desirability of environmental protection	8	6
Potential for cost savings due to more environmentally sensitive and efficient maintenance	7	7
Increase in maintenance and operations budget to compensate for increased costs	10	4
Easily obtained documentation of best practices of other agencies regarding maintenance related environmental issues	1	8
Other	0	9

TABLE A.8
IMPACTS OF COMPLIANCE

Impact	Percentage
Did less maintenance overall	8
Deferred low priority maintenance	7
Used more cost effective materials	13
Has had no effect	2
Improved productivity of maintenance personnel	2
Contracted out certain maintenance activities at less cost	8
Improved the productivity of equipment (e.g., reconfigure or replace obsolete equipment)	7
Entered into public/private partnerships to share costs	14
Made the business process more efficient	15
Defer high priority maintenance	3
Achieved cost savings in procurement of equipment and materials	9
Other	12

While general response comments were rare, those responding sounded a familiar theme: concern over their agencies' ability to conform to mandates in the face of constant or shrinking budgets.

Summary

The following salient points have been extracted from the surveys:

Technological innovations that result in cost savings and reductions in environmental impacts are more likely to be implemented. Environmental concerns, combined with a demand for more cost-effective products, are driving forces behind constant technological innovation in maintenance technology.

Best practices are in the eye of the beholder. Respondents tended to use their own experience as a reference point for reporting best practices. Therefore, where an innovation or practice is implemented for the first time, it has a higher probability of being reported in contrast to a practice that might be unusual or best from a national perspective.

Line staff must take ownership of environmental concerns. Crew members ultimately implement environmentally sound practices, such as optimal salt application rates, choice of herbicide, or waste disposal practices. Management practices that instill a sense of ownership encourage staff to carry out these procedures.

Laws and regulations drive changes in maintenance practices. Technological innovation and changing internal policies and procedures make more environmentally sensitive maintenance practices possible, these changes seem to have been driven by legislation such as the Clean Water Act (CWA)—as opposed to being driven solely by a sense of environmental stewardship. The questionnaire did not ask respondents whether their specific best practices were mandated by regulations. Although many of the provisions of the environmental legislation are interpreted and enforced at the local/state level, the federal legislation has imposed a minimum level of environmental protection on which states and municipalities can build.

Practices that minimize or eliminate environmental liability appear to be preferred. In their documentation of best practices, Minnesota DOT and others described environmental liability concerns as a reason for their choice of a particular approach or material. Contracting out services is one way in which maintenance agencies limit their own liability. This can present its own problems, however. The Pennsylvania DOT reports that, before it issued new painting specifications, contractor compliance with applicable regulations was uneven. One contractor in particular received the highest penalty ever issued by OSHA to a painting contractor—$5 million.

Public perception is important. North Carolina DOT got a very favorable public response to its wildflower program, which reinforced the practice of reduced mowing. In some cases, public education is an added expense to a change in maintenance practices. For example, the public must be assured of safety when reducing or eliminating salt or abrasives applications.

Reported direct cost savings from environmental practices are rare. Most reported practices result in an increase in costs, due to higher-priced materials, contracting out of services, more staff required, or lower productivity. Reported cost savings tended to focus on long-term benefits, such as reduced use of resources (i.e., land, electricity, fuel). State agencies tended to report on impacts as they related to their ability to carry out the maintenance mission effectively. Vegetation control is one exception to this, where mowing frequency has been reduced or where areas are allowed to return to a natural state.

APPENDIX B

Survey Summaries

Practices cited by survey respondents are summarized by maintenance area, environmental area, and management area in the tables below:

TABLE B.1
SELECTED MAINTENANCE PRACTICES CITED IN SURVEY

Maintenance Area	Practice
Roadway and Shoulder Surfaces	Recycling roadway millings for shoulder backup and roadway surfaces (MDSHA, VTAOT) Restricted use of cutback asphalts to prime and winter coat (ARHTD) Use of liquid emulsions only in surface treatment (NHDOT) Use of harrow type/retriever equipment to reuse existing shoulder material (New Brunswick, Canada) Use of high-performance patching materials rather than cold-patch (NJDOT) Use higher quality, longer lasting materials for roadway striping (Newark, NJ)
Roadside Vegetation	Integrated Roadside Vegetation Management Plans (Mn/DOT, UDOT) Reduction in/Limited mowing (Mn/DOT, NEDOT, NCDOT, Dane Co., WI, Manitoba, Canada) Pesticide policy developed by DES (Mn/DOT) Landscape management plan, a "comprehensive land stewardship policy" (MassPike) Reduction in herbicide application (Manitoba) Use of native plants (Manitoba, Cedar Rapids, IA) Turf needs study to identify sites for remediation (MDSHA) Champion tree retention program (MDSHA) Tree expert and training and testing (MDSHA) Pesticide certification training (MDSHA) Use only non-restricted herbicide. Use only in areas that will not create erosion problems. Not for use in environmentally sensitive areas (Honolulu, HI) High volume broadcasting, restricted use herbicides, growth regulants not used (FDOT) Contracting out herbicide program (ConnDOT) Wildflower program, revegetation of ROW (ARHTD, SCDOT, NCDOT, Dane Co., WI) Reduction/Elimination of chemical application (NHDOT) Use of salt-tolerant grasses along roadside (NHDOT) Development of a computerized injector for herbicide truck fleet (TxDOT) Right-of-Way re-establishment of native vegetation (ARHTD)
Drainage	Grass-lined/stone-lined treatment swales (NHDOT) Levee system; annual drainage cleaning, regular cleaning, inspection of drainage, inlets and lines (Sioux Falls, SD) Watercourse maintenance guidelines—maintenance for "naturally vegetated watercourse" (Tucson, AZ) Adopt-a-Wash program (Tucson, AZ) Incorporation of erosion and sediment control structures into maintenance operations (New Brunswick, Canada)
Cleaning/Litter Pickup	Adopt-a-highway program (Mn/DOT, Little Rock, AR, NEDOT, Dane Co. ,WI, NHDOT, PennDOT) Mobile roadway debris removal (CDOT) Use of correctional inmates (NEDOT) Annual neighborhood cleanup (Sioux Falls, SD) Graffiti Abatement Program (Tucson, AZ) Cleaning services contracted to handicapped and vending concessions to blind (INDOT)
Sweeping	Mechanical sweeping in CBD/University area on cyclical basis (Little Rock, AR, Honolulu, HI/Columbus, OH, Sioux Falls, SD) Priority sweeping next to lakes (Ramsey Co, MN)

TABLE B.1 *(Continued)*

Maintenance Area	Practice
Bridge Maintenance	Use of abrasive recyclers (steel shot) in lead paint removal (MoDOT) Development of BMPs for bridge painting (MEDOT) Use of Calcium Sulfonate paint requiring very little surface preparation (ARHTD) Use of settling basins and cofferdams (sheet pile, sandbags) for dewatering work areas (NHDOT) Joint seals treated with bareground herbicides applied with hand sprayers (UDOT) Enclosures for Lead Paint Removal (NYSDOT) Vacuum shrouded power tools, low VOC coatings and tinted automobile undercoating grease (VTAOT)
Snow and Ice Control	Living snowfences (Mn/DOT) Increased use of Mg Chloride (MDSHA) Zero-velocity spreaders (INDOT) Calcium chloride and other pre-wetting systems (NJDOT, INDOT, Ramsey Co, MN) Roadway weather information systems (INDOT, NJDOT) Truck-mounted sensors (INDOT) In-ground pavement sensors (INDOT) Advanced equipment, training, policies and procedures reduce amount of salt used (MassPike, New Brunswick, Canada) Salt alternatives, accurate application equipment, timely weather information (CALTRANS,VTAOT) Snow disposal sites selected based on the environmental impact of contaminants (Manitoba) Use of salt alternatives (Cheyenne, WY) Snow and ice control program (Columbus, OH) Rare use of sand/abrasives (NJDOT) Best practices manual for snow and ice control (VDOT)
Signs, Striping, and Pavement Markers	Water-based paints (INDOT, City of Tucson) Use of lead-free, solvent-free pavement marking materials (FDOT, ARHTD, NHDOT) Painting specifications; airborne emissions, lead paint abatement, clean up criteria, HAZMAT storage and disposal criteria, health and safety requirements (PennDOT) Testing of spray guns on paved surfaces only; paint residue and overspray recycled (WSDOT) Plastic sheeting under illuminated arrow boards to prevent fuel seepage (New Brunswick, Canada)
Other Traffic Control Devices	Solar-powered VMS and arrow panels (MDSHA) Traffic signals timed for four travel periods and way-finding signage system (Newark, NJ)
Emergency Maintenance	Traffic Incident Management Systems in selected areas (INDOT) Microbial organisms used to break down hydrocarbons in hydrocarbons (liquids and vapors) using "microblaze" portable sprayers. (El Paso, TX) Annual training for road maintenance personnel for petroleum spill control (MassPike) Environmental response unit mitigates, cleans and disposes with all non-hazardous spills on public right-of-way (Virginia Beach, VA)
Equipment	Vehicle painting contracted to outside vendors (INDOT) Conversion of some fleet to alternate fuels. (Hamilton Co, OH, ARHTD, El Paso TX) Energy-efficient air conditioning units (Hamilton Co, OH) Sphagnum moss filter for effluent from truck washing (ODOT) Asphalt equipment cleaning/recycling facility (Ramsey Co, MN) Urethane coating for vehicle coating systems (VTAOT) Total cost purchase program for large equipment (Dane Co, WI)
Materials and Handling	Major effort to comply with federal & state laws and rules for handling of motor fuels, storage devices, protection, etc. (NHDOT) Furnace oil tanks being upgraded to bladder type tanks (New Brunswick, Canada)
Buildings and Grounds	Coverage of salt, winter chemicals, stockpiles (Mn/DOT, Hamilton Co, OH, ConnDOT, Sioux Falls, SD, NYSDOT) Salt storage building for loading, storage mixing and reloading in confined space, elimination of salt, brine runoff (INDOT) Salt sheds, impervious surfaces, closed drainage system (ConnDOT) Model stockpile program, policies, procedures (PennDOT) Oil/Water separators installed at maintenance facilities (WSDOT) BMP manual for drainage design, facility management and maintenance operation '98 (NJDOT)
Other	Pentathol-treated posts rather than creosote (NHDOT) Light pollution abatement program (Tucson, AZ)

TABLE B.2

SELECTED ENVIRONMENTAL AREAS CITED IN SURVEY

Environmental Area	Practice
Stormwater Runoff/Water Quality	NPDES Program (Multinomah Co., OR, Honolulu, HI, Sioux Falls, SD) Stormwater ponding/water quality ponds in construction (Mn/DOT, Ramsey Co., MN) Erosion and sediment control program/BMPs (MDSHA, MEDOT, TxDOT, AKDOT & PF, ConnDOT, Nova Scotia) Quarterly reports to DES (MDSHA) Timely inspection of storm drains (Honolulu, HI) Erosion protection at ends of roadway/ditch conduits (Hamilton Co, OH) Stormwater pollution prevention plans for all facilities (ConnDOT) Stormwater management plan for maintenance activities for permitting (CALTRANS) Special detention basins sand/oil separators, special erosion control in sensitive areas i.e., Lake Tahoe (NVDOT) Adherence to guidelines of Environment Department (NHDOT) Manual on BMPs for winter chemicals, disposal of street sweepings, seeding and mulching, use of pesticides, erosion and sediment (NCDOT) Water quality ponds in road construction (Ramsey Co, MN) Use of petroleum absorbent pads in sensitive wetland areas. (RIDOT) Water quality, dry weather field screening, wet weather monitoring for drainage systems and storm-water management facilities (Virginia Beach, VA) Peat treatment beds for wastewater (New Brunswick, Canada)
Air Quality	Elimination of sandblasting and vehicle spray painting (INDOT) CMAQ funds used to pave unpaved roads (Riverside Co CA) Developed "Ozone Action Day Response Plan" (MDSHA) No burning allowed on construction or maintenance projects (NHDOT)
Noise	Modeling of road projects (Ramsey Co, MN) New equip must meet OSIER noise levels (FDOT)
Soil Contamination	Bioremediation, farming, incineration (Mn/DOT, INDOT, El Paso, TX) Remove most underground gasoline storage tanks (INDOT) Temporary Fuel Storage Spill Program (New Brunswick, Canada) UST replacement (Mn/DOT, MDSHA) In-house evaluation of soil contamination (GDOT) In-Situ bioremediation (PennDOT)
Wetland and Habitat Preservation	Wetland replacement/removal (Mn/DOT, Manitoba, MDSHA, INDOT, NHDOT, NJDOT, Ramsey Co, MN) Construction of wetland to treat runoff at maintenance facility (Tucson, AZ)
Hazardous Waste/Hazardous Materials	Solvent-based marking/bridge paint burned in cement kilns; long term liability reduced (MoDOT) Development of guidelines/procedures for removal of asphalt from truck bodies (Mn/DOT) Waste oil, antifreeze recycling (MDSHA) General recycling program (INDOT) Hazardous waste plan (NHDOT) Storage facility for waste mostly from painting operations (NHDOT) Contracting out HAZMAT clean up and disposal (Virginia Beach, VA)
Other Waste Disposal	Discarded tires used for power plant fuel. (MoDOT) Used oil used as supplemental heating supply (MoDOT, ARHTD) Testing, identification and use of recyclable sorbent materials; published results (Mn/DOT) Fly ash, spent foundry materials used in trench backfill (Hamilton Co, OH) Recycling task force/waste audit (PennDOT) Recycling of waste oil, anti-freeze, and sand (Ramsey Co, MN) Dewatered catch basin sludge and sand recycled for soil amendment and shoulder repair (WSDOT) Policy statement on street waste solids recycling and disposal (Snohomish Co., WA)
Worker Health and Safety	Elimination of solvents in sign fabrication, water-based road paints (INDOT) No sandblasting, vacuum attachments on tools (NHDOT) Annual blood lead levels (NHDOT) Material data safety sheets acquisition contracted out (NCDOT) Formal safety policies and procedures for trenching/excavation/lead in construction/shoring/use of explosives and asbestos management (NCDOT) Training in right-to-know, work in confined places, workplace safety and hazardous waste disposal (Ramsey Co, MN)

TABLE B.2 *(Continued)*

Environmental Area	Practice
	Regular meetings regarding proper chemical and herbicide handling and use (Honolulu, HI) In-house asbestos inspectors (INDOT)
Other	Comprehensive "Environmental Protection Plan" (New Brunswick, Canada) Forest and tree mitigation and preservation (MDSHA) Environmental audit procedures to verify facility compliance (MIDOT, New Brunswick, Canada) Utilize rights-of-way to raise hardwood trees for harvesting (INDOT)

TABLE B.3

SELECTED ENVIRONMENTAL AREAS CITED IN SURVEY

Management Area	Practice
Environmental Planning and Impact Assessment	Environmental auditing (MIDOT) Sweepings Testing (Snohomish Co., WA) Full EIS on pesticide operations (TxDOT)
Research and Development	Ongoing research program in over 40 areas, with research in several environmental practices, including bioremediation (Mn/DOT, INDOT) Data on stormwater quality (Ramsey Co, MN) Extensive outdoor evaluation facility for erosion control products (TxDOT) Acrylic emulsion tests (Snohomish Co, WA)
New Product Implementation	Mag Chloride replacement for Calcium Chloride (INDOT) Salt alternatives (Sioux Falls, SD)
Organizational Development	Bureau of Environmental Quality (PennDOT) Environmental Program for Operations Division costs 75% less than consultants (WSDOT) Performance standards for maintenance activities to max. removal of pollutants in SW plan (Alameda Co, CA)
Innovative Research Agency Coordination and Permitting	Monthly meetings with Environment Department (NHDOT) Environmental services branch monitors projects, coordinates with DES (Nova Scotia DOT)
Public/Private Partnerships	Performance contracting for energy efficiencies at headquarters (MDSHA) Participant in "Partners for Clean Air" (INDOT) Extensive cooperation with private sector and other levels of government (Mn/DOT)
Policies	Comprehensive waste minimization strategy (Mn/DOT)
Technical Guidance and Procedures (including manuals)	Manuals in environmental training, construction, environmental studies (INDOT) Use of DES management and sediment control BMP handbook (NHDOT) Manual for stabilization and vegetation practices (TxDOT) Best practices manual for all aspects of maintenance (VDOT) Bridge maintenance guidelines to minimize environmental impacts (WSDOT) Field Guide on Environmental Protection Practices (New Brunswick, Canada) HAZMAT substitution manual (PennDOT) Herbicide operations manual (TxDOT)
Other	Cost analysis on vegetation management (Ramsey Co, MN)
Training	Training for HAZMAT handling (FDOT, MoDOT, Virginia Beach, VA, Little Rock, AR) Training in all areas of maintenance (Mn/DOT) Training in environmental issues and their resolution taught by environmental staff (FDOT) Maintenance worker training academy '98 (CDOT, VDOT, VTAOT) Training on environmental issues (UDOT) Snow academy training (PennDOT)
Outreach, Education and Awareness	CMAQ funding for public awareness campaigns (INDOT) Input to legislative representatives related to environmental regulations (Ramsey Co, MN) Public education campaign on pollution prevention (Riverside Co, CA) Information brochure on pollution control for public awareness (TxDOT) Noxious weed poster (UDOT)

TABLE B.2 *(Continued)*

Management Area	Practice
Automation (computer systems, decisions support systems, groupware, expert systems)	Software for generating hazardous waste reports (PennDOT) GIS used for sweeper routes (Riverside Co, CA) Computerized maintenance management program (Tucson, AZ) GIS/IMS system (Sioux Falls, SD) Have GIS section and crews that conduct storm drain inventory (Ada Co., IN) CASPER software for efficient snow and ice removal routes (INDOT) Computer logs of most maintenance activities - (Multinomah Co, OR)
Continuous Improvement/Total Quality Management	TQM includes office recycling and operation study of asphalt plant (Little Rock, AR) Cash incentives for innovative, money saving ideas (INDOT) Best overall site maintenance contest (VTAOT) Re-engineering of many maintenance functions including: emergency operations, bridge and pavement management and budget allocation model for maintenance operations (VDOT)

APPENDIX C

NCHRP 20-5, Topic 28-01

SURVEY INSTRUMENT

Best Management Practices for Environmental Issues Related to Highway & Street Maintenance

QUESTIONNAIRE

PURPOSE

Highway maintenance practices have evolved to respond to increased concerns about water, soil, air, and many other environmental issues. Today, practices more successfully mitigate the environmental impacts of highway maintenance.
In 1995, the Transportation Research Board's Task Force on Environmental Maintenance distributed a survey to states and local governments on the subject of environmental issues related to maintenance. Respondents cited the *need for a compilation of Best Management Practices (BMPs) for maintenance activities affecting the environment as the most significant "next step" the Task Force could take.* Consequently, the Transportation Research Board is conducting a follow-up survey of transportation agencies to collect information on BMPs for simultaneously addressing environmental and highway maintenance needs for incorporation into an NCHRP Synthesis Report.

Please complete the following request for information to aid the processing of this survey:

Agency _____
Address _____
_____
City: _____ State: _____ ZIP: _____

Questionnaire Completed By: _____
Position/Title: _____
Telephone: _____ FAX: _____ E-Mail: _____

PLEASE RETURN QUESTIONNAIRE AND SUPPORTING DOCUMENTS BY: ***March 1, 1997***

TO: William A. Hyman
Cambridge Systematics, Inc.
5225 Wisconsin Ave., N.W., Suite 409
Washington D.C. 20015
Telephone: (202) 466-5542; FAX: (202) 466-5548; E-Mail: wah@camsys.com

THANK YOU FOR YOUR VALUABLE ASSISTANCE ON THIS PROJECT.

PLEASE WRITE ON THE BACK OF ANY PAGES IF YOU NEED ADDITIONAL SPACE FOR YOUR RESPONSE.

SECTION 1. EXEMPLARY AND BEST MANAGEMENT PRACTICES

We are seeking information on best management practices that address each important environmental issue that arises within a maintenance program. Formally, best practices in environmental maintenance can be defined as, ". . . current innovative practices or combinations of practices which utilize technological, economic and institutional guidelines or policies to mitigate routine or unusual maintenance problems in a manner compatible with environmental quality goals."

Practically speaking, however, we are looking to document practices that are well thought-out, competently performed and that provide an overall benefit to the environment, within the constraints under which the agency operates. Unless you tell us your story, neither you or we will be able to discern what's above average from the rest. Our approach is to be inclusive in our documenting of management practices so as to capture practices which may be considered routine by the local engineering community, but might in fact be considered exemplary when considered on a larger scale.

In developing your responses, please consider obtaining input from managers in both the maintenance/operations units and environmental units of your agency. Also consider headquarters versus district practices.

1. *Do you have any environmental-related maintenance practices that you would consider exemplary or best practices from which other state and local agencies could learn or benefit? (Please check all that apply):*

____ Maintenance activities

a. ____ Roadway and shoulder surfaces
b. ____ Roadside vegetation
c. ____ Drainage
d. ____ Litter pickup
e. ____ Sweeping
f.. ____ Bridge maintenance (including cleaning and painting)
g. ____ Snow and ice control
h. ____ Signs, striping, and pavement markers
i. ____ Other traffic control devices
j. ____ Emergency maintenance (including spills, storms, accidents)
k. ____ Care and cleaning of parks, rest areas, and weigh stations
l. ____ Equipment (vehicles, maintenance equipment)
m. ____ Materials and handling
n. ____ Buildings and grounds
o. ____ Other: _____

____ Environmental Areas

a. ____ Stormwater runoff/water quality
b. ____ Air quality
c. ____ Noise
d. ____ Soil contamination
e. ____ Wetland and habitat preservation
f. ____ Hazardous waste/hazardous materials toxic substances
g.. ____ Other waste disposal (non-hazardous, non-toxic)
h. ____ Worker health and safety
i. ____ Other: _____

____ Broader management, planning and other ways of addressing environmental issues related to maintenance and operations:

a. ____ Environmental planning and impact assessment
b. ____ Research and development
c. ____ New product testing evaluation and implementation
d. ____ Organizational development
e. ____ Innovative resource agency coordination and permitting
f. ____ Public/private partnerships
g. ____ Policies
h. ____ Procedures (including manuals)
i. ____ Cost effectiveness and productivity
j. ____ Technical guidance (including manuals)
k. ____ Training
l. ____ Outreach, education and awareness
m. ____ Automation (computer systems, decision support systems, groupware, expert systems)
n. ____ Strategic, policy or long-range planning
o. ____ Programming and budgeting
p. ____ Business planning and process re-engineering
q. ____ Continuous improvement/total quality management
r. ____ Other: _____

If you checked any area above as a good, exemplary or best practice that you would like to share with other state and local agencies, please describe it and provide whatever written documentation you have such as policies, procedures, and manuals. Please copy and complete this sheet for each item you checked, as necessary. Additional sheets have been provided for your use (3).

Name of Exemplary or Best Practice: _____

Description _____

Identify the environmental impacts which resulted:

How were the costs of maintenance affected by this practice? Provide dollar estimates if possible.

Any other positive or negative impacts? ____ Yes ____ No.
If yes, please describe: _____

Please provide documentation regarding this exemplary or best practice. (Indicate here if you are returning documentation)

__ Yes __ No.

2. *Have any of your environment-related maintenance practices been recognized, commended, received an award, etc. ? Check each that applies:*

a. ____ Written up in a newspaper?
b. ____ Showcased on TV?
c. ____ Described in an internal newsletter?
d. ____ Shown on an internal video?
e. ____ Received award?
f. ____ Commended by the general public or outside organization through correspondence?
g. ____ Commended by upper management or elected governing body (legislature, city council, county board)?
h. ____ Other: _____

Please describe each practice that received recognition, commendation, an award, etc. and provide documentation. If you already completed a description sheet in response to Question 1, please refer to it:

Please provide documentation regarding this exemplary or best practice. Indicate here if you are returning documentation.

__ Yes __ No.

SECTION 2. FACTORS AFFECTING PRACTICES AND COSTS

3. *Identify the three most important factors that motivate your agency's environmental procedures as they relate to maintenance and operations (1=most; 2=second most; 3=third most important):*

_____ Laws and regulations
_____ Pressure from public interest groups
_____ Total quality management/continuous improvement
_____ Additional funds and resources being devoted to environmental compliance, protection and enhancement
_____ Economic cost savings and efficiencies that are sometimes positive side effects of environmental protection and enhancement
_____ A corporate philosophy of environmental stewardship
_____ Other: _____

4. *Identify the three most important factors that influence a successful, environmentally sensitive maintenance program (1=most; 2=second most; 3=third most important):*

_____ Staff understanding of the environmental impacts associated with maintenance practices
_____ Existence of laws and regulations regarding maintenance related environmental issues
_____ Penalties and tort liability associated with failure to comply with laws and regulations
_____ Conviction of maintenance personnel in the desirability of environmental protection
_____ Leadership on environmental protection and enhancement from top management
_____ Increase in maintenance and operations budget to compensate for increased costs
_____ Potential for cost savings due to more environmentally sensitive and efficient maintenance
_____ Development of policy, procedure, and technical manuals for maintenance personnel to follow
_____ Easily obtained documentation of best practices of other agencies regarding maintenance related environmental issues
_____ Other: _____

5. *How has compliance with environmental procedures modified maintenance and operations procedures/activities? Check each applicable statement:*

a. ____ Improved productivity of maintenance personnel
b. ____ Improved the productivity of equipment (e.g., reconfigure or replace obsolete equipment)
c. ____ Used more cost effective materials
d. ____ Made the business process more efficient
e. ____ Achieved cost savings in procurement of equipment and materials
f. ____ Contracted out certain maintenance activities at less cost
g. ____ Entered into public/private partnerships to share costs
h. ____ Did less maintenance overall
i. ____ Deferred low priority maintenance
j. ____ Defer high priority maintenance
k. ____ Has had no effect
l.. ____ Other: _____

SECTION 3. GENERAL RESPONSE

Please offer additional comments or suggestions regarding good, exemplary or best management practices that address environmental issues related to highway and street maintenance:

Additional sheets for Best Practices Documentation

Name of Exemplary or Best Practice: _____

Description:_____

Identify the environmental impacts which resulted:

How were the costs of maintenance affected by this practice? Provide dollar estimates if possible.

Any other positive or negative impacts? ____ Yes ____ No.
If yes, please describe. _____

Please provide documentation regarding this exemplary or best practice being returned. Indicate here if you are returning documentation. __ Yes __ No.

Name of Exemplary or Best Practice: _____

Description _____

Identify the environmental impacts which resulted:

How were the costs of maintenance affected by this practice? Provide dollar estimates if possible.

Any other positive or negative impacts? ____ Yes ____ No.

If yes, please describe: _____

Please provide documentation regarding this exemplary or best practice. Indicate here if you are returning documentation.

__ Yes __ No.

APPENDIX D

Management Practices from Hazardous Waste Program Manuals

MANAGEMENT PRACTICES FROM THE OHIO DOT HAZARDOUS WASTE PROGRAM MANUAL

Type of Product	Regulatory Review	Management Practice
Abandoned Drums and Containers	• Abandoned drums and containers become responsibility of DOT • Need to determine if hazardous • Need to exercise extreme caution • OSHA standards may apply regarding training, protective clothing, and monitoring equipment	• If found, immediately notify supervisor • Leave drum where found if does not pose safety hazard to traveling public or employees • Should be moved by persons trained in hazardous waste management • Do not move drum to ODOT garage or outpost
Aerosol Cans	• Considered empty when inner pressure equals atmospheric pressure • Empty cans may be disposed through a scrap metal dealer or in landfill • Ohio EPA regulates aerosol cans containing material or propellant, and cans must be tested for hazardous waste. If not empty and they contain listed solvents, they are considered hazardous	• Recycle completely empty cans through a local scrap metal dealer if possible • If not possible to recycle, dispose of through a landfill if not hazardous • If aerosol cans must be disposed of as waste, test first and then dispose of properly (most probably as hazardous waste)
Animal Carcasses	• Ohio EPA requires animal carcasses to be disposed of as solid waste. • Burial on ROW is not approved • Proper disposal methods include landfills, rendering plants, zoos or humane societies	• Collect animal carcasses as soon as possible. Large animals that pose a traffic hazard may be picked up; smaller animals may be picked up if general public requests and crews have the time • Arrange disposal sites ahead of time
Antifreeze	• Although water and ethylene glycol contained in antifreeze does not have hazardous waste characteristics, Ohio EPA requires testing before disposal to determine if hazardous because of possible presence of heavy metals or benzene	• If antifreeze is non-hazardous, dispose of through sanitary system if approval has been obtained or have a company remove it as a toxic but not hazardous waste • If a test determines the waste is hazardous, manage as such • Antifreeze may be recycled
Batteries	• Spent lead-acid batteries are exempt from regulation if recycled • Nickel -Cadmium batteries may be hazardous waste and need to be recycled	• Service agreement with vendors selling batteries to ODOT requires vendor to pick up and recycle used batteries • Store lead-acid batteries on impermeable base, such as concrete and preferably inside. Stacking of batteries not recommended, and any leakage should be cleaned up immediately • Nickel-Cadmium batteries can be collected and offered for recycling through vendors specializing in this type of battery • Ordinary flashlight batteries can be disposed of at landfills.

MANAGEMENT PRACTICES FROM THE OHIO DOT HAZARDOUS WASTE PROGRAM MANUAL *(Continued)*

Type of Product	Regulatory Review	Management Practice
Excess or Out-Dated Chemicals	• Ohio EPA lists certain chemical products as hazardous wastes • If the listed chemical is the primary ingredient, then the waste product or the discard must be managed as hazardous waste, unless it is recycled	• Maintain accurate inventory at each location • Check with vendors who may accept unopened containers for disposal • Check Material Safety Data Sheets for disposal instructions. If product is opened or identification has been lost, then testing is required. • Do not accept excess chemicals from other sources if you cannot use them in a reasonable time period.
Floor Drain Sludge	• Ohio EPA requires that a representative sample of sludge be tested for 8 heavy metals, (TCLP), TPH, BTEX, Flammability, Reactivity, Corrosivity, and Toxicity. • If the sludge is non-hazardous, it may be disposed in a landfill or wastewater treatment facility. Otherwise it must be disposed of as a hazardous waste.	• All floor drain sludge must be tested before disposal and prior to emergency conditions • A landfill disposal permit must be obtained to dispose of non-hazardous sludge on ODOT property, which is not recommended. • Arrange for disposal of non-hazardous sludge with the local wastewater treatment facility or landfill • Hire a company approved to handle hazardous wastes if the sludge is determined to be hazardous.
Herbicide Containers	• Triple rinse herbicide container and collect and reuse rinse water. Once triple rinsed, the containers are considered non-hazardous and may be disposed of in a landfill or sent to be recycled. • If a container has herbicide in it, it must be managed as hazardous waste; consult the Material Safety Data Sheet or call the manufacturer	• Completely empty herbicide containers and triple rinse. Add the rinse water to the contents of the spray tank. Never empty containers on the ground or down a drain. • Dispose of the empty triple rinsed containers at a landfill. Check with vendors to see if a recycle program exists. • Know your application areas and rates and do not mix more of tank mix than needed.
Paint Drums	• Containers with less than three percent by weight remaining are considered empty and therefore exempt from hazardous waste regulation. Containers with more than three pounds of residual weight are subject to hazardous waste regulation including testing.	• Empty drums as much as possible by pouring, pumping, and scraping. • Save all drums for recoiling by the Department's drum recycler • Avoid using empty paint drums to store other material, which can lead to mixing of hazardous waste and lead to costly waste disposal.
Paint Sludge, Solvent Based	• Mixtures containing residual paint and paint solvents are hazardous waste. • Deliberate evaporation of paint solvents constitutes treatment and is not acceptable to the Ohio EPA, unless a permit is obtained.	• Collect all solvent based paint sludge in the appropriate waste container and manage it as hazardous waste as per Ohio DOT's Waste Management Plan. • Storage of the containers shall be consistent with the generator status of the site. • Since the waste is ignitable, storage must be in a safe place away from any source of ignition.
Paint Sludge, Water Based	• A sample of the sludge must be tested using the TCLP and if hazardous must be disposed of in an Ohio EPA permitted hazardous waste disposal facility. • If none of the parameters are exceeded, the waste is non-hazardous and may be disposed of in a landfill provided there are no free liquids.	• Collect all water-based paint sludge in approved containers and mark them as waste. • Obtain a sample of the sludge and submit it for testing. • Dispose of sludge in accordance with test results. • Hazardous wastes should be handled by a reputable waste disposal firm.

MANAGEMENT PRACTICES FROM THE OHIO DOT HAZARDOUS WASTE PROGRAM MANUAL *(Continued)*

Type of Product	Regulatory Review	Management Practice
Paint Solvents	• Spent or waste solvents typically used for paint thinning and equipment cleaning include toluene, xylene, acetone, methyl ethyl kettle and various combinations. The Ohio EPA specifically lists each of these solvents as hazardous waste when they are no longer usable. These solvents must be disposed of at a permitted hazardous waste disposal facility.	• Carefully manage the amount of solvents in one's operations to reduce the amount of waste generated. • When cleaning equipment, carefully collect all solvents in an approved container. Never flush solvent cleaners into a drain or on the ground. • Containers of waste solvents must be labeled as hazardous waste and removed from the site in the time frame allowed by the facilities generators status.
Paint Stripping, Sand Blasting Media	• A representative sample of sand blasting material must be submitted for testing using the TCLP procedures for heavy metals, benzene, and volatile organic compounds (VOCs) • The waste is considered hazardous if any one of the parameters exceeds regulatory limits. Disposal must be through a permitted hazardous waste management company. • If none of the parameters exceed regulatory limits, then the material may be disposed of at a landfill.	• Do not use paints from any other source than those supplied by statewide contract, since they attempt to purchase paint as non-toxic as possible. • Test the sand blasting material and keep the results on file. Dispose of the waste as the test indicates (hazardous or non-hazardous) • If the sandblast material has been tested and determined to be non-hazardous, then it is not necessary to test it again provided the paint formulation does not change.
Parts Wash Solvent	• Materials in parts wash solvent (i.e. petroleum distillates, mineral spirits, and naphtha) are considered hazardous due to ignitability. • If the used product is recycled, it is not considered a hazardous waste. A manifest must still be processed.	• Keep the parts washer closed and non-circulating while in use. • If the waste is not recycled, it must be managed as hazardous waste. • Do not locate the units near sources of ignition. • Paper filters used in the units may be hazardous waste. Ask the vendor for appropriate disposal instructions.
Salt Pile Storage	• Salt is not considered a hazardous waste. Water runoff, however, may be toxic to aquatic life and vegetation. • Care should be taken to make sure salt piles are covered and the drainage cannot move off property if it contains high salt concentrations. • Damage from groundwater contamination can lead to Department liability if there is excessive salt runoff from an ODOT site.	• Contain and cover salt or salt/sand mixtures at all times. • Keep doors or covers on salt storage sheds closed during periods of non-use. • Do not over treat loads with liquid calcium.

Source: (Ohio Department of Transportation, n.d.)

MANAGEMENT PRACTICES FROM THE IOWA DOT WASTE MANAGEMENT MANUAL

Type of Product	Regulatory Review	Management Practice
Ballast and Capacitors	• Regulated by U.S. EPA as hazardous wastes • PCB ballast and capacitors generated from an Iowa DOT maintenance facility must be handled as Conditionally Exempt Small Quantity Generators (CESQG). Each light pole rest area, RME office, etc., will be handled as CESQG, unless located within the property lines of a maintenance facility. • CESQG's are not required to meet storage, manifesting or transporting requirements. Therefore PCB articles generated from the CESQG's site can be transported to a maintenance facility and stored there until a transporter is available. During storage at the maintenance facility, the PCB articles must be identified as generated from the CESQG location. These PCB articles will not be included as part of the maintenance facility's hazardous waste generation quantities.	• Determine whether waste ballast or capacitors contain PCBs. Ballast and capacitors should be considered PCB articles unless labeled or stamped "no PCB's" on casing. • Store spent PCB articles in barrels, and attach a hazardous waste label with date when first article was placed in it. • Number of articles must be entered in manifest and IDOT transport drivers will pick up PCB articles on regular route. PCB articles not generated from Maintenance garages must be packaged separately and tracked as to the location of origin. • Handle capacitors with care. Avoid puncturing of outer casing. Take care if storing ballast in same containers as capacitors to avoid puncturing and release of oil. If this occurs contact agency's waste coordinator for disposal instructions.
Biohazardous Wastes	• Iowa regulations specify five categories of infectious wastes: (a) contaminated sharps, (b) cultures and stocks of infectious agents (c) human blood and blood products (d) pathological waste (e) contaminated animal carcasses. • Iowa law requires all infectious wastes to be rendered non-infectious prior to landfill. Incineration and sterilization are recommended. • A SWA is required from DNR. • OSHA requirements include (a) develop an exposure control plan (b) use engineering and work practice controls to minimize employee exposure (c) use personal protection equipment (e) perform post-exposure evaluations and follow-up surveys (f) train employees (g) maintain records.	• Biohazardous wastes must be collected in red bags. • An Iowa DOT designated medical waste disposal contractor will pick up red bag wastes at each Maintenance residency collection point. • Employees responsible for handling biohazardous wastes need to be trained and provided with protective equipment.
Debris Piles	• The accumulation of road-side trash may present a health risk, attract rodents that may carry infectious disease, or create noxious odors if stored too long.	• Store collected debris in contained areas to protect from wind and rain. • Dispose at least monthly.
Emulsion Area	• Waste that can be recycled into production of new asphalt is exempt from hazardous waste regulations. • TCLP must be applied to a sample of any overflow (spilled) emulsion. If test determines waste as non-hazardous it may be disposed in a construction landfill • TCLP must be applied to a sample of any overflow (spilled) emulsion. If test determines waste as non-hazardous it may be disposed in a construction landfill. • A request for reuse of non-hazardous waste must be approved, case-by-case, by Iowa DNR.	• Hook up hose into fill tank. Place catch pan beneath coupling to prevent any leakage from reaching soil. • Tanks must be attended while filling. • When the tank is full, unhook couplings and empty contents of the fill hose into the catch pan. • Add contents of catch pan back to emulsion truck. • Collect spillage that builds up on tank and ground monthly. Reuse material when making patch and edge rut, or assess reuse and disposal options

MANAGEMENT PRACTICES FROM THE IOWA DOT WASTE MANAGEMENT MANUAL *(Continued)*

Type of Product	Regulatory Review	Management Practice
Fluorescent and high Intensity Discharge Bulbs	• U.S. EPA regulates these as hazardous wastes because they contain mercury. • Bulbs generated from a maintenance facility must be handled in accordance with CESQG requirements. • CESQG's in Iowa DOT are not required to meet storage, manifesting or transport requirements, but must ensure delivery to an approved waste facility or recycling facility. Therefore bulbs generated from the CESQG site can be transported to a maintenance facility and stored there until a transporter is available. While being stored, bulbs must be identified as generated from the CESQG location.	• Store spent fluorescent bulbs in boxes they were received. HID bulbs must be stored in a large enough box or barrel and ensure there is no breakage. If breakage occurs, pieces should be stored in a separate box or container. • Attach appropriate label. • IDOT transport drivers will pick up bulbs on appropriate route, and exact number of bulbs or containers must be recorded in manifest. • Bulbs not generated from maintenance garage property must be handled differently, and must be packaged separately and be tracked to identify the location of origin. Bulbs will be taken from CESQG sites to a maintenance facility and stored in the same area as bulbs from that facility, until shipped.
Street Sweepings	• Iowa DOT views street sweepings as solid waste • U.S. EPA requires a generator of solid wastes to demonstrate waste is non-hazardous, either through knowledge of the process that generates the waste or through testing (by applying TCLP to a sample)	• Each Iowa DOT garage should contact the Waste Management Coordinator to determine if direct landfill disposal is approved. • Each facility that generates street sweepings should have a documentation, either from sample test results or a letter from the Iowa DNR/landfill accepting the waste based on thorough knowledge. • Street sweeping operations should avoid areas of vehicle accidents, released chemicals, or abandoned or lost drums. • When the street sweeping trucks are emptied, immediately move the waste into an assigned area in the yard that provides shelter and sufficient room until landfill disposal is arranged. Disposal should occur at least once a month to prevent buildup of debris and excess dirt.
Waste Asphalt	• U.S. EPA does not exclude from hazardous waste regulations construction debris, including waste asphalt, broken asphalt and dried emulsion. Therefore, since this material meets the definition of a solid waste, a hazardous waste determination is necessary before the debris can be disposed. • Used asphalt that can be recycled into new asphalt is exempt from hazardous waste regulations • The Iowa DNR's Fisheries Bureau has determined that broken asphalt, waste asphalt, and dried emulsion is not acceptable for use as shoreline protection or other similar uses where the material would be in contact with surface water supplies. However the DNR does consider the material reusable as clean fill for road bases. • Material that cannot be recycled must be managed as a solid waste and disposed of through a sanitary landfill.	• The removal of old asphalt is a condition of most contract bid packages. Each garage that is overseeing an asphalt project should contact the Iowa DOT's Waste Management Coordinator to confirm that removal of the old asphalt is part of the awarded contract. • Collect waste asphalt generated from other than contracted bids and store on an impermeable, curbed and roofed area. Reuse the material when making patch and edge rut. Use the waste asphalt collected over a year within the next paving season. If the material is not being heated to be used as asphaltic or emulsion products, contact the Department's Waste Management Coordinator for confirmation of use or disposal options.

MANAGEMENT PRACTICES FROM THE IOWA DOT WASTE MANAGEMENT MANUAL *(Continued)*

Type of Product	Regulatory Review	Management Practice
Wood Posts, Arsenic-treated	• Discarded wood products treated with arsenic (i.e. sign posts, guard rails) are exempt from EPA hazardous waste regulations provided (1) the product was used for its intend use and (2) the only reason the product is considered a hazardous waste is due to arsenic content. Because of the preservation technique, options such as chipping for bedding or fertilizer as a fuel in a wood burning stove are unacceptable. • Arsenic treated wood posts leach arsenic if stored outside, uncovered on the ground. Soil contaminated with a hazardous substance becomes a regulated hazardous waste. Though the wood posts are exempt from hazardous waste regulation, contaminated soil is not.	• Store arsenic-treated wood posts off the ground and under a roof to prevent leaching from the wood posts and contaminating underlying soils. • Inspect the used wood posts for reuse. If the wood posts are not rotten, possible reuse options may exist at the garage for construction. Do NOT burn. If the garage does not have use for the wood posts, contact the IWRC waste exchange to find a market for resuse.
Wood Posts, Creosote-Treated	• The EPA requires that a generator of solid waste demonstrate that the waste is non-hazardous either as a result of thorough knowledge or testing. • Use the TCLP to test for creosol and chromium in a representative sample of the waste, if testing is required to characterize the waste.	• Garages shall store creosote-treated wood poles off the ground and under a cover to protect the wood posts from rain and snow which can cause rotting. • Inspect used wood posts for possible reuse. If the wood posts are not rotten, the Department may have a possible use for the wood. The IWRC can offer help in finding a market for the wood. • If disposal is required, the Department Waste management Coordinator shall be contacted to schedule sampling and determine if landfill disposal is acceptable. • If the creosote treated wood is hazardous, then arrange off-site disposal through the Department's designated management company • Non-hazardous treated wood that is degraded can be landfilled once a SWA is approved. The Department's Waste Management Coordinator must be contacted prior to disposal.

Source: (Iowa Department of Transportation, n.d.)

MN/DOT ROAD MAINTENANCE WASTE INFORMATION POSTER

Type of Waste	Pesticides Herbicides Rodenticides Insecticides	Pesticide, Herbicide Containers	Used Florescent and High-Intensity Discharge Lamps	Asphalt Emulsion and Cutbacks Solvent Based	Asphalt Emulsion Water Based	Asphalt Dissolving/ Cleaning Agents	Asphalt Release Agents	Treated Wood Creosote/CCA
Why/ When Hazardous	▪All are typically listed as hazardous wastes or are lethal.	▪Hazardous if not rinsed properly.	▪Contain mercury, lead and sometimes cadmium.	▪Cold asphalt is not a hazardous material, but it is an industrial solid waste. ▪Asphalt emulsions, cutbacks and heated asphalt are regulated hazardous substances.	▪Cold asphalt is not a hazardous material, but is an industrial solid waste. ▪Heated asphalt materials are regulated hazardous substances.	▪The solvents used to remove asphalt from equipment may be ignitable hazardous waste.	▪Most asphalt release agents do not contain hazardous materials. (Check MSDS)	Treated wood contains toxic chemicals and must be managed properly.
Hazard Reduction Method	▪Products should be stored in well ventilated indoor areas with fire resistant spill containment. ▪Where possible, all product should be used to avoid generation of listed hazardous wastes. ▪By law, product must be applied according to the instructions given on the label. ▪Use ALL product purchased.	▪Triple rinse containers. ▪Each rinse should use at least 10 percent of the container volume. ▪Use rinse water as make-up for next application of same material if appropriate.	▪Store so as to prevent breaking. ▪Recycle used lamps.	▪Ignitable liquid emulsions would be ignitable hazardous wastes if disposed, so use all materials rather than disposing of them. ▪Tanks used to store asphalt emulsions should be diked and padded to prevent leakage or spillage from entering storm sewers or streams.	▪Use ALL material purchased. ▪Tanks used to store asphalt emulsions should be diked and padded to prevent leakage or spillage from entering storm sewers or streams.	▪To reduce the amount of waste solvent discharged, the equipment should be cleaned in contained areas that trap the solvents.	▪Use only amount needed. ▪Do not spill. ▪Do NOT over apply.	▪Reuse existing supplies of treated wood. ▪Minimize stockpiles. ▪Use treated wood alternatives, such as plastic and fiberglass.
Method of Disposal	▪Dispose of as hazardous waste through a licensed disposal facility.	▪Storage containers may be disposed of as residual wastes if rinsed properly. ▪Rinse should be disposed of as per the instructions on the container. ▪Return containers to vendor.	▪Do not break or put in trash. ▪Store broken lamps in a sealed container. Label lamp storage areas or each lamp container as hazardous waste. ▪Follow Mn/DOT consolidation requirements. ▪Utilize a Mn/DOT approved lamp recycler.	▪If hazardous, label as hazardous waste for shipment to a licensed disposal or recycling facility.	▪Cold asphalt may be disposed of as industrial solid waste.	▪Do not place in septic system. ▪If the discharge flows to a treatment plant, the plant must determine if the contaminants are allowed. ▪Do not allow cleaning agent to contact the soil.	▪If used properly, a waste will not be generated.	▪Treated wood may be reused. ▪Used creosote wood may be chipped and burned for fuel by approved vendors. ▪Treated wood may be landfilled in an approved industrial landfill.

Source: (Minnesota Department of Transportation, n.d.).

MN/DOT VEHICLE MAINTENANCE WASTE MANAGEMENT POSTER

Type of Waste	Spent Solvents	Water-Based Non-Ignitable Part Washing Solutions	Part Washing Used Filters/ Skimmed Oil Solvent Based	Part Washing Used Filters/ Skimmed Oil Water Based	Used Oil	Fuel and Oil Filters	Lead Acid Batteries	Anti-freeze	Brake Washing Filters and Solutions	Waste Water From Truck Washing	Shop Rags	Sorbents Waste Trap, Floor, etc.
Why/When Hazardous	▪Hazardous due to ignitability and/or toxicity. ▪Chlorinated solvents (e.g., 1, 1,1-trichloren-thane) are usually hazard-ous due to toxicity. ▪Non-chlorinated solvents are usually hazardous due to ignitability. (e.g., toluene, acetone, xylene).	▪Part washing solutions that are non-hazardous before use, may be hazardous after being used due to the presence of heavy metals.	▪Hazardous if ignitable or contains Toxicity Characteristic Leaching Procedure (TCLP) metals such as chromium (Cr) or Lead (Pb). ▪Filters and skimmed oil from solvent parts washer must be evaluated to determine if hazardous (this includes high flash and 'citrus' based part washing solutions.	▪Part washing filters and skimmed oil are hazardous wastes unless recycled or burned for energy recovery.	▪Used oil is a hazardous waste unless it is recycled or burned for energy recovery. ▪Used oil is a hazardous waste if mixed with a "listed" waste. ▪Used oil is a hazardous waste if mixed with a characteristic hazardous waste that renders the entire mixture hazardous.	▪Used filters are hazardous waste unless they are recycled.	▪Hazardous due to lead and acid content. ▪Lead acid batteries are hazardous waste unless they are recycled.	▪May be hazard-ous due to the presence of heavy metals. ▪Waste must be tested, or it is assumed to be hazard-ous.	▪Must be specially handled due to the presence of asbestos unless there is proof that the brakes are asbestos free. ▪All brake washing waste must be treated as if it contains asbestos unless there is proof that the brakes being washed are asbestos free.	▪Waste water that flows to a storm sewer which empties out into surface waters is regulated by the MPCA.	▪Used oily shop rags may be classified as hazardous unless they are laundered or burned for energy recovery. ▪Shop rags contami-nated with solvents may be hazardous due to ignitability and/or toxicity.	▪Used oily sorbents may be classified as hazardous unless it is laundered or burned for energy recovery. ▪Sorbent material contami-nated with solvents may be hazardous due to ignitability and/or toxicity.

MN/DOT VEHICLE MAINTENANCE WASTE MANAGEMENT POSTER *(Continued)*

Type of Waste	Spent Solvents	Water-Based Non-Ignitable Part Washing Solutions	Part Washing Used Filters/ Skimmed Oil Solvent Based	Part Washing Used Filters/ Skimmed Oil Water Based	Used Oil	Fuel and Oil Filters	Lead Acid Batteries	Anti-freeze	Brake Washing Filters and Solutions	Waste Water From Truck Washing	Shop Rags	Sorbents Waste Trap, Floor, etc
Hazard Reduction Method	▪Use the minimum amount needed. ▪Use solvent as long as possible. ▪Recycle on-site with a solvent recovery unit if possible. ▪Change to water-based cleaner/ degreasers.	▪Use the minimum amount needed. ▪Recycle on-site with a recovery unit if possible. ▪Do not blend part washing solutions with used oil.	▪Replace solvent based parts washing solutions with water based part washing solutions.		▪Do not mix anything with used oil. ▪Use drip pans when possible. ▪Fix equipment that leaks oil.	▪Pierce dome and hot drain thoroughly for 24 hours or overnight into approved used oil container. ▪Place into properly labeled container with secure cover.	▪Store batteries upright to lessen chance of leakage. ▪Inspect battery storage areas weekly for leaks. ▪Batteries must be placed in acid resistant containers, indoors, on an impermeable surface away from drains.	▪Recycle if practical. ▪Do NOT add used anti-freeze to used oil.	▪Purchase brakes that do not contain asbestos.	▪National Pollutants Discharge Elimi-nation System (NPDES) required if waste flows to surface waters.	▪Use reusable rags instead of disposable rags. ▪Keep rags in a closed container away from potential fire hazards. ▪Use rags until no longer usable.	▪Minimize waste by using only as much absorbent as needed. ▪Keep in a closed container away from potential fire hazards.

MN/DOT VEHICLE MAINTENANCE WASTE MANAGEMENT POSTER *(Continued)*

Type of Waste	Spent Solvents	Water-Based Non-Ignitable Part Washing Solutions	Part Washing Used Filters/ Skimmed Oil Solvent Based	Part Washing Used Filters/ Skimmed Oil Water Based	Used Oil	Fuel and Oil Filters	Lead Acid Batteries	Anti-freeze	Brake Washing Filters and Solutions	Waste Water From Truck Washing	Shop Rags	Sorbent Waste Trap, Floor, e
Method of Disposal	▪Do not place in sewer or septic system. ▪Do not evaporate solvent from sludge. ▪Do not blend solvents with used oil. ▪If hazardous, label as hazardous waste for shipment to a licensed disposal or recycling facility.	▪Test degreaser. ▪Do not place in septic system. ▪Do not place in sewer without written permission from the waste water treatment facility. ▪If waste contains TCLP metals, label as hazardous waste for shipment to a licensed disposal or recycling facility.	▪Label as hazardous waste for shipment to a licensed disposal or recycling facility.	▪Filters from water based part cleaning solutions can be burned for energy recovery (may be added to used oily sorbent container). ▪Skimmed oil from water based part cleaning solutions can be recycled or burned for energy recovery.	▪Follow Mn/DOT consolidation requirements. ▪Do not place in trash. ▪Do not place in sewer or septic system. ▪Do not spread on roads, driveways or ground. ▪Recycle or burn for energy recovery.	▪Utilize Mn/DOT approved oil filter hauler for recycling.	▪Recycle through approved reclaimers or collectors. ▪Battery sellers are required by law to accept used batteries. ▪Records must be kept.	▪Do not place in septic system. ▪Do not place in sewer without written permis-sion from the waste water treatment facility. ▪Recycle through an approved Mn/DOT antifreeze recycling program. ▪Sludge/ solids should be disposed of as hazardous waste.	▪Liquids may not be placed in landfills. ▪Asbestos waste should be double bagged with six mil plastic and labeled. ▪This waste may be dis-posed of in a landfill with approval from landfill. Contact your Waste Manage-ment Coordina-tor for informa-tion.	▪If waste flows to sewage treatment plant, effluent must comply with local sanitary authority rules.	▪Used oily rags can be returned to a vendor for washing or burned for energy recovery by a Mn/DOT approved vendor. ▪Used shop rags contami-nated with hazardous material must be handled as hazardous waste unless evaluated and proven by testing to be non-hazardous.	▪Used oil sorbent c be return to a vend for washi or burne energy recovery Mn/DOT approve vendor. ▪Used sorbent contamin d with hazardou material must be handled hazardou waste un evaluate and prov by testin be non-hazardo

Source: (Minnesota Department of Transportation, n.d.)

MN/DOT GENERAL WASTES POSTER

Type of Waste	Sign Manufacturing Inks and Solvents	Striping/Message Truck Materials and Washes (Alkyd)	Stripping/Message Truck Materials and Wastes (Latex)	Waste Paint (wet) sludge	Dried Paint Waste Paint Brushes, Paint Chips, etc.	Spent Abrasive Sand, Coal Slag, etc.	Empty PAINT Containers, Drums, Cans, etc.	Aerosol Paint Cans
Why/When Hazardous	▪Inks are considered ignitable and/or toxic hazardous wastes. ▪Solvents used in sign shops may be classified as hazardous waste.	▪Paint may require testing. ▪Check with your Waste Management Coordinator to determine if product is hazardous. ▪Hazardous if ignitable or contains Toxicity Characteristic Leaching Procedure (TCLP) metals such as chromium (Cr) or lead (Pb).	▪Paint may require testing. ▪Check with you Waste Management Coordinator to determine if product is hazardous. ▪Hazardous if it contains lead (Pb), or chromium (Cr), or TCLP metals.	▪Hazardous if ignitable or contains Toxicity Characteristic Leaching Procedure (TCLP) metals such as chromium (Cr) or lead (Pb).	▪Hazardous if it contains lead (Pb), chromium (Cr), or other TCLP metals.	▪May be hazardous due to the presence of heavy metals.	▪Not hazardous if emptied properly (a drum is considered emptied properly when it contains less than one inch of material or when all of the pourable product has been removed; whichever is less). ▪If more than one inch of material is left in drum; evaluate material to determine if hazardous.	▪Partially full or unused cans are considered an ignitable, hazardous waste.
Hazard Reduction Method	▪Use all the ink if possible to reduce the amount of generator waste. ▪Use less hazardous inks where possible.	▪Let the solids settle, then pump solvent off the top for reuse. ▪Segregate solvents used to clean equipment by color. Use with the next batch of same color paint. ▪Recycle on-site with solvent recovery unit. ▪Replace solvent based paints with water based paints.	▪Use ALL paint purchased. ▪Use paints that do not contain toxic metals.	▪Use ALL the paint purchased. ▪Substitute paints that do not contain toxic metals. ▪Replace solvent-based paints with water-based paints. ▪Take solvent from cleaning spray guns or brush and pour it back into paint tanks.	▪Use ALL the paint purchased. ▪Use paints that do not contain toxic metals. ▪Replace solvent-based paints with water-based paints.	▪Use abrasive methods that minimize the amount of waste generated. ▪Test spent material to determine if hazardous; segregate hazardous materials from non-hazardous materials.	▪Use ALL paint purchased., ▪Use paints that do not contain toxic metals. ▪Replace solvent-based paints with water-based paints.	▪Use ALL paint purchased.
Method of Disposal	▪Liquid inks must be disposed of as hazardous waste.	▪Do not place in sewer or septic system. ▪Label as hazardous waste for shipment to a licensed disposal or recycling facility.	▪Do not place in septic systems. ▪Do not place in sewer without written permission from the waste water treatment facility. ▪If waste contains TCLP metals, label as hazardous waste for shipment to a licensed disposal or recycling facility.	▪Do not place in sewer or septic systems. ▪Do not evaporate solvent from sludge. ▪Do not dispose of in a landfill. ▪Label as hazardous waste for shipment to a licensed disposal or recycling facility.	▪If hazardous, label waste for shipment to a licensed disposal or recycling facility. ▪If waste paint does not contain TCLP metals, dried paint waste may be treated as solid waste.	▪If hazardous, label as hazardous waste for shipment to a licensed disposal or recycling facility. ▪If spent abrasive does not contain TCLP metals it may be treated as solid waste.	▪If more than one inch of material is left in drum and is determined to be hazardous; label as a hazardous waste for shipment to a licensed disposal or recycling facility. ▪If properly emptied, recycle as scrap metal.	▪If hazardous, label as hazardous waste for shipment to a licensed disposal or recycling facility. ▪Unused or defective aerosol spray paint cans should be returned to the vendor. ▪If properly emptied, aerosol paint cans may be treated as solid waste.

MN/DOT LEAD PAINT REMOVAL TECHNIQUES POSTER

Technique	Dry Blasting	Blasting with Water	Hand and Power Tools	Chemical Stripping
Description	Compressed air is used to blow abrasive (sand, coal slag, steel shot, dry ice, etc.) at high velocity against surface	Includes water at high pressure or abrasive mixed with water.	Hand held equipment with HEPA vacuum attachment	Paste applied, then scraped or washed off along with removed paint.
Advantages	Technology and equipment is readily available. Usually effective at removing paint and rust.	With abrasive, usually effective at removing paint and rust. Water helps control dust emissions and lead levels.	Vacuum attachment effectively controls dust and lead levels, if used properly.	No dust, very low lead levels.
Disadvantages	Large amount of dust and waste created, high lead concentrations, extensive containment requirements, costly controls, extensive preparation and cleanup.	Must capture water. Extensive preparation and cleanup.	Labor-intensive; low productivity. Vacuum must be powerful enough. Must maintain seal between tool and surface. Awkward to use.	Time-consuming; less efficient at low temperatures. Not effective on all paints. Will not remove rust.

Source: (Minnesota Department of Transportation, n.d.)