Evaluation of Remedial Measures
to
Control Non-Point Sources of Water Pollution
in
the Great Lakes Basin

International Reference Group on
Great Lakes Pollution
f rom
Land Use Activities

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Re: Evaluation of all Remedial Measures
to Control Non-Point Sources of Water
Pollution in the Great Lakes Basin
D.S.S. File: 02SS KE109-6-6151
Final Report

Dear Sir:

We take pleasure in submitting this final report in accordance with the terms of reference established for this study.

This assignment has brought together into one document a wide variety of alternative measures which can be implemented in an effort to reduce the contamination of surface water from non-point sources. Since new or modified remedial measures are continuing to be developed, the report has been bound in a 3-ring style binder in order that new pages can easily be added by copy holders.

We trust you will find the comments made during our technical review meetings and upon the draft final report incorporated to your satisfaction, and the report in general conformance to your expectations.

It has been a pleasure working with the PLUARG Sub-committee on this most interesting project.
Yours very truly,

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REFERENCES

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In the preparation of this document the members of the PLUARG Task A Technical Advisory Subcommittee provided valuable assistance and guidance. Mr. G. Bangay, Chairman of that Subcommittee acted as liaison between the subcommittee and the consultants. The other members of the Technical Advisory Subcommittee were as follows:

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ABBREVIATIONS

BOD or BOD_5	five day biochemical oxygen demand
cm	centimetre
COD	chemical oxygen demand
cu. m.	cubic metre
d	day
gm	gram
kg	kilogram
ha	hectare
hr	hour
1	litre
lin. m.	linear metre
m	metre
MLD	million litre per day
mm	millimetre
sec.	second
sq. m.	square metre
SS	suspended solids
TOC	total organic carbon
µgm/l	microgram per litre

ABSTRACT

Remedial and preventative measures for the control of non-point sources of water pollution are the subjects of this extensive state-of-the-art study. The control of sediments, nutrients, pesticides and chemicals from eleven different land use activities is discussed. A description, evaluation and cost estimate is presented for each of the approximately one hundred remedial and preventative techniques contained in the catalogue. References to over two hundred documents on the control of non-point sources of water pollution are listed. Analytical techniques used to evaluate the application of remedial measures are discussed.

1. INTRODUCTION

1.1 Purpose of the Catalogue

On April 15, 1972, the Governments of Canada and the United States signed the Great Lakes Water Quality Agreement. As an integral part of this Agreement, the International Joint Commission was asked to establish a Reference Group to study pollution in the Great Lakes system from agriculture, forestry and other land uses.

Subsequently, the eighteen-member "Pollution From Land Use Activities Reference Group" (PLUARG) was formed with an equal number of Canadian and United States members to answer the following three questions:

(1) Are the boundary waters of the Great Lakes System being polluted by land drainage (including ground and surface runoff and sediments) from agriculture, forestry, urban and industrial land development, recreational and park land development, utility and transportation systems and natural resources?

(2) If the answer to the foregoing questions is in the affirmative, to what extent, by what causes, and in what localities is the pollution taking place?

(3) If the Commission should find that pollution of the character just referred to taking place, what remedial measures would, in its judgement, be most practicable and what would be the probable cost thereof?

In order to provide an adequate response to this last question, the Reference Group proposed a series of studies to define all those remedial measures pertinent to the solution of the problem areas identified.

This study was undertaken to provide an evaluation of the structural/ non-structural remedial measures available to control non-point sources of water pollution in the Great Lakes Basin. For the purposes of this study, non-point water pollution was defined as including all sources of water pollution with the exception of discharges from industrial operations and municipal sewage treatment plants. The latter two categories were classified as point sources.

1.1 Purpose of the Catalogue (Cont'd)

Although the study was completed in Canada, it is expected that the findings will be utilized in both Canada and the United States.

The study was approached in two phases. In the first phase, the contractor inventoried and evaluated the remedial measures related to the control of sediments, nutrients, pesticides and chemicals associated with eleven land use categories. The evaluation included a description of the technique and a discussion of the frequency of use, source of design information, level of pollutant control achieved and the associated benefits and costs. This information is presented for each technique on a single catalogue page.

In order to avoid problems where a single remedial measure may be used to treat problems associated with a number of different land use activities, a system of cross references has been prepared in matrix form in Figure l. By referring to this matrix, the user can quickly identify the remedial measures available to control any of the four pollutants associated with each of the designated land use activities. A page number is also included to direct the user to the correct catalogue entry.

It should also be stressed that this catalogue represents a compendium of individual practices applicable to the treatment of specific problems. Real world situations may often require the application of several of these practices in combination in order to provide proper land treatment system.

Many of the individual practices found in this catalogue have been developed over a long period of time and are known to be effective when properly applied and maintained. When applied as a land treatment system, each practice in the system has a specific and complimentary relationship to the other practices. Often the total land treatment system is more effective in reducing a given problem than the sum of its component parts.

1.1 Purpose of the Catalogue (Cont'd)

The second study phase involved a review of those analytical techniques currently available to evaluate the application of individual remedial measures or combinations thereof in specific problem situations.

Information was collected from federal, provincial, state and local agencies, as well as universities, research institutes and private industry. Due to time and fiscal constraints, the contractor was unable to do independent field investigations or original analysis, therefore, most of the descriptions, efficiencies, advantages, and other disadvantages are from the statements of others contained in the literature.

2. THE NATURE OF THE POLLUTANTS

Four basic categories of contaminants have been identified by PLUARG as nonpoint source pollutants affecting the water quality of the Great Lakes. These are Sediments, Nutrients, Chemicals and Pesticides.

2.1 Sediments

Sediments are solid particles which are transported by water in suspension or as bed load. These solid particles are predominantly soil particles of various sizes but also include insoluble organic and inorganic compounds which have sufficiently small mass size to be detached from their place of origin and transported. Sediments are considered pollutants when they render water unfit for a particular use either by their presence in suspension or as deposits on the bottom. The detrimental effects of sediments may include obstruction of drainage channels and conduits, interference with navigable waterways and harbours, filling of reservoirs, deterioration of aquatic habitat due to turbidity and deposition, clogging of water filters, and concentration of pollutants in sewers which result in highly polluted discharges during the "first flush" of storm runoff events.

Associated with the physical aspect of the sediments, are the other pollutants which are contained within or tightly attached to the sediment particles. Most of the phosphorus in the soil, whether it comes from organic or inorganic sources, is absorbed onto the soil particles. Organic or humus nitrogen lost from soil into water is associated with sediment. Because of the tight binding characteristics of some pesticide residues to soil particles it is suggested that the general pollution of waters by pesticides occurs through the transport of soil particles to which the residues are attached. This phenomenon also holds true for a number of chemical pollutants as well. Thus control of many other pollutants in the chemical, nutrient and pesticide classification depends largely upon the control of sediment production and transport.

2.2 Nutrients

Eutrophication is regarded as one of the most important water quality problems for the Great Lakes. Phosphorus and nitrogen are considered to be the nutrients limiting the growth of algae in most lake waters. Control of these nutrients has been emphasized as the approach for controlling eutrophication. Various other nutrients essential to plant growth are contained in runoff from many land uses, but there has been little evidence to date that nutrients other than nitrogen and phosphorus limit algal growth in lake waters.

In natural systems, Phosphorous (P) occurs as the orthophosphate anion PO_4^{---}, which may exist in purely inorganic form ($H_2PO_4^-$ and HPO_4^{--}) or be incorporated into an organic species - organic P. Under certain circumstances inorganic phosphate may exist as a poly - or condensed phosphate. A secondary distinction is made between particulate and dissolved forms of P, the split conventionally being made at 0.45 micron particle size.

In soils and waters, N occurs as the nitrate ion (NO_3^-), the ammonium ion (NH_4^+) and in organic compounds (amino N, hetercyclic N etc.). Small amounts of nitrite (NO_2^-) may be present but the amount are usually small compared to other forms. All of these forms may occur in the dissolved and the particulate form, with the conventional distinction also being made at the 0.45 micron particle size.

2.3 Pesticides

Pesticides are widely used in the Great Lakes Basin today. Overall, more than half the harvested area for crop production has been treated with pesticides.

Most pesticides fall into three major categories: insecticides, herbicides and fungicides. Herbicides and insecticides account for most of the pesticides applied, with herbicides being the predominant type.

2.3 Pesticides (Cont'd)

Most pesticides are potential pollutants to the aquatic environments. The amount and nature of pesticides reaching the Great Lakes is primarily a function of the persistence of the compounds used, intensity and lengths of time pesticides have been applied and the applicable transport mechanisms. The use of organophosphate and carbamate insecticides has increased because of the need to replace the majority of the persistent organochlorine insecticides.

Residues of pesticides, or their metabolites, may find their way to the aquatic environments through the atmosphere, leaching to groundwater and via runoff. The major route of pesticides to the waterways is via erosion. Because of the tight binding characteristics of many pesticide residues to soil particles, it is suggested that, in general, pollution of waters by pesticides occurs through the transport of soil particles to which the residues are attached. Suspended plant material or leaching of crop residues are also pesticide transport mechanisms, but less dominant than the movement via soil erosion and sediment transport.

2.4 Chemicals

The class of pollutants designated "chemicals" refers to the remainder of the chemical substances not included in the nutrient or pesticide category, which enter the aquatic environment and can cause potential problems. Included in this category, but not limited to, are the following: Deicing salts, motor vehicle wastes, landfill leachates, brines, heavy metal compounds, liquid industrial wastes, polychlorinated bi-phenols and others released as stack emissions that settle on the land surface for washoff during storm events.

Chemical contaminants from the land surface are washed into nearby receiving waters with the surface runoff generated by precipitation. Several mechanisms operate to remove the pollutants from the surface. The impact of raindrops, the emulsifying action of the tires on roadways and sheet flow act to provide good mixing and a continuous replenishment of water to help dissolve soluble chemicals; while they also help dislodge particulates from the surface and carry them off as suspended material.

3. THE SOURCES OF THE POLLUTANTS

Pollutants of a nonpoint source nature are contributed to the environment by a host of natural processes but are most affected by man's activities. The Reference Group on Pollution from Land Use Activities has developed a grouping of activities into eleven land use categories, namely; Urban, Agricultural, Recreation, Forestry, Extraction, Transportation, Liquid Waste Disposal, Deep Well Disposal, Solid Waste Disposal, Lakeshore and Riverbank Erosion, and Shoreline Landfilling. It is to these categories of land use that the search for remedial measures for the control of nonpoint source water pollution has been addressed.

3.1 Urban

The urban land use is perhaps the most complex land use with regard to the sources and transport mechanisms of nonpoint source pollutants. Although all are interrelated to some degree, the pollutant sources can be described by four general groupings; urban wash off, combined sewer overflow, hydrologic modification, and seepage to groundwater.

Within the context of the urban land use there are innumerable contributors of contaminants which, in turn, are washed off the urban surfaces and into the aquatic environment. These contributors include particulate emissions from industry, automobile residues and emissions, litter, leaves and garden waste, animal excreta, pesticides, deicing compounds, dust, etc. These substances contain contaminants which are not normally naturally found in surface runoff, or in such significant quantities, as are introduced to the land surface by urban use.

The next group of urban nonpoint source pollution is from the overflow of combined sewers which not only discharges the contaminants listed above from washoff to the storm drains, but also introduces sanitary wastes directly to the watercourse with resultant nutrient, organic and bacterial significance.

3.1 Urban (Cont'd)

Perhaps the most visible effect of the urbanization of an area is the hydrologic modification. Increased areas of impervious surface tend to increase both the total volume of runoff and the flow velocities.

The resultant effect is the increased ability of the runoff to mobilize contaminants through solution, scour and suspension and to transport those contaminants to the receiving waters. The reduction of infiltration also reduces the portion of the contamination which is absorbed, filtered or otherwise attenuated by the soil. Construction activities in urban or urbanizing areas, can increase vulnerability to soil erosion unless control measures are taken. Significant quantities of sediments can be discharged from a denuded, unprotected construction site.

Seepage of nutrients, chemicals and pesticides, to the groundwater system and their resultant discharge to surface waters has also been identified as a significant source of urban nonpoint source pollution in some cases, particularly road salts and septic tank effluents.

3.2 Agriculture

Potential nonpoint agricultural sources of surface and groundwater pollution includes sediment from water and wind erosion, fertilizers, pesticides and plant residues and animal manures from cropland, grazing areas and animal confinement areas.

Erosion occurs as a natural geological process, but may be accelerated by man's activities. Soils are protected naturally by vegetation and vegetation residues. If moisture or fertility is too low, the land is more vulnerable to erosion. Tilling the soil, over grazing, crop harvesting, and burning of vegetation remove or bury portions of the organic material which protects soils from erosion and may expose more vulnerable, erodible conditions.

3.2 Agriculture (Cont'd)

Factors influencing nutrient losses are precipitation and excess irrigation, temperature, kind of soil, type of crop, nutrient mineralization, denitrification, fertilizer type, application method and rates, tillage practices and soil erosion rates.

Pesticides enter the aquatic environment by wind drift, runoff and erosion, and seepage to subsurface drains or groundwater. Factors influencing pesticide loss include precipitation, type and persistence of chemical, temperature, tillage practices and soil erosion rates, livestock types, housing types, etc.

Disposal of plant residues and animal manures on land is a potential source of nonpoint water pollution. Animal manure is particularly high in nutrient and organic content. Proper application to the land can provide benefits for crop production and assist in reducing surface runoff. Inadequate practices can lead to highly contaminated runoff.

3.3 Recreation

Recreational lands, recreational activities and recreation-associated activities within the Great Lakes Basin contribute a variety of pollutants to surface and groundwaters. Because of the diversity in the physical nature of recreational land, and the wide variety of recreational events and activities, the pollutant loads are difficult to classify. Inputs are sediment, plant nutrients, heavy metals, oil and grease, combustion engine emissions, pesticides, bacteria and viruses, nutrients from inadequate sanitary waste treatment etc.

Factors influencing the generation of these contaminants include intensity and density of activity, soil types and depths, groundwater depths, use and application rates of pesticides, precipitation, etc. Intense recreational development along the Great Lakes shorelines damages shoreline vegetation, increases runoff and erosion, and contributes nutrients along with sewage discharges.

3.4 Forestry (Silviculture)

Based upon the literature surveyed, it appears that forest lands contribute a relatively small portion of the total pollutants delivered to the Great Lakes. However, there may be local concentrations of these pollutants that result in the deterioration of the upland surface waters.

Accelerated release of pollutants to upland surface waters can result from such activities as timber harvesting, road construction, fires, woodland grazing, and insect and disease control. Pollutants generated from these activities include sediments, nutrients, herbicides, insecticides, organic matter and road deicing compounds and dust control chemicals.

Factors important in influencing the release of such pollutants include intensity of operations, harvesting techniques, road design, steepness of terrain, types, rates and application methods of pesticides, precipitation and reforestation practices, etc.

3.5 Extractive

This land use category includes such activities as pits and open cuts mainly for extraction of sand and gravel but also for clay and peat; quarries for the removal of bedrock as crushed stone; open-cut mines for extractions of iron ore and coal; underground mines for the extraction of metals, gypsum, and rock slate; well fields, where brines are pumped for their content of dissolved salts; and oil fields where brine is produced as an unwanted byproduct of oil withdrawal.

Pollutants from these activities include suspended solids or sediments, dissolved salts, acidic or basic leachates and other related chemicals.

Factors influencing the release of such pollutants include mining techniques, site drainage containment, hydrogeology, intensity of operations, rehabilitation measures, precipitation, etc.

3.6 Transportation

Land use activities related to transportation include highways and roads, railroads, airports, and pipeline and utility corridors. Runoff from the surfaces of these facilities during their construction, operation and maintenance carries many different pollutants to the aquatic environment.

Sediments from soils eroded during site clearing and construction along rights-of-way; pesticides; salts used as deicing chemicals; oils, heavy metals and other waste productions from vehicle emissions and highway operations; and roadside littering and spilled materials contribute to the types of pollutants from transportation.

Factors influencing the generation of such pollutants include intensity of use and maintenance activity, soil type, precipitation, pesticides used, climate, amounts of deicing compounds needed, etc.

3.7 Liquid Waste Disposal

Use of land for the disposal of liquid wastes includes such activities as the disposal of municipal sewage effluents and sludges, industrial liquid wastes, and runoff from livestock confinement areas. While industrial liquid wastes are seldom beneficial to the land, there are several benefits to be derived from the recycling of municipal sewage effluents and sludges and runoff from livestock confinement areas. Utilization of these latter two types of liquid wastes is usually because of its nutrient and soil conditioning value. Pollutants associated with these activities are nutrients, organic materials, heavy metals, chemicals, some sediments, and pathogenic bacteria and viruses.

Factors influencing the release of the above pollutants through either surface or subsurface drainage relate to soils and hydrogeology, application rates and methods, topography, cropping practices, precipitation, control of operations, and migration of pollutants through aerosol production and wind drift.

3.8 Deep Well Disposal

Large quantities of liquid waste have been injected underground into deep geologic formations of adequate porosity to accept foreign liquids. The use of deep wells recognizes the feasibility, and in most cases less expensive means, of disposing of highly toxic or noxious liquid waste products. In addition, these wastes are purported to be stored in a confined reservoir system that is far removed from topographic and climatic influences and in which vertical migration is limited.

Due to the strict regulatory control and the well developed state of the art, very few instances of pollution of surface waters or surficial groundwater zones have been identified. Where pollution migration has posed a problem it is normally related to a design failure, and remedial measures are limited to the cessation of further injection of wastes, and possibly the withdrawal of a portion of the previously injected waste.

3.9 Solid Waste Disposal (Landfills)

Contamination of surface water by solid waste disposal landfills will, by definition result from indirect processes. The transport mechanisms will be water or air. For water to act as a transport mechanism it must first become contaminated and then it must reach the receiving water body. The contamination processes may include: contamination by surface water flowing through or from landfills; contamination of water percolating through the landfill and subsequently infiltrating to the groundwater regime; groundwater flowing through landfills; and gases from landfills dissolving in groundwater. Air can act as a transport mechanism by carrying decomposition gases and particulate matter for dissolution or suspension in surface waters.

Pollutants from uncontrolled landfills can include nutrients, pesticide residues and a vast array of chemicals resulting from leaching or decomposition of the materials disposed of in the landfill. Gaseous constituents consist primarily of carbon dioxide, methane, hydrogen sulphide, hydrogen and nitrogen.

3.9 Solid Waste Disposal (Landfills) (Cont'd)

Factors affecting the movement of contaminants from landfills include hydrogeology, precipitation, construction of the landfill, contaminants migrating and attenuative capacity of the soils prior to surface discharge of the contaminated groundwater.

3.10 Lakeshore and Riverbank Erosion

The nonpoint source pollution associated with Lakeshore and Riverbank Erosion relates to the erosional activity as a result of wave action and flow velocities. The generation of sediments is the primary contaminant associated with these areas. Factors influencing the release of pollutants from shorelines and streambanks include soil types, wave action, flow velocities, steepness of banks, precipitation, vegetative cover, adjacent land uses, seepage and overland flow.

3.11 Shoreline Landfilling

Landfilling of the shoreline to extend the dryland areas, and the dredging of bottom deposits and their disposal, are the two activities associated with this land use category. Sediment is the dominant pollutant released to the aquatic environment by these activities, although some landfill materials and bottom deposits may contain other contaminants which could be significant.

Although open-water or adjacent-to-water disposal of fill or dredged materials is a well established procedure, the aggregate effect of this activity together with the waste disposal practices of lakeside communities is being viewed with concern that the benefits from expensive remedial measures to control some practices are not jeopardized by shortcomings in others. This is certainly the case in open-water dredged material disposal, where both nutrients and toxic substances may be redistributed to adversely affect some viable water uses.

Factors influencing the release of sediments and other contaminants during these activities include fill or spoil material characteristics, landfilling or dredging techniques, containment measures around filling operations or spoil disposal areas, precipitation, wave action and current velocities. etc.

4. GENERAL PHILOSOPHIES OF THE REMEDIAL MEASURES STUDY

4.1 Overview

Remedial measures for the control of nonpoint sources of water pollution range in sophistication from well defined structural methods, such as sedimentation ponds or treatment processes, to the intangible aspects such as the use of common sense or adherance to manufacturers' specifications for pesticide application. An attempt has been made to catalogue all those remedial measures, both structural and non-structural where there is sufficient tangible information on the measure to fully describe and evaluate it.

By no means is the importance of such intangible techniques as the use of common sense, the application of modern methods, the use of additional control, increased pre-construction study and design effort, etc., to be discounted. It is, perhaps, from these philosophies that the initiative to implement the more physical remedial measures will derive.

The need for education of the public or persons concerned is probably the first step in a remedial measures implementation program in order to inform those affected of the nature of the problems and the measures available for their control. However, each and every public education program design would be specific to the area involved and the target population and therefore, even though important, this type of program has not been catalogued as a remedial measure *per se.*

One area which the terms of reference of this study did not include was the consideration of the regulatory aspects of the control of nonpoint sources of water pollution. No speculation upon land use controls, planning agency involvement, creation of incentives or penalties, etc. has been included. It is understood that this is the subject of a parallel study by the Task A Committee of PLUARG.

4.1 Overview (Cont'd)

In addition to the structural and non-structural distinction between remedial measures is the aspect of source control versus treatment of pollutants already in the transport system. It is generally recognized that prevention measures to abate the generation of contaminants before they become mobile, is a preferable approach. Source control techniques themselves may not be adequate to achieve sufficiently the desired water quality criteria and hence treatment of the waste stream may sometimes be necessary in tandem with source controls. In some circumstances it may be more cost effective to concentrate the remedial efforts primarily on in-transit pollutants. Both types of control measures have been included in the catalogue section of this study.

4.2 Use of the Matrix and Catalogue Entries

This study has considered eleven categories of land use activities and four groups of pollutants. A matrix has been designed to act as an index and to correlate the remedial measures to the land use activities and pollutants to which its application serves benefit. The matrix was also organized so that a reader not having previous knowledge as to the name or nature of the remedial techniques might access the matrix, follow down the subject land use activity and have all applicable remedial measures for various pollutants identified.

The user would then select the titles of the remedial measures which address both the subject land use activity and pollutant the user is wanting to control and view the catalogue pages identified.

The catalogue page identifies the remedial measure, applicable land use and pollutants controlled by the measure, and gives a description of the design, configuration, practice or materials. The description also suggests efficiencies where applicable and suggestions for design considerations, in some cases. Advantages and disadvantages are listed and capital, operating and maintenance costs, or cost implications are identified where applicable. Costs (in U.S. dollars) have been indexed to June 1976 and can be related to an Engineering News Record (ENR) Construction Cost Index of 2533. Comment is also made with regard

4.2 Use of the Matrix and Catalogue Entries (Cont'd)

to previous experience in terms of recent applications, status of design criteria or whether the measure is in common use. The last, but definitely a significant entry on the catalogue page is a listing of sources in information. For a catalogue user interested in pursuing: further details of remedial measure, an extensive list of references is given in the latter section of this report with applicable references identified on the catalogue page.

The intent of the information contained on the catalogue page is to give the user a sufficiently detailed explanation of the remedial method, its use, cost, advantages, and disadvantages, such that the user can decide whether to pursue the techniques in a more rigorous manner prior to implementation.

5. ANALYTICAL EVALUATION TECHNIQUES

5.1 General

The solution of a non-point source water pollution problem, if viewed in a systems analysis approach, requires the methodical consideration of all aspects of the problem, all alternative methods of solving the problem, and the evaluation of alternatives to identify the most cost-effective solution or otherwise most appropriate course of action to follow. Extensive research in recent years has addressed the definition and quantification of non-point sources of water pollution. Several predictive techniques and procedures for analytically calibrating these predictive techniques have been developed and these techniques are sometimes compatible with use to evaluate proposed remedial measures.

This study has included a cataloging of technical remedial measures which form a large portion of the alternative methods available to solve non-point source water pollution problems. In this chapter of the study discussion is given on the existence, usefulness, and description of many of the currently available analytical techniques used to evaluate the application of specific remedial methods in a given problem situation.

The indirect nature of the way in which these analytical evaluation techniques are capable of considering the effects resulting from the use of various remedial measures is discussed in detail in latter sections. However, due to this indirect method of predicting resultant pollutant loads, most of these techniques are capable of being used equally well for evaluating the effects of land use planning and regulatory control decisions for a particular watershed. It should therefore be emphasized that although this following discussion on analytical evaluation techniques has been undertaken in conjunction with a cataloging of technical remedial measures, these techniques are equally applicable to the evaluation of the effect of non technical watershed management, land use planning, or regulatory control decisions.

5.2 Alternative Approaches

Two broad categories of methods are available for estimating non-point source pollution loadings to surface waters. The first is an indirect approach that utilizes measurements of water quality parameters in streams, rivers, and lakes and infers the importance of the pollution sources from these observations. The alternative direct approach focuses on the non-point sources and attempts to mathematically describe the transport of pollutants to the water body.

Indirect approaches are generally based upon the comparison of pollutant concentrations in streamflow from watersheds. The watersheds are characterized, for example as to land use, and then compared with the pollutant discharge. The result is a pollution loading factor indicating pollutant mass per unit area per unit time. By their very nature, these indirect methods must be based upon averaged data and often upon a site specific inference approach. However, they can be extended beyond the simple loading factors by the use of regression models which have watershed land use characteristics as independent variables, and in-stream water quality parameters as dependent variables, thus increasing the sensitivity and reliability of the model. In fact, these extended relationships form the basis of many of the sophisticated computer models in current use. The Universal Soil Loss Equation is an excellent example of a loading function that is utilized in many computer models for non-point source pollution analysis.

Unlike the indirect methods for non-point source pollution analysis simulation models are also available for estimating pollutant loadings and the effects that remedial or control measures have thereupon. Simulation models, as the name implies, attempt to mathematically and dynamically represent the physical, chemical and biologic processes which occur within the watershed as they relate to the generation, transport, and transformation of pollutants. It is desirable to have methods that mirror real processes and that have the capability of being calibrated, i.e. having parameters which can be adjusted

5.2 Alternative Approaches (Cont'd)

to more closely simulate measured data for a particular watershed. The Storm Water Management Model (SWMM) and the Hydrocomp Simulation Program (HSP) are examples of direct dynamic simulation models which can be calibrated to yield reliable results.

5.3 Evaluation of Specific Remedial Measures

Techniques for the prediction or evaluation of non-point source pollution are, in the main, just transgressing beyond the developmental stage into the age of application. With the exception of the Universal Soil Loss Equation, which has been in common use for many years, the evaluative techniques have only recently been fully tested and documented to the point where practitioners in the field of non-point source pollution, engineers and planners, are adopting the techniques for use in the prediction of pollutant loadings. Each of the evaluation techniques requires input data upon which the function or model makes its prediction.

Remedial or control measures influence the prediction made by the evaluation technique by varying one of the source characteristics, or by causing an effect on the transport processes. For example, since most techniques predict sediment washoff, which is influenced by such factors as precipitation energy, soil erodibility, topography, vegetative cover, etc. any remedial measure which modified one or more of these factors will cause a resultant change in the prediction of sediment yield. A difficulty arises, however, in that the magnitude of the modification of the characteristic, is not sufficiently researched or documented for direct use of many soil conservation and land management practices, most source control remedial measures are not well documented for pollutant control efficiencies. It is therefore necessary for most techniques to possess parameters which will vary within a finite range according to the combined influence of the local conditions and any superimposed remedial measure. The input characteristics are then adjusted according to the users judgement as to the relative influence of the remedial measure under consideration. For example, if the use of soil incorporation of sewage sludge is under

5.3 Evaluation of Specific Remedial Measures (Cont'd)

consideration, and the sediment contribution to the watercourse is under study, the user would vary the input to the simulation model to reflect the increased roughness of the soil, the increase to the water balance, the effect of the nutrient value of the sludge to vegetative cover, the soil conditioning effect on infiltration and vegetative cover etc.

The group of remedial measures which influence the pollutant transport processes have been quantified in their pollutant control efficiency more fully. This is primarily due to the fact that since water is the transport medium there are only a small number of physical processes which are involved, i.e. sedimentation, flocculation and precipitation, plus the chemical and biological reactions which take place in more controllable or well defined conditions. Remedial techniques such as sedimentation ponds, grit chambers, storage treatment lagoons, can have their sediment reduction influence evaluated either in isolation or by the use of a well developed equation such as Stokes Law for the settling velocity of particles in fluids. Such an equation or its results can be stored as part of a simulation model to identify the effect dynamically.

Some non-point sources are not amenable to evaluation by loading functions, for one or more reasons: (1) the source may be so irregular in occurrence that it can only be described by local personnel; (2) data on loads may be lacking; and (3) the source itself cannot be described in terms which can be translated into rates of pollutant emission. A list of sources and pollutants which fall in this latter category follows:

Roadside erosion
Gully erosion
Landslide, creep
Streambank erosion
Improper manure spreading or dumping
Bacteria from nonurban areas, except feedlots
Direct deposition of vegetation in surface waters; leaf fall, wind blown organic matter

5.3 Evaluation of Specific Remedial Measures (Cont'd)

Floodwater transport of floodplain debris
Floodwater scouring of floodplains
Salt leakage from oil fields
Drainage-borne pollutants: forests, wetlands, agricultural lands
Nutrients in irrigation return flow
Groundwater contamination with nitrates, metals, bacteria, pesticides
Direct deposition of fertilizers and pesticides in surface waters
Improper disposal of construction and demolition debris
Nonregulated, unauthorized dumping of domestic and industrial wastes

5.4 Discussion of Techniques

In the following pages, a number of evaluative techniques are discussed. Most of the techniques are solely prediction oriented, however some, like the Storm Water Management Model (SWMM) and the Storage Overflow at Treatment Model (STORM), have built in functions which simulate the operation of some remedial measures in the transport process. The accuracy of the predictions will be governed by the development of data to document the site specific efficiencies of the remedial measures. As the quality and quantity of this directly relatable data increase, so will the accuracy and usefulness of the analytical evaluation techniques.

The format in which the evaluation techniques are presented was developed to give the reader a general indication of what the techniques are; how sophisticated, sensitive and accurate it is; what the input requirements and cost implications are; and what stage of present use or past experience the technique experiences. The techniques vary from simplistic loading functions to sophisticated simulation models and it is impossible within the scope of this study to give more than an introduction to the technique. References are given which can be referred to for additional information.

5.4 Discussion of Techniques (Cont'd)

The evaluation techniques discussed are as follows:

5.4.1	AGRICULTURAL RUNOFF MANAGEMENT (ARM) MODEL
5.4.2	FEEDLOT RUNOFF MODEL
5.4.3	NON-POINT SOURCE POLLUTANT LOADING (NPS) MODEL
5.4.4	UNIVERSAL SOIL LOSS EQUATION
5.4.5	STORM WATER MANAGEMENT MODEL (SWMM)
5.4.6	STORAGE OVERFLOW AND TREATMENT MODEL (STORM)
5.4.7	HYDROCOMP SIMULATION PROGRAM (HSP) MODEL
5.4.8	LOADING FUNCTIONS
5.4.9	MULTI RESOURCE SYSTEM MODEL
5.4.10	PESTICIDE TRANSPORT AND RUNOFF MODEL
5.4.11	MISCELLANEOUS

5.4.1
TECHNIQUE: Agricultural Runoff Management (ARM) Model

DEVELOPED BY: Hydrocomp Inc., Palo Alto, California

PURPOSE/FUNCTION: To simulate runoff, snow accumulation, and snowmelt, soil loss, pesticide-soil interactions, and soil nutrient transformations on small agricultural watersheds (less than 500 hectares).

DESCRIPTION OF TECHNIQUE: The ARM Model simulates runoff, snowmelt, sediment, pesticides and nutrient contributions to stream channels from both surface and sub-surface sources. No channel routing procedures are included, thus the model is applicable to watersheds that are small enough that channel processes and transformations can be assumed negligible. Although the limiting area will vary with climatic, vegetative soil and topographic characteristics, watersheds greater than 250 to 500 hectares are approaching the upper limit of the applicability of the ARM Model. Channel routing processes will significantly affect the water quality resulting from larger watersheds.

The mathematical foundation of the hydrologic aspects of the ARM Model was originally derived from the Stanford Watershed Model and as further developed by Hydrocomp Inc. The hydrologic parameters utilized in this model are identical to those used in the Hydrocomp Simulation Program Model (HSP) and the Pesticide: Transport and Runoff Model (PTR). Both the ARM and PTR Models include capability to simulate the areal variation in agricultural chemical concentrations on the land surface.

SEDIMENT LOSS SIMULATION: The basis for sediment loss in the ARM Model was derived from work done by Moshe Negev at Stanford University. Although Negev simulated the entire spectrum of the erosion process, only sheet and rill erosion were included in the ARM Model since gully erosion was not significant on the small test watersheds used. The component processes of sheet and rill erosion pertain to (1) detachment of soil fines-silt and clay fractions, and (2) pick up and transport of soil fines by overland flow. These mechanisms are represented in the ARM Model by the following algorithms:

5.4.1 (Cont'd)

Soil Fines Detachment:

$$RER(t) = (1\text{-}Cover\ (T)\ ) * KRER * PR(t)^{JRER}$$

Soil Fines Transport:

$$SER(t) = KSER * SRER\ (t)\ OVQ(t)^{JSER}$$

$$ERSN(t) = SER(t) * F$$

Where
RER(t) = soil fines detached during time interval t, tonnes/ha.
COVER(t) = fraction of vegetal cover as a function of time, T, within the growing season
KRER = detachment coefficient for soil properties
PR(t) = precipitation during the time interval, MM
JRER = exponent for soil detachment
SER(t) = transport of fines by overland flow, tonnes/ha
JSER = exponent for fines transport by overland flow
KSER = coefficient of transport
SRER(t) = reservoir of soil fines at the beginning of the time interval t, tonnes/ha
OVQ(t) = overland flow occurringduring the time interval (t), MM
F = fraction of overland flow reaching the stream during the time interval, t
ERSN(t) = sediment loss to the stream during the time interval, t, tonnes/ ha

PESTICIDE ADSORPTION/DESORPTION SIMULATION: Once the hydrology and sediment production of a watershed has been simulated, the process of pesticide adsorption/ desorption is a major determinant of the amount of pesticide loss which will occur. This process established the division of available pesticide between the water and sediment phases, and thus specified the amount of pesticide transported in solution and on sediment. The algorithm employed to simulate this process is as follows:

$$X/M = K\ C^{(1/N)} + F/M$$

Where
X/M = pesticide adsorbed per unit soil, micrograms/grams
F/M = pesticide adsorbed in permanent fixed state per unit soil. F/M is less than or equal to FP/M when FP/M is the permanent fixed capacity of the soil in micrograms/gram for pesticide.
C = equilibrium pesticide concentration in solution
N = exponent
K = coefficient

5.4.1 (Cont'd)

NUTRIENT SIMULATION: In the ARM Model, as a first order approximation, all chemical and biological reactions are represesneted by first order kinetics. The rate of a first order reaction is proportional to the amount of the reactant; the proportionality factor is the rate constant. Modelling of adsorption-desorption chemical reactions produces a linear relationship between adsorbed and dissolved compounds at equilibrium. This representation is a simplification of the equilibrium relationships defined by more complex methods. Chemical and biological reactions are also corrected for temperature.

DATA REQUIREMENTS:

Impervious Area Fraction
Interception storage parameter
Soil moisture storage parameters
Index to actual evaporation
Ground water loss and percolation parameters
Infiltration characteristics
Interflow characteristics
Length of overland flow plane
Average overland flow slope
Mannings "n" for overland flow
Interflow and groundwater recession
Nutrient concentrations
Temperatures
Mineralization rates
Chemical reaction rates
Depth of soil incorporation
Fraction of land cover on a monthly basis
Time when soil is tilled
Fine deposits produced by tillage
Exponent of rainfall intensity
Coefficient of soil splash equation
Initial soil fines deposit
Pesticide application method
Time of pesticide application
Year of pesticide application
Maximum solubility of pesticide in water
Permanent fixed pesticides adsorption capacity of soil
Coefficient and exponents for Freundlich Equation
Depth of surface zone
Bulk density of soil
First order pesticide degradation rate

OUTPUT ACCURACY AND SENSITIVITY: The model was developed for and calibrated for the South Piedmont region of the United States. Use in the Great Lakes Region would require recalibration of the model. In general the results indicate that the most sensitive parameters are related to soil moisture and infiltration, land surface, sediment transport, pesticide-soil interactions and pesticide degradation.

5.4.1 (Cont'd)

COST IMPLICATIONS: Extensive data base required to allow real time simulation of runoff quantity and quality from agricultural lands. Detailed soils information and chemical analyses are required. Operation of computer model is only small amount ($20. to $50. per run) compared to the data gathering costs. Uncalibrated modelling to compare relative effects of agricultural and conservation processes appears feasible for reasonable cost.

PREVIOUS EXPERIENCE: Model testing for sediment pesticide loss has been performed on watersheds in the southern Piedmont and Great Lakes Regions.

APPLICABLE REMEDIAL MEASURES EVALUATED: 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 62

SOURCE OF INFORMATION: 158

5.4.2

TECHNIQUE: Feedlot Runoff Model

DEVELOPED BY: Kansas State University

PURPOSE/FUNCTION: To evaluate the performance of feedlotrunoff control facilities on a site specific basis by computer simulation.

DESCRIPTION OF TECHNIQUE: This is a continuous model with the capability of evaluating the impact of chronic wet weather events. The simulation consists of three components. The first component is a model to generate runoff from the feedlot surfaces. The second is a wastewater (runoff) storage facility model that accounts for pond level fluctuations in response to feedlot runoff inputs, evaporation and irrigation disposal outputs. The third is a soil moisture accounting model that enables the monitoring of conditions and the testing of alternatives in an irrigation disposal area. In synthesizing the model, emphasis was placed upon selection of physically meaningful parameters which attempt to minimize inputs required. The result is a model in which the constants and coefficients in any function could be selected from existing data for any geographic and climatic area.

DATA REQUIREMENTS:

Precipitation
Atmospheric conditions
SCS runoff curve number
Criteria for disposal
Storage facility geometry
Evapotranspiration rates
Vegetative cover
Soil types and depths
Maximum pumping rates

OUTPUT ACCURACY AND SENSITIVITY: not available

COST IMPLICATIONS: Model primarily utilizes existing data that is readily available and it can be utilized in any location with a minimum effort expended to obtain model soil and crop constants. The program is written in FORTRAN IV and requires a maximum core storage of 48k-bytes. Computer charges vary relative to the system used but the cost of a 25-year daily simulation should be about $6.00.

PREVIOUS EXPERIENCE: Model is calibrated and tested for Kansas conditions but is designed to be readily relocatable.

APPLICABLE REMEDIAL MEASURES: 58, 2

SOURCE OF INFORMATION: 44

5.4.3

<u>TECHNIQUE:</u> Non-Point Source Pollutant Loading (NPS) Model
<u>DEVELOPED BY:</u> Hydrocomp Inc., Palo Alto, California
<u>PURPOSE/FUNCTION:</u> The NPS Model is comprised of sub-programs to represent the hydrologic response of a watershed, including snow melt, and the processes of pollutant accumulation, generation and washoff from the land surface.

<u>DESCRIPTION OF TECHNIQUE:</u> The Non-point Source Pollutant Loading (NPS) Model is a continuous simulation model that represents the generation of non-point source pollutants from the land surface. The model continuously simulates hydrologic processes (surface and subsurface), snow accumulation and melt, sediment generation, pollutant accumulation, and pollutant transport for any selected period of record of input meteorologic data. The NPS Model is called a "pollutant loading" model because it estimated the total transport of pollutants from the land surface to a watercourse. It does not simulate channel processes that occur after the pollutants are in the stream. Thus, to simulate in-stream water quality in large watersheds, the NPS Model must be interfaced with a stream simulation model that evaluates the impact of channel processes. The model uses mathematical equations, or algorithms, that represent the physical processes important to non-point source pollution. Parameters within the equations allow the user to adjust the model to a specific watershed. Thus, the NPS Model should be calibrated whenever it is applied to a new watershed. Calibration is the process of adjusting parameter values until a good agreement between simulated and observed data is obtained. It allows the NPS Model to better represent the peculiar characteristics of the watershed being simulated. Fortunately, most of the NPS Model parameters are specified by physical watershed characteristics that do not require calibration. However, the importance of calibration should not be under estimated; it is a critical step in applying and using the NPS Model.

The NPS Model can simulate non-point pollution from a maximum of five different land uses in a single simulation run. The water quality constituents simulated include water temperature, dissolved oxygen (DO), sediment, and a maximum of five user-specified constituents. All are considered to be conservative due to the short resident time on the land surface that is characteristic of non-point pollution.

5.4.3 (Cont'd)

Pollutant accumulation and removal on both pervious and impervious areas is simulated separately for each land use. The model allows monthly variations in land cover, pollutant accumulation, and pollutant removal to provide the flexibility of simulating seasonally dependent non-point pollution problems, such as construction, winter street salting, leaf fall etc.

Output from the NPS Model is available in various forms. During storm events flow, water temperature, dissolved oxygen, pollutant concentration, and pollutant mass removal are printed for each 15-minute interval. Storm summaries are provided at the end of each event, and monthly, yearly summaries are printed. The yearly summaries include therein, maximum, minimum and standard deviation of each variable. To assist interfacing with other continuous models, the NPS Model includes the option to write the 15-minute output without summaries to a separate file (or output device) for later input to the stream model.

DATA REQUIREMENTS:

Interception storage parameter

Soil moisture storage parameters by zone

Soil distribution types and index

to actual evaporation precipitation

Potential evapotranspiration

Deep ground water recharge

Infiltration characteristics

Interflow characteristics

Fraction land cover of pervious surfaces on a monthly basis

Exponents of rainfall intensity Coefficient of soil splash equation

Overland flow coefficients and exponents in sediment washoff equation for pervious and impervious areas

Sediment accumulation and removal rates on a daily basis

OUTPUT ACCURACY AND SENSITIVITY: The model has been tested on 3 urban watersheds comprised of residential, commercial, industrial and open land. The results indicated good agreement between recorded and simulated hydrology and pollutant washoff. Highly soluble pollutants may demonstrate significant deviation from the simulated values. Since the NPS Model does not simulate channel processes, comparison of simulated and recorded values should be performed on watersheds greater than 250 to 500 hectares in order to avoid the effects of channel processes on the recorded flow and water quality.

5.4.3 (Cont'd)

COST IMPLICATIONS: The NPS Model is written in IBM Fortran IV and can be run on IBM 260, Univac 1108, CDC 6000 and Honeywell Series 32 computer systems. The computer core requirement ranges from 125K to 195K bytes. Manpower requirements to become familiar with system, collect and analyse data, prepare model input, evaluate parameters and coefficients and calibrate the model are in the order of 6 to 8 man weeks per year of simulation.

PREVIOUS EXPERIENCE: Model testing has been carried out in Durham, North Carolina; Madison, Wisconsin; and Seattle,Washington. This is a non proprietary model and is available from the U.S. Environmental Protection Agency.

APPLICABLE REMEDIAL MEASURES: All soil and water conservation techniques.
Does not have provisions for evaluation of on-stream treatment measures.

SOURCE OF INFORMATION: 255,256

5.4.4

TECHNIQUE: Universal Soil Loss Equation

DEVELOPED BY: Wischmeier and Smith

PURPOSE/FUNCTION: The Universal Soil Loss Equation predicts soil loss as a function of precipitation, soil characteristics, topography, cropping practices and erosion control practice. The model can be used for sediment prediction when reliable delivery ratios are applied to the gross potential soil loss.

DESCRIPTION OF TECHNIQUE: The Universal Soil Loss Equation is:

$$A = RKLSCP$$

where A = the computed annual soil loss per unit area, tons per acre

R = the rainfall factor, or the member of erosion index units in a normal years rain (the erosion index is a measure of the erosive force of specified rainfall)

K = the soil erodability factor

L = the slope length factor

S = the slope gradient factor

C = the cropping management factor

P = the erosion control practice factor

The storm soil loss from cultivated fields has been shown to be directly proportional to the produce of the total kinetic energy E of the storm and its maximum 30 minute intensity I. The sum of the computed storm EI values for a given time period is a numerical measure of the erodability of all the rainfall within that period. Thus the R factor is expressed as

$$R = EI / 100$$

where E is the storm energy in limits such as Kg - M/M^3 and I is the maximum 30 minute itensity. The EI factors have not been evaluated from actual rainfall data for the western regions of North America. Interim EI and R data have been developed by the U.S. Agricultural Research Station for use in only non-orographic rainfall areas where rainstorms of high energy and intensity are common.

5.4.4

DESCRIPTION OF TECHNIQUE (Cont'd)

The soil erodability factor K defines the inherent erodability of the soil. Standard K values were developed for most soil types by the U.S. Soil Conservation Service. Several factors influence the erodibility of cohesive soils including texture, soil structure, thickness and permeability, organic matter content and nature of clay materials. Wischmeier and coworkers, in 1971, developed a soil erodability nomograph for estimating the K factor if five soil parameters are known; percent silt, percent sand, organic matter content and structure and permeability.

The soil loss is affected by both length and degree of slope. For convenience, these two factors are usually combined into a single topographic factor LS. The soil loss ratio from any given slope conditions can be readily determined by a set of graphs developed by the U.S. Agricultural Research Station.

The C factor is a complex factor to evaluate because of the many different cropping and management combinations in a given area. This is further complicated by the variable distribution of rainfall-erosion potential during different periods of crop cover. Fertilizing, mulching, crop residues, crop sequence and other factors influence the rate of soil loss. The C factors have been developed for a number of cropping practices by the U.S. Soil Conservation Service.

The P factor for croplands depends on the cropping practices such as contour tillage, striperopping on the contour, and stabilized waterways. It also varies with the slope of the land.

The Universal Soil Loss Equation was developed primarily for predicting soil loss on cultivated lands so that adequate soil and water conservation practices could be identified and evaluated. Extensive research has been done to characterize all the parameters for most soil, crop and rainfall conditions in North America. While a number of erosion control, soil conservation practices have been characterized for use with this equation, more research is needed to qualify others. The user however, can often interpolate many practices and obtain reasonable answers.

5.4.4 (Cont'd)

DATA REQUIREMENTS:

Precipitation data	Length of slopes
Soil permeability	Degree of slope
Organic soils fraction	Cropping and management factors
Nature of clay minerals	Conservation practice factors
Percent silt	Percent sand

OUTPUT ACCURACY AND SENSITIVITY: Since the output is directly related to the magnitude of each of the parameters, each has the same potential sensitivity. However, the parameters of K, C and P gradient rates possess the widest range of values and have the most sensitivity with respect to output. Output accuracy is good for annual soil loss volumes and fair to good for single event soil losses.

COST IMPLICATIONS: Extensive research has been done to develop mathematical and graphical relationships of all the parameters. Since the data input is readily available this desk top analytical technique is very inexpensive to use.

PREVIOUS EXPERIENCE: The Universal Soil Loss Equation was developed from statistical analyses and associated data obtained in 40 years of research by the U.S. Agricultural Research Service. This technique is in wide use throughout North America and enables estimates of gross erosion rates for a wide range of rainfall, soil, slope, crop and management conditions, to be made.

APPLICABLE REMEDIAL MEASURES: 11, 12, 13, 14, 16, 17, 19, 21, 22, 23, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 54, 79

SOURCE OF INFORMATION: 69, 185, 93

5.4.5.

TECHNIQUE: Storm Water Management Model (SWMM)

DEVELOPED BY: Metcalf and Eddy Inc., University of Florida

PURPOSE/FUNCTION: A comprehensive mathematical model capable of representing urban stormwater runoff and combined sewer overflow phenomena, and the effect of correctional devices.

DESCRIPTION OF TECHNIQUE: The comprehensive Storm Water Management Model uses a high speed digital computer to simulate real storm events on the basis of rainfall (hyetograph) inputs and system (catchment, conveyance, storage/treatment, and receiving water) characterization to predict outcomes in the form of quantity and quality values.

The simulation technique - that is, the representation of the physical systems identifiable within the Model -- was designed to permit relatively easy interpretation and permit the location of remedial devices (such as a storage tank or relief lines) and/or denotes localized problems (such as flooding) at a great number of points in the physical system.

Since the program objectives are particularly directed toward complete time and spatial effects, as opposed to simple maxima (such as the rational formula approach) or only gross effects (such as total pounds of pollutant discharged in a given storm), it is essential to work with continuous curves (magnitude versus time), referred to as hydrographs and "pollutographs". The units selected for quality representation, pounds per minute, identify the mass releases in a single term. Concentrations are also printed out within the program for comparisons with measured data.

In the simplest terms the program is built up as follows:

1/ The input sources:

RUNOFF generates surface runoff based on arbitrary rainfall hyetographs, antecedent conditions, land use, and topography.

FILTH generates dry weather sanitary flow based on land use, population density, and other factors.

INFIL generates infiltration into the sewer system based on available groundwater and sewer condition.

5.4.5 (Cont'd)

2/ The central core:
TRANS carries and combines the inputs through the sewer system using a modified kinematic wave approach in accordance with Manning's equation and continuity; it assumes complete mixing at various inlet points.

3/ The correctional devices:
TSTRDT, TSTCST, STORAG, TREAT, and TRCOST modify hydrographs and polluto- graphs at selected points in the sewer system, accounting for retention time, treatment efficientcy, and other parameters; associated costs are computed also.

4/ The effect (receiving waters):
RECEIV routes hydrographs and pollutographs through the receiving waters, which may consist of a stream, river, lake estuary, or bay.

The quality constituents considered for simulation are the 5-day BOD, total suspended solids, total coliforms (represented as a conservative pollutant), and DO. These constituents were selected on the basis of available supporting data and importance in treatment effectiveness evaluation. In addition, the Runoff Block also models COD, settleable solids, total nitrogen, phosphate and grease. However, routing of these parameters through subsequent blocks usually involves special programming efforts. The contribution of suspended solids by urban erosion processes is also simulated by the program.

Program Blocks: The adopted programming arrangement consists of a main control and service block, the Executive Block, a service block (Combine), and four computational blocks: (1) Runoff Block, (2) Transport Block, (3) Storage Block, and (4) Receiving Water Block.

Executive Block: The Executive Block assigns logical units (disk/tape/drum), determines the block or sequence of blocks to be executed, and, on call, produces graphs of selected results on the line printer. Thus, four blocks are set up to carry through a major step in the quantity and quality computations. All access to the computational blocks and transfers between them must pass

5.4.5

Executive Block (Cont'd)

through the subroutine MAIN of the Executive Block. Transfers are accomplished on offline devices (disk/tape/drum) which may be saved for multiple trails or permanent record.

Combine Block-- This block allows the manipulation of data sets (files stored on offline devices) in order to aggregate results of previous runs for input into subsequent blocks. In this manner large, complex drainage systems may be partitioned for simulation in smaller segments.

Runoff Block-- The Runoff Block computes the stormwater runoff and its characteristics for a given storm for subcatchment and stores the results in the form of hydrographs and pollutographs at inlets to the main sewer system. A snow melt capability has recently been added to the SWMM Model by Canadian Researchers.

Transport Block-- The Transport Block sets up pre-storm conditions by computing dry weather flow infiltration and distributing them throughout the conveyance system. The block then performs its primary function of flow and quality routing, picking up the runoff results, and producing combined flow hydrographs and pollutographs for the total drainage basin and at selected intermediate points. Of course, the program may also be used strictly for stormwater routing, with neither dry weather flow or infiltration.

Storage Block-- The Storage Block uses the output of the Transport Block and modifies the flow and characteristics at a given point or points according to the predefined storage and treatment facilities provided. Costs associated with the construction and operation of the storage/treatment facilities are computed.

Receiving Water Block-- The Receiving Water Block accepts the output of the Transport or Runoff Blocks directly, or the modified output of the Storage Block, and computes the resulting hydrodynamics and concentration distributions in the receiving river, lake, estuary, or bay.

5.4.5 (Cont'd)

Total Simulation-- In principle, the capability exists to run all blocks together in a given computer execution, although from a practical and sometimes necessary viewpoint (due to computer core limitations), typical runs usually involve only one or two computional blocks together with the Executive Block. Using this approach avoids overlap and, moreover, allows for examination of intermediate results before continuing the computations. Further, it permits the use of intermediate results as start-up data in subsequent execution runs, thereby avoiding the waste of repeating the computations already performed.

DATA REQUIREMENT: The data requirements for SWMM are extensive. The drainage area and drainage system must be broken down into its smallest components and each physical parameter for the drainage area or flow system must be inputed. Procedures for lumping,i.e.simplifying of the system, are available. Precipitation hyetographs, treatment options, initial pollutant concentrations and decay rates are required.

OUTPUT ACCURACY AND SENSITIVITY: The SWMM Model is designed as a "Deterministic" model in that if all parameters are accurate, the physics of the processes are simulated sufficiently well to produce accurate results without calibration. This concept may fail in practice because the input data or the numerical methods may not be accurate enough for most real applications. While most input parameters have default values which the program uses if input data are absent, the program should not be used without the full understanding of the source and meaning of the default values. The runoff and hydraulic aspects of the model are well developed and will provide accurate output within reasonable limits. Difficulty is still being experienced in the accuracy of the absolute values of the quality parameters but the quality model is a useful tool to provide qualitative and relative information on water quality.

COST IMPLICATION: Cost per simulation for computer time varies between $15.00 and $50.00 per run, depending upon the size of the study area, and the computer facility used. The most costly aspect is the gathering, assembling and coding of the necessary input data.

5.4.5 (Cont'd)

PREVIOUS EXPERIENCE: The SWMM Model is readily available from U.S. and Canadian Government sources and through some computer time sharing companies. Extensive supporting research and documentation has been supported by both U.S. and Canadian Governments in recent years, and most large consulting engineering firms working in the field of municipal or water resources engineering, are using the SWMM Model.

APPLICABLE REMEDIAL MEASURES EVALUATED: 43, 44, 45, 46, 47, 48, 49, 50, 81, 91 and all under Universal Soil Loss Equation.

SOURCE OF INFORMATION: Storm Water Management Model User's Manual Version II. U.S. Environmental Protection Agency., 93, 169, 185, 186, 260, 261

5.4.6

TECHNIQUE: Storage, Overflow and Treatment Model (STORM)

DEVELOPED BY: U.S. Corps of Engineers and Water Resources Engineers Inc.

PURPOSE/FUNCTION: A model to provide continuous simulation of stormwater runoff and the effects of treatment devices upon the runoff quality.

DESCRIPTION OF TECHNIQUE: The STORM Model computes storm water runoff from a single catchment in hourly time steps based on the record of a single rain gauge. The rainfall depth in excess of the depression storage is transformed to direct runoff through the use of a specified runoff coefficient at each time step. Runoff from both pervious and impervious areas of the catchment is simulated. Snowmelt computations based upon the "degree-day" method may also be performed. The water balance between storms is determined via the recovery of depression storage based upon specified potential evapotranspiration rates.

The model performs no routing computations, and all direct runoff computed for each time step is assumed to drain from the catchment in that time step. Various combinations of storage and treatment capacities may be modelled and the effect of these on storm water overflows investigated. Quality computations may be performed in each time step, based upon the pollutant washoff from different land uses. Five common pollutants can be simulated. The quality computations are essentially the same as those performed in the SWM. Dry weather flow was not considered in the original version whereas it is in the recently released version. Between storms, the amounts of available surface pollutants are modified according to the number of dry days for accumulation and the number of street sweepings. Soil loss is estimated through the use of the Universal Soil Loss Equation.

5.4.6 (Cont'd)

INPUT REQUIREMENTS:

Precipitation	Sediment generation and wash off parameters
Atmospheric conditions	Sediment accumulations and removal parameters
Soil moisture	
Percolation to groundwater	Nutrient and chemical potency factors
Soil Characteristics	
Watershed characteristics	Initial conditions Snow melt parameters

OUTPUT ACCURACY AND SENSITIVITY: Storm has been tested against measured data and against the results of simulations by SWMM. This model was found to give reasonably good estimates of the overall magnitudes and frequencies of overflows. Close simulation of measured hydrographs can be achieved within the limitations of the 1 hour time steps used; however, the primary objective of the application of STORM is to provide long term simulation results. The State-of-the-art of quality modelling is such that emphasis should be placed on the overall pollutant discharge rather than on instantaneous concentration values. In this respect, STORM may be used to provide a useful summary of runoff quality over a long period.

COST IMPLICATIONS: Computer costs are about $10.00 to $20.00 per year of simulation. Although input data requirements for precipitation are extensive, the data requirements for the other watershed and drainage system parameters are less detailed than for SWMM.

PREVIOUS EXPERIENCE: The STORM Model is well documented, tested, is non- proprietary and is available from the U.S. Corp of Engineers, Hydrologic Engineering Centre, Davis, California.

APPLICABLE REMEDIAL MEASURES: All soil and water conservation techniques. Does not have provisions for evaluation of on-stream treatment measures.

SOURCE OF INFORMATION: 93

5.4.7

TECHNIQUE: Hydrocomp Simulation Program (HSP) Model

DEVELOPED BY: Hydrocomp Inc. Palo Alto, California

PURPOSE/FUNCTION: The HSP Model is a continuous simulation program for storm runoff with the capability of evaluating remedial techniques.

DESCRIPTION OF TECHNIQUE: The HSP Model, simulates runoff from a multi-subcatchment watershed using precipitation data from one or more gauges. Short time intervals are usually used, and runoff from both pervious and impervious areas is simulated. The runoff computations are more sophisticated than those used in most continuous simulation models. Infiltration, interception, evapotranspiration, and depression storage are computed and the model may be calibrated through adjustment of the coefficients for each of these processes.

Snow accumulation and melt are computed using the Corps of Engineers' energy equations. Dry weather flow is also computed and combined with the surface runoff.

Complete routing computations are performed for sewers and channel networks using the Kinematic Wave Theory, accounting for upstream and downstream controls. Diversion and storage structures may be modelled at specific points in the network. Quality computations are performed for surface runoff, dry weather flow and consistuent routing through the network. Up to 17 constituents may be modelled. The pollutant accumulation and water balance between storm events is also considered. The computer program is proprietory to Hydrocomp International Inc.

5.4.7 (Cont'd)

INPUT REQUIREMENTS:

Precipitation

Evapotranspiration

Atmospheric conditions Stream flow

Watershed parameters

Physical chemical, biological and recreation characteristics

Soil type, distribution and characteristics

Vegetal cover

Drainage network characteristics

All of the above must be provided on a daily basis.

OUTPUT ACCURACY AND SENSITIVITY: When calibrated, the HSP gives good long term simulation results. Quality prediction is particularily sensitive to the simulation of long flows. Extensive study is required to understand sensitivity of all parameters.

COST IMPLICATIONS: The computer program is proprietary to Hydrocomp International Inc. and requires extensive data collection and analysis time. Computer storage required is very large. The HSP is the largest and most sophisticated model in current use.

APPLICABLE REMEDIAL MEASURES: Functions for the evaluation of remedial measures are not included in the program. However, by indirect methods, many of the input parameters can be altered to reflect the effect of a modified land use on effluent quality and thereby evaluate the downstream effects of the remedial measures. Therefore the same remedial measures listed under SWMM could be evaluated with the HSP.

SOURCE OF INFORMATION: 263, 264

5.4.8

TECHNIQUE: Loading Functions

DEVELOPED BY: Various researchers

PURPOSE/FUNCTION: Relations and equations used to indirectly estimate non-point source pollution in runoff.

DESCRIPTION OF TECHNIQUE: A loading function is a mathematical expression which one uses to calculate the emission of a pollutant from a non-point source and the discharge of that pollutant into surface waterways. This indirect inference approach can be extended beyond simple loading factors by the use of regression models, which have watershed land use characteristics as dependent variables, and instream water quality parameters and independent variables. A load is defined as the quantity of pollutant discharged to surface waters from the source per unit of time: load = kilograms sediment per source per day, etc. The loading function is the expression or equation which permits calculation of the load.

It may perhaps be construed from the above discussion that loading functions are straight forward expressions, matched by precise, well documented data, and that calculations can be made by routine procedures with little indiscriminatory inputs of judgement by the user. This is seldom the case. A substantial portion of the presentations of these loading functions are devoted to procedural descriptions which would assist the user in using his or other local judgements on inputs, and to instructing the user on the limits of applicability of the functions.

The loading functions described in the literature cover the following sources and pollutants:

Sources	- Agriculture:	cropland, pasture, and rangeland, irrigated land, woodland and feedlots.
	- Silviculture:	growing stock, logging, road building
	- Construction:	urban development and highway construction
	- Mining:	surface mining and underground mines
	- Terrestrial disposal:	landfill and dumps

5.4.8 (Cont'd)

- Utility maintenance: highways and streets, and deicing
- Urban runoff
- Precipitation
- Background sources: native forests, prairie land, etc.

Pollutants:
- Nutrients: nitrogen and phosphorus
- Sediment
- Biodegradable organics
- Pesticides
- Salinity
- Radioactivity
- Mine drainage
- Metals
- Microorganisms

INPUT REQUIREMENTS: A variety and quantity of data are necessary for the productive use of the loading functions. Each loading function has its unique requirement for input data.

OUTPUT ACCURACY AND SENSITIVITY: Emphasis has been given to loading functions on estimating prcedures which are generally useful from the standpoint of the depth and quality and quantity of available data or information. For this reason the functions generally utilize simple and basic concepts, as opposed to theoretically oriented descriptions of physical, chemical, mechanical and biological processes. Indeed, where necessary and appropriate, estimates and the rule of thumb approach have been preferred to more rigid theoretical functions which suffer from the lack of their data.

Indirect approaches such as loading functions, may provide general indications of the relative magnitudes of non-point pollution discharges. Many are insensitive to local variations in soils and weather and, in many cases, alternative land management options. However, where data availability prevents the use of more rational prediction tools, such as simulation models, the loading functions can give valuable information, not otherwise available to the decision maker.

5.4.8 (Cont'd)

COST IMPLICATIONS: In general, input data is readily available and the computations are inexpensive to execute.

PREVIOUS EXPERIENCE: Usage varies from extensive, i.e. Universal Soil Loss Equation, to only research applicability i.e. equations for heavy metals and radioactive loadings.

SOURCE OF INFORMATION: 2, 28, 183, 255

5.4.9

TECHNIQUE: Multi-Resource System Model

DEVELOPED BY: B.B. Bare, J.A. Ryan, G.F. Schreuder, University of Washington
Sponsored by the National Science Foundation

PURPOSE/FUNCTION: A complete simulation model for examining the physical, economic and environmental consequences of alternative land-use decisions and manipulations of a forest ecosystem.

DESCRIPTION OF TECHNIQUE: The system model is composed of a series of sub- system models which include forest production processes, recreation supply processes, fish and wildlife supply processes and atmospheric and hydrologic processes. Manipulations of the ecosystem are assessed in relation to their utilizable goods and services. Since many of the manipulations generate non- point sources of pollution, a large portion of the program is directed at modelling these processes. The model is composed of a timber production section, a timber harvesting section, a hydrology section and a recreation section. The latter section is external to the complete model but still allows the estimation of environmental impacts.

INPUT REQUIREMENTS:

Monthly precipitation
Monthly atmospheric conditions
Topography
Timber harvesting practices
Equipment used
Fertilization practices
Timber management and harvesting costs

OUTPUT ACCURACY AND SENSITIVITY: Temporal resolution is an important decision when using the Multi-Resource Model for a forest ecosystem. Not only does temporal resolution affect model efficiency, it also significantly affects the estimation of the severity of environmental impacts associated with non- induced manipulations. A yearly resolution with aggregated monthly hydrologic values has been suggested. Spatial resolution is a second important modelling decision. Many site specific impacts are, in effect, masked out when aggregated over an entire watershed. Theoretically, this problem can be circumvented by considering the impact of decisions

5.4.9 (Cont'd)

on an acre by acre basis, however, this is very laborious for large forested areas. Output detail and manpower must be traded off to reach an acceptable level of detail.

COST IMPLICATIONS: Not available.

APPLICABLE REMEDIAL MEASURES: All soil and water conservation techniques that are utilized within the forest system, including various logging techniques, can be evaluated by proper adjustment of the input variables with this model.

PREVIOUS EXPERIENCE: Snohomish River Basin in western Washington.

SOURCE OF INFORMATION: 25

5.4.10

TECHNIQUE: Pesticide Transport and Runoff Model (PTR)

DEVELOPED BY: Hydrocomp Inc., Palo Alto, California

PURPOSE/FUNCTION: A mathematical model developed to describe quantitatively, pesticide runoff as a function of pesticide and soil properties, agricultural practices, watershed characteristics and climatic factors.

DESCRIPTION OF TECHNIQUE: The PTR Model is a dynamic single rainfall-event type model. Description of the physical state of the pesticide and its vertical distribution with respect to the soil surface is considered as a general requirement. The initial pesticide phase, spatial distribution and application techniques are then categorized and quantified. Precipitation characteristics and drainage basin topography are the major factors influencing the water balance and hence pesticide movement. A kinetic degradation sub- model is utilized to determine the decline in pesticide concentration with time between rainfall events with five chemical processes utilized to determine the overall rate of pesticide decay.

INPUT REQUIREMENTS:

Detailed precipitation data
Pesticide characteristics
Application technique
Spatial distribution
Soil characteristics and distribution
Vegetative cover and distribution
Chemical reaction rates
Plant uptake rates
Atmospheric conditions
Soil adsorptive capacity
Basin topography

OUTPUT ACCURACY AND SENSITIVITY: The PTR Model has demonstrated the capability of providing reasonable estimates of surface runoff and sediment loss from agricultural watersheds in the Southern Piedmont. The model

5.4.10 (Cont'd)

utilizes the major modes of transport of pesticides and other non-point source pollutants to water bodies. Consequently, further refinement of the pesticide functions (adsorption/desorption, volatilization, and degradation) will upgrade the capability of the model to predict the pesticide input to water bodies from surface washoff.

COST IMPLICATIONS: Detailed data input required, however, data is generally available from existing sources. Model calibration is required for areas other than the Southern Piedmont.

APPLICABLE REMEDIAL MEASURES: All soil and water conservation techniques will influence input parameters.

PREVIOUS EXPERIENCE: Model has been tested by USEPA and the developers. Application elsewhere was not available.

SOURCE OF INFORMATION: 34

5.4.11

<u>TECHNIQUE:</u> Miscellaneous

The following is a partial list of sediment prediction methods for which detailed review was not possible, but which may offer the reader further awareness to research should the techniques described herein prove insufficient to meet his needs.

Einstein Bedload Function
Colby Modified Einstein Function Toffaleti Total Load Method
Lacey's Silt Theory
Pemberton Modified Einstein Function Flaxman Statistical Analysis
Woolhiser's Deterministic Watershed Model
U.S. Agricultural Research Station's Upland Erosion Model
U.S. Agircultural Research Station's USDAHL-73 Watershed Model
U.S. Agricultural Research Station's "ACTMO" Chemical Transport Model
NEGEV's Watershed Model
STANFOR IV Watershed Model
Huff Hydrolic Transport Model
Royal Institute (Sweden) Hydrologic Model
Snyder's Parametric Hydrologic Model
Sediment Transport Computer Model (Kling & Olsen, Cornell University)

REMEDIAL MEASURES APPLICATION MATRIX

6

Remedial Measures Application Matrix

#	Remedial Techniques \ Land Use	Urban	Agriculture	Recreation	Forest	Extractive	Transportation	Liquid Waste Disposal	Deepwell Disposal	Solid Waste Disposal	Lakeshore & Riverbank Erosion	Shoreline Landfilling
1	Chemical Soil Stabilizers	S n	S n				S n				S	
2	Roof Top Ponding	s n										
3	Dutch Drain (Gravel filled ditches with option drainage pipe in base)	s n										
4	Porous Asphalt Paving	s c		S n			s c					
5	Precast Concrete Lattice Blocks and Bricks	s n c					s n c				S n	
6	Seepage Basin or Recharge Basin (Single Use)	s n c										
7	Recharge - Detention Storage Basins (Multi-Use)	s n c	s n									
8	Seepage Pits or Dry Wells	s n c										
9	Pits, Gravity Shafts, Trenches and Tile Fields	s n c										
10	Recharge of Excess Runoff by a Pressure Injection Well	s n c										
11	Conservation Construction Practices	S			S	S	S				S	
12	Temporary Mulching and Seeding of Stripped Areas	S			S	S	S					
13	Conservation Cultivation Practices on Steep Slopes	S	S		S		S					
14	Temporary Diversions on Steeply Sloping Sites & Temporary Chutes	S	S		S	S	S				S	
15	Temporary Check Dams on Small Swales and Watercourses	S	S			S	S				S	

Significantly Effective in
Reducing Magnitude of Pollutant
C - chemicals
N - nutrients
P - pesticides
S - sediments

Moderately Effective in
Reducing Magnitude of Pollutant
c - chemicals
n - nutrients
p - pesticides
s - sediments

Remedial Techniques \ Land Use		Urban	Agriculture	Recreation	Forest	Extractive	Transportation	Liquid Waste Disposal	Deepwell Disposal	Solid Waste Disposal	Lakeshore & Riverbank Erosion	Shoreline Landfilling
16	Seeded Areas Protected with Organic Mulch	S	S		S	S	S				S	
17	Seeding Areas protected by Netting or Matting	S			S	S	S				S	
18	Single Family Aerobic Treatment Systems	N c	N c	N c								
19	Contour Listing		S									
20	Disposal of Treated Sewage Effluent by Spray Irrigation	s N c	s N c	s N c				s N c	s N c			
21	Surface Water Diversion	S	S		S	S	S					
22	Terraces (Diversion Terraces)	S	S		S	S	S					
23	No-Tillage Cultivation (Slot Planting, Zero Tillage)		S									
24	Pesticide Application Methods	P	P	P	P		P					
25	Alternatives to Chemical Pesticides	P	P	P	P		P					
26	Slow Release Fertilizers		N c		N c							
27	Placement of Fertilizer		N c		N c							
28	Timing of Fertilizer Application		N c		N c							
29	Roughening of the Land Surface		S									
30	Promotion of Soil Clods or Aggregates		S									
31	Strip cropping		S		S	S						
32	Miscellaneous Tillage Alternatives		S									
33	Conservation Tillage		S									
34	Sod-Based Crop Rotation		S									
35	Winter Cover Crops		S									

Remedial Techniques	Land Use	Urban	Agriculture	Recreation	Forest	Extractive	Transportation	Liquid Waste Disposal	Deepwell Disposal	Solid Waste Disposal	Lakeshore & Riverbank Erosion	Shoreline Landfilling
36	Improved Soil Fertility		S									
37	Timing of Field Operations		S									
38	Contouring or Contour Cultivation		S									
39	Grassed Outlets	S	S				S				S	
40	Direct Dosing of Alum to a Septic Tank	N	N	N								
41	Swirl Concentrator for Runoff Treatment	S n	S n									
42	Retention Basins for the Treatment of Wet-Weather Sewage Flows	S n										
43	Stationary Screens	S n										
44	Horizontal Shaft Rotary Screen	S n										
45	Vertical Shaft Rotary Fine Screen	S n										
46	Treatment Lagoons *	s N	s N	s N								
47	Rotating Biological Contactors *	N	N	N								
48	Trickling Filters *	N	N	N								
49	Contact Stabilization	N		N								
50	Air Flotation	S n										
51	Physical-Chemical Systems	s N										
52	Reverse Osmosis of Mine Tailings Effluent					C						
53	Chemical Adsorption onto Clays in Experimental Environment		P		P							
54	Surface Water Diversion		S n c		S n c	S n c				S n c		
55	Reducing Ground or Mine Water Influx					n C				n C		

	Remedial Techniques \ Land Use	Urban	Agriculture	Recreation	Forest	Extractive	Transportation	Liquid Waste Disposal	Deepwell Disposal	Solid Waste Disposal	Lakeshore & Riverbank Erosion	Shoreline Landfilling
56	Underdrains for Mineral Stockpiles or Tailings					n C						
57	Evaporation Ponds					n c						
58	Street Cleaning	S n c					S n c					
59	Interception of Aquifers		n c	n c		n c				n c		
60	Neutralization of Mine Acid Waste					c						
61	Stream Neutralization					n c						
62	Improved Methods of Sludge Disposal on Land	n c	n c					n c				
63	Annual Storage and Land Application of Livestock Wastes		N									
64	Sewer Flushing	S n c										
65	Combined Sewer Overflow Regulators	S N c										
66	Overburden Segregation	S n				Sn	Sn					
67	Mineral Barriers or Low Wall Barriers					S n c						
68	Longwall Strip Mining					S n C						
69	Modified Block Cut or Pit Storage					S n c						
70	Head-of-Hollow-Fill					S n C						
71	Box Cut Mining					S n C						
72	Area Mining					S n C						
73	Auger Mining					s n C						
74	Reducing Surface Water Infiltration					n c				n c		
75	Road Planning & Design				S		S					

	Remedial Techniques \ Land Use	Urban	Agriculture	Recreation	Forest	Extractive	Transportation	Liquid Waste Disposal	Deepwell Disposal	Solid Waste Disposal	Lakeshore & Riverbank Erosion	Shoreline Landfilling
76	Blocking					C						
77	Check Dams	S	S				S				S	
78	Retaining Walls for Road Construction for Steeper Slopes				S		S					
79	Revegetation -Reforestation Cut Areas and Bare Slopes	S			S	S	S				S	
80	Vegetative Buffer Strips	S	S			S	S	S n				
81	Sediment Basin	S	S		S	S	S			S		
82	Rip Rap Bank Protection	S	S				S				S	S
83	Protection of Culvert Outlet, Chute Outlets, etc.	S	S				S				S	
84	Dolos (Offset asymmetric tetrapods)											S
85	Engineering Design & Management For Shoreline Landfilling											S n c
86	Revegetation of Mine Tailings: Stabilization					S						
87	Slope Lowering of Spoil and Tailings Stockpiles					S						
88	Package Sewage Treatment Plants (Multi-Family Use)	s N c	s N c	s N c								
89	Waste Exchange for Resource Recovery									C		
90	Head Gradient Control									s n C		
91	Biological Treatment									S N C		
92	Streambank Protection with Vegetation	S	S								S	
93	Grass Channels or Waterways	S n	S n				S n				S	
94	Permanent Diversions	S n	S n		S n		S n				S n	
95	Bank Protection By Jetties, Deflectors	S	S				S				S	S

Remedial Techniques \ Land Use		Urban	Agriculture	Recreation	Forest	Extractive	Transportation	Liquid Waste Disposal	Deepwell Disposal	Solid Waste Disposal	Lakeshore & Riverbank Erosion	Shoreline Landfilling
96	Reduction and Elimination of Highway Deicing Salts	C					C					
97	Septic Tank/Tile Bed Sewage Disposal	N	N	N								
98	Miscellaneous Methods to Reduce Storm Runoff	S n					S n					
99	Exclusion of Livestock From Watercourses		S n									
100	Land Smoothing		S									
101	Gabion Baskets	S	S								S	S
102	Miscellaneous Erosion Control Fabrics and Materials	S	S								S	S
103	Miscellaneous Individual Wastewater Treatment Systems	N	N	N								
104	Clivus Multrum	N	N	N								
105	Controlling Feedlot Runoff		N									
106	Landfill Liners									C		
107	Hydroseeding	S			S	S	S				S	
108	Catch Basin Cleaning	S n c					S n c					
109	Plant Materials For Bank and Slope Stabilization	S	S	S	S	S	S				S	S

CATALOGUE OF REMEDIAL MEASURES 7

Title Chemical Soil Stabilizers	1

Keywords Urban, Agriculture, Transportation, Sediments, Nutrients, Erosion.

Applicable Land Use		**Pollutant Controlled**
Urban Agriculture Transportation	Lakeshore and Riverbank Erosion	Sediments Nutrients

Description

Chemical soil stabilizers include a number of various chemicals which are used to in- crease the cohesion between soil particles. These include alkyd emulsion; a mixture of sodium polypectate; glycerin and ammonia; polyvinyl acetate copolymer emulsion; hypolymer synthetic resin; liquid asphalt; high strength rubber emulsion; etc.

The liquids are normally sprayed upon recently seeded areas or denuded soil to increase the cohesion of the surface soil in order to reduce erosion and evaporation losses and thereby help effect the development of a permanent vegetative cover. With the exception of liquid asphalt and rubber emulsion, these liquids are normally applied using standard hydroseeding equipment or coarse pressure spraying equipment. Duration of effectiveness ranges from a few weeks to a few months with very little long term effect in excess of six months; therefore it must be considered a temporary technique. Could be useful in stabilizing banks following alterations of channels, ditching or resloping or eroding banks to allow revegetation of the exposed bank slope. High degree of short term effectiveness.

Advantages	**Disadvantages**
- relatively easy and quick method for stabilization of disturbed areas - adaptable to most conditions and topographies - non-toxic to plant or aquatic life (to our knowledge)	- relatively costly for large area - may reduce infiltration to a limited degree
Capital Costs	**Operating and Maintenance Costs**
Costs estimated at $.30 to $1.20 per sq.m. for application.	

Previous Experience

Materials are widely available in the Great Lakes Basin and some types, such as liquid asphalt, are in very common use.

Source of Information 49, 38, 108, 110, 92, 106, 180, 106.

Title Roof Top Ponding	2
Keywords Urban, Sediments, Nutrients	

Applicable Land Use	**Pollutant Controlled**
Urban	Sediments Nutrients

Description

The purpose of roof top ponding is to lower the flood peaks by delaying runoff from roofs. The method is applicable where the increased load of impounded water on roofs does not significantly increase the building cost. Flat roofs are normally designed for the impoundment of 15 to 18 cm of water for other structural safety reasons. Runoff may be controlled in three ways. Firstly by a perforated strainer with limited capacity on the down pipe inlet. Provision must be made for an emergency overflow before water spills over the top of the roof parapet and designed to overflow before the maximum permissible load on the roof is reached. Secondly, gravel detention barriers on flat roofs have been found to be effective to slow the velocity of the water entering into the roof downpipe. Thirdly, on sloping roofs, it is possible to construct runoff checks which effectively increase time of concentration. However, as soon as such "findams" are full, the rate of runoff will be constant provided that the storm continues at the same intensity. These are of limited usefulness and often very undesirable.

Plugging of outlets would result in over spilling of parapets, however slow release drains are not significantly different in design than conventional roof top drain screens. Due to increased residence time of water on roof top, incidence of roof leakage may be aggravated.

Advantages	**Disadvantages**
- by retarding runoff at source it may be possible to reduce size of storm drainage facilities all over site thus allowing urban washoff to be more concentrated and more readily contained for treatment - reducing urban runoff peaks also significantly decreases erosion - increased cooling of building during summer due to evaporation of ponded water.	- retarding runoff on flat roofs will result in a greatly increased load, which in turn may result in increased cost of construction if not otherwise provided for in the building code - the storage capacity of "findams" on sloping roof is too small to effect hydrographed characteristics except for extremely short duration storms.
Capital Costs Inlet devices cost $60 to $100 each with gravel barriers in the $20 to $30 range.	**Operating and Maintenance Costs** Inlet structures must be periodically cleaned of debris.

Previous Experience

Roof top ponding rings and barriers in common use for flat top buildings. Denver, Colorado has done quantitative research. Southern Ontario experience is wide spread.

Source of Information 119, 120, 110, 207, 237, 92.

Title Dutch Drain (Gravel filled Ditches with optional Drainage Pipe in Base)	3

Keywords Urban, Sediments, Chemicals, Nutrients

Applicable Land Use	**Pollutant Controlled**
Urban	Sediments Chemicals Nutrients

Description

The purpose of dutch drains is to reduce the volume of storm runoff and to reduce flooding by increasing infiltration. The dutch drains intercept sheet runoff prior to concentration. This technique may be used on sites where permeability of soil is sufficient and where seasonably high water tables are not anticipated. These drains may be designed for either maximum flow or design storm depth and thus act as in- filtration basins with limited outflow or they may act as a retarding device as far as the reduction of flood peaks is concerned. The drain is basically a granular filled ditch covered by a grate or coarse brick covering with sufficient opening spaces to allow the collection and containment of the sheet runoff. The ditches must run perpendicular to the direction of the sheet flow. By intercepting the pollutant washoff, this technique can reduce pollutant contributions to water courses in almost direct proportion to the percentage of total runoff which they contain.

Advantages	**Disadvantages**
1) Reduces the total volume of runoff and reduces peaking effect of local floods, 2) Enhances groundwater supply. 3) Improves quality of vegetation on site. by increasing available water in ground. 4) Will result in a reduction of the size of storm drains required downslope of the facility,	Unless "at source" seepage facilities are either designed for large storms or incorporate some method of controlled runoff relief they may not effectively reduce flood peaks when one storm follows another. ie. before the ditches have fully infiltrated and capacity is fully returned. Dutch drains are subject to clogging due to sediments carried in the sheet runoff.
Capital Costs	**Operating and Maintenance Costs**
Cost is estimated at about $0.04 per 1. of stored water ie. about $18 per cm.m. of trench constructed.	Since these drains are subject to clogging from debris and sediment, consideration must be given to replacement or re-excavation periodically, in the order of every 5 to 10 years depending upon local conditions.

Previous Experience

The technique is applicable to the Great Lakes Basin and has been used to date primarily for small areas where storm drainage outlet capacity is limited.

Source of Information 92, 110.

Title Porous Asphalt Paving	4

Keywords Urban, Transportation, Recreation, Sediments, Chemicals

Applicable Land Use	**Pollutant Controlled**
Urban Transportation Recreation	Sediments Chemicals

Description

The purpose of porous paving is to increase infiltration and to reduce flood peaks. It may be used to reduce the need for separation of storm and sanitary sewers, especially in the case where the system is already overloaded. During very intense storms some runoff may still be generated and provisions must be made for overflow. There is a requirement certainly for free-draining sub-base and underlying soils unless lateral drainage is provided. Porous paving is an asphalt and aggregate mix such that voids are maintained through the mixture and water is allowed to infiltrate freely through the surface material into the sub-base. The surface of the porous pavement must be cleaned regularly and after each storm using a vacuum type road sweeper to keep sur- face porosity as great as possible.

Degree of pollution control efficiency is related to the resulting percentage reduction in peak flows and the percentage of roadway contaminant which are able to infiltrate directly into the subgrade and underlying soil. Absolute values for efficiency are dependent upon site characteristics and frequency of cleaning.

Advantages	**Disadvantages**
1) Reduces the total volume of runoff from paved area. 2) Can reduce peaking effect and enhance groundwater supply. 3) Porosity increases surface friction resistance. 4) Preservation of natural urban drainage patterns. 5) Savings in design costs.	1) Benefits or efficiency of filtering effect not yet clearly established. 2) Where runoff is severely polluted this pavement is not recommended. 3) Certain circumstances can lead to clogging and reduced permeability. 4) Higher construction costs where curbs necessary. 5) Susceptible to frost heaving.

Capital Costs	**Operating and Maintenance Costs**
The cost of a 5 cm. porous asphalt topping is estimated at \$6.60 per sq.m. as compared to \$4.00 per sq.m. for conventional asphalt. Porous asphalt also requires a heavier sub-base. There should, however, be savings in cost of curbing and storm water piping which can be less extensive. The higher cost of porous asphalt results from its rare use requiring special mixing plant operations.	- Effective life span not yet documented but less than 10 years is anticipated due to clogging. - Life span in areas susceptible to freezing is less than conventional asphalt due to problems with frequently saturated subgrade

Previous Experience

Usage has been limited to research facilities and the southern states. No significant installations in the Great Lakes Basin were described in the literature researched however the technique appears to be applicable to a degree, in the Basin.

Source of Information 110, 207, 221, 237, 92.

Title Precast Concrete Lattice Blocks and Bricks	5

Keywords Urban, Transportation, Recreation, Sediments, Nutrients, Erosion.

Applicable Land Use		**Pollutant Controlled**
Urban	Lakeshore and Riverbank	Sediments
Transportation	Erosion	Nutrients
Recreation		

Description

These are various types of precast paving slabs which provide a hard surface and yet are porous to varying degrees allowing greater infiltration than conventional paving systems. These materials may be used in a wider variety of ways than porous paving. Perforated slabs on a honeycomb base may be used to cover Dutch drains (Catalogue #3) between areas of impermeable paving (making a lattice of permeable paving throughout a parking area). Brick strips incorporating tree pits may also be used in similar ways. These precast heavings are tolerable where paving or wide spread gravelling is not desirable. It is possible to fill the voids of the lattice with free draining soil and to establish a vegetative cover thereby improving the aesthetics of some parking lots. Also used for lining of grass swales to provide protection from erosion and for grass ramps where underlined support is required.

Advantages

- in case of lattice blocks, grass can substantially cover site
- flexible and can withstand movement
- sections can be lifted to plant trees, place street signs, etc. or to maintain utility beneath
- tend to be used where coarse conventional pavement is not aesthetically suitable

Disadvantages

Most of these materials are not as useful as porous pavement for the following reasons:

1) expensive and difficult to lay
2) permeability not as good as asphalt
3) only perforated slabs on a honeycomb give a good walking surface

Capital Costs

The cost of precast lattice concrete blocks was estimated at $6.60 per sq.m. with an additional installation cost of $4.80 per sq.m equalling a total of $11.40 per installed sq. m.

Operating and Maintenance Costs

Minimal

Previous Experience

Several suppliers are available in Ontario and the northern states with many comparable products. This technique has gained popularity in recent years as an alternative to
asphalt and concrete paving.

Source of Information 92, 110.

Title Seepage Basin or Recharge Basin (Single Use)	6

Keywords Urban, Sediments, Nutrients, Chemicals.

Applicable Land Use	**Pollutant Controlled**
Urban	Sediments Nutrients Chemicals

Description

The purpose is to allow a large percentage of annual rainfall to recharge. Runoff is collected prior to being passed into the basin which is a structural tank capable of holding a predetermined amount of runoff for infiltration into the underlying soil or most probably an aquifer. Recharge basins are extensively used in urban areas of Long Island to recharge groundwater to important aquifers. Generally, provided soil is reasonably porous, a recharge basin can recharge large quantities of water in a very short time without the use of much land. The sizing of the basin depends upon desired retardation and attenuation of runoff peaks. A good understanding of hydrologic design criteria for the area is required. As all basins require sediment traps it is possible to provide an overflow system for the trap which would bypass a considerable quantity of runoff if the tank becomes full. A considerable amount of recharge can occur through the sidewall of the basin and it is preferable that these should be constructed of pervious material. Gabion baskets have been found as ideal sidewalls providing other structural requirements can be maintained. The base of the basin must be kept free of silt therefore extensive maintenance is required. Pollutant control efficiency is proportional to the degree of total contaminant of runoff that the facility provides, and the component of the runoff, ie. "first flush" that the basin receives.

Advantages

- because basins are deeper than seepage areas they operate under greater head and therefore are capable of recharging a greater volume of water per unit area in a given time
- seepage basins require less land area than are often used for other infiltration methods such as porous pavement, etc.

Disadvantages

- seepage basin is generally regarded as a single use facility managed intensively for recharge
- should be fenced and regularly maintained and are often unattractive if not properly landscaped
- seepage basins need constant maintenance to ensure porosity is not reduced
- possible safety hazards

Cost Implications

Costs are a function of volume required, depth available, infiltration capacity of underlying and lateral soils, size of required sediment trap, amount of sediment expected to enter and therefore degree of maintenance required, land costs, landscaping requirements, etc. Estimated capital costs are in the range of $10100 to $20.00 per cu.m. recharge capacity.

Previous Experience

This technique is widely applicable and has been used in various forms for many years.

Source of Information 19, 110, 119, 108, 134, 133, 92.

Title Recharge - Detention Storage Basins (Multi-Use)	7
Keywords Urban, Agriculture, Sediments, Nutrients, Chemicals	

Applicable Land Use	**Pollutant Controlled**
Urban Agriculture	Sediments Nutrients Chemicals

Description

Multi-use recharge basins are large downstream impoundment areas for the temporary storage and infiltration of storm runoff. Recharge basins can only be effectively used where infiltration characteristics are favourable. These facilities are often used as a detention storage facility primarily with recharge as a secondary benefit. Recharge basins are designed on the basis of the desired storm runoff volume to be contained and recharged and/or the degree of retardation of the flood peak. Sediment traps are required to minimize clogging of the basin bottom and extensive maintenance is needed both to maintain permeability and to clean debris to facilitate other open space uses of the basin. Proper design of the inlet to prevent scour of the basin floor is important and will reduce maintenance. The establishment of dense turf on the basin side slopes is recommended.

Advantages	**Disadvantages**
- when recharge basin has benefits in dis- posing storm water as well as recharging aquifer system it can be an economically attractive method of conserving ground & surface water resources - often recharge basins can be constructed in a borrow pit as part of a major construction project or previous borrow pit can be put to use as recharge basins	- method does not take advantage of filtering effect of the soil therefore is a risk of pollution where recharge water is of variable quality - basins extremely susceptible to clogging unless recharge water is fairly free of sediment & the basin is maintained frequently
Capital Costs	**Operating and Maintenance Costs**
Costs consist of volume of excavation required, amount of site preparation needed, landscaping requirements, outfall structure detail and soils encountered.	Sediments should be removed from the basin floor regularly. Light equipment should be used in removal operation. Growth of algae has been a problem where there is a continuous summer inflow from domestic watering.

Previous Experience

- design methodology and criteria well documented - many installations throughout North America

Source of Information 110, 146, 143, 108, 134, 122, 92.

Title Seepage Pits or Dry Wells	8
Keywords Urban, Sediments, Nutrients, Chemicals.	

Applicable Land Use	**Pollutant Controlled**
Urban	Sediments Nutrients Chemicals

Description

Seepage pits or dry wells are pits usually filled with gravel or rubble and are sometimes cased. Seepage pits collect runoff and store it until it percolates into the soil but unlike dutch drains seepage pits do not conduct water along the length when filled. They are constructed as a pit backfilled with gravel with an inlet preceded by a sediment trap to prevent clogging. The inlet to the sediment trap comes directly from roof downspouts. Overflow provision is made so that roof drainage will not be impeded. These pits may be used where permeability of soil is sufficient and where seasonally high water tables are not anticipated. Seepage pits are often designed to accommodate maximum design frequency storm of 24 hours in duration or they may be designed to allow for infiltration to attempt to maintain runoff at pre-development levels. Pollutant control efficiency is proportional to the degree of total runoff containment that the facility can accommodate.

Advantages	**Disadvantages**
- if properly designed, seepage pits may reduce local flood peaks - enhance groundwater supply - in some cases may eliminate the need for storm drains or reduce size of storm drains necessary	- unless very large (equivalent to at least 5 cm. of runoff from impermeable surfaces drained) it may not result in a reduction of flood peaks - seepage pits are liable to clogging by sediments unless it is a direct connection from roof downpipes
Capital Costs	**Operating and Maintenance Costs**
Costs will be similar to those associated with dutch drains in the order of $15.- $19 per cu.m. of pit or $30 to $40 per cu.m of water stored.	Due to clogging potential, provision must be made for periodic replacement or re- excavation.

Previous Experience

In common use, particularly in communities without storm sewers.

Sourced Information 110, 146, 143, 108, 134, 140, 92.

Title Pits, Gravity Shafts, Trenches and Tile Fields	9
Keywords Urban, Sediments, Nutrients, Chemicals.	

Applicable Land Use	**Pollutant Controlled**
Urban	Sediments Nutrients Chemicals

Description

The purpose of these techniques is to recharge storm drainage to shallow aquifers where surface conditions are favourable. These techniques can mostly be used only where the aquifer is within two metres of the surface (gravity shafts may be deeper), thus, these techniques are generally for use on natural aquifer recharge and bordering areas.

In most cases these measures are sufficiently cheap to replace when the infiltration rate becomes too low. However, where periodic maintenance is cheaper some modification may be necessary. For instance, reverse filters should be applied to the bottom wherein coarse gravel is placed at the bottom reducing to pea-gravel and medium sand in the upper 2-3 metres.

Advantages	**Disadvantages**
- inexpensive to construct, does not rely on costly maintenance programs - may often be abandoned and reconstructed - vertical side walls self cleaning and show promise where clogging is problem - use of small diameter shallow holes very encouraging - inexpensive to install and can be abandoned and rebored when clogged	- pits and trenches must penetrate well in- to aquifer - hafts and pits may be backfilled with granular material but may cause serious loss of head which in turn will reduce infiltration rate - with the exception of tile fields, all measures must be landscaped carefully to fit development - may be safety hazards
Capital Costs	**Operating and Maintenance Costs**
A seepage pit of minimum 50 cu.m. capacity costs in the order of $20.00 per cu.m. of storage. Capital costs are not available for other techniques as they are very site specific.	- replace filter material periodically due to clogging.

Previous Experience

Commonly used particularly in communities without storm sewers.

Source of Information 92, 110, 134, 140

Title Recharge of Excess Runoff by a Pressure Injection Well	10

Keywords Urban, Nutrients, Chemicals.

Applicable Land Use	**Pollutant Controlled**
Urban	Nutrients Chemicals

Description

The purpose of pressure injection wells is to recharge groundwater by injecting the water directly into the water bearing strata under pressure. This technique may be used in an area which overlies a water bearing formation and is at a reasonable depth. Water used for injection must be oi a quality compatible with existing groundwater, or better. The injection wells are the reverse of water supply wells in that the storm water, the river water or even sewage effluent is injected into the well under high pressure and out into the aquifer formation below. Care must be taken that the temperature and chemical contamination of the injected water does not render the aquifer unfit for nearby consumptive uses.

Advantages	**Disadvantages**
- the same wells may be used for injection (during water rich periods) as for withdrawal (during water scarce periods) as long as water quality of the injected water is suitable - the technique is applicable to areas which are not directly on the outcrop of an aquifer or in highly permeable soils	- expensive installation and must be very carefully monitored and maintained to avoid loss of efficiency - very vulnerable to pollution of ground- water - effectiveness depends on aquifer characteristics - very susceptible to clogging by sediments or bacterial or chemical deposits
Capital Costs	**Operating and Maintenance Costs**
Very high - dependent upon geology, depth of well pretreatment facilities, capacity, etc.	Major maintenance costs result from: - clogging from sediments - sealing of aquifer by pollutants which may react with the soil chemicals - clarification of recharged waters using poly-electrolitic polymers - about $13 per million litres

Previous Experience

Technique used in locations where groundwater augmentation is needed. No known locations in Great Lakes Basin.

Source of Information 140, 145, 92.

Title Conservation Construction Practices	11

Keywords Urban Construction, Transportation, Extractive, Forestry, Sediments.

Applicable Land Use	**Pollutant Controlled**
Urban Construction, Transportation, Extractive, Forestry, Lakeshore & Riverbank Erosion	Sediments

Description

The purpose of these measures is to reduce the generation of sediments by minimizing the areas stripped during construction and filtering or diverting runoff from large stripped areas. These techniques can be applied to all sites undergoing construction especially those where there are large areas stripped of vegetation at any one time. Minimization of stripped areas is accomplished by careful programming of the development and phasing of construction to ensure minimal area is disturbed prior to revegetation. Conservation of topsoil is achieved by stripping it from areas to be regraded or disturbed(ie. by the installation of services), and stockpiled in concise piles for respreading at a later date. By concentrating the topsoil piles into limited areas it is easier to control the sediment and runoff than if it were more widely disturbed. Straw bale filters are rows of straw bales which are stacked tightly together lengthwise perpendicular to the prevailing ground slope. Usually a double row of straw, for removal of sediment, is necessary, particularly when used on long slopes. Where their usefulness is finished, the straw may then be used for mulching of the area when it is to be finally seeded. May reduce bank erosion and instability during and following ditching operations. Sediment control efficiency may be very high for low intensity storms if techniques are applied intensively.

Advantages

1) A vegetative cover will minimize erosion, thus minimizing the area of bare ground at any one time during construction which reduces the erosion potential.
2) Minimizing erosion on site and limiting the amount of sediment being carried off by runoff may be cost effective by eliminating the need for regrading and downstream drainage claims.

Disadvantages

1) Economy of scale for earthmoving machines are such that all earthmoving done at one time.
2) Straw bale barriers or diversions may limit the maneuverability of equipment on the site.
3) May obstruct site operations and therefore require double handling.

Capital Costs

Minimization of stripped areas is a management technique which is not costed due to site specific requirements. Conservation of topsoil: estimated $1.25-$1.65 per cu. metre to strip and replace. Straw bales for filter construction: estimated cost $1.50- $2.00 per bale installed.

Operating and Maintenance Costs

Previous Experience

Technique is applicable throughout the Great Lakes Basin and is being widely used. Acceptance of the additional inconvenience is slowly being gained by contractors.

Source of Information 92, 38,107,108,110,133,180.

Title Temporary Mulching and Seeding of Stripped Areas	12
Keywords Urban, Transportation, Extractive, Forestry, Sediments.	

Applicable Land Use	**Pollutant Controlled**
Urban Transportation (Construction) Extractive Forestry	Sediments

Description

The purpose of this technique is to reduce the erosion on sites which remain bare up to 12 months. It is also useful for the stabilization of temporary stock piles of spoil or topsoil. All areas which would remain open for more than six months on steeply sloping or highly erodible sites should be mulched or seeded. Straw is the most commonly used mulch. It is spread at the rate of about 300 to 375 bales per ha and disked into the surface of the soil. Areas which are subject to continuous wear by construction traffic, should be treated in a similar way as construction roads receiving a dressing of crushed stone or incorporating diversion berms at regular intervals to intercept longitudinal runoff. Depending on the area of the country, temporary seedings with barley, wheat, rye, ryegrass, sudan grass, buckwheat, oats or bromegrass at rates ranging from 38 to 68 kg per ha can give rapid vegetative cover and a useful green fertilizer for incorporation into the soil during final grading. It is estimated that 50 to 75% of the sediment generated from the stripped area could be controlled by a good covering of seed and mulch. The thicker the application of mulch, the higher the initial reduction of sediment generation, however excessive thicknesses of mulch will impede seed germination and growth.

Advantages	**Disadvantages**
- is a relatively cheap form of erosion control but should only be used where final grading and seeding is not possible - vegetation will not only prevent erosion from occurring but will also trap sediment in runoff from other parts of site - temporary mulching and seeding offers rapid protection to open areas for both sheet erosion and wind erosion	- as a temporary cover crop it is sown on subsoil and in most cases growth is often poor unless heavy applications of fertilizer and lime are made while seeding - once seeded, areas cannot be used for heavy traffic without destroying the cover.

Cost Implications

Costs of seeding and mulching are in the order of $.25 to $.50 per sq.m. if used with a hydroseeder type device."It' is' in the order of $.12 per sq.m. if agricultural equipment can be used.

Previous Experience

This technique is widely used throughout the Great Lakes Basin.

Source of Information 191, 38, 102, 108, 110, 120, 128, 180, 106, 232, 92.

Title Conservation Cultivation Practices on Steep Slopes	13
Keywords Urban, Transportation, Agriculture Forestry, Sediments.	

Applicable Land Use	**Pollutant Controlled**
Urban Transportation Agriculture Forestry	Sediments

Description

These are techniques used during the construction period on areas which may be bare for periods too short to make use of temporary mulches or cover crops. Careful cultivation can in these cases, greatly reduce the volume of sediment generated on the area. This technique is based upon three general management practices.1) Direction of Cultivation: generally where it is not hazardous for the operator, cultivation should be along the contour leaving the surface as rough as possible for the purpose required. 2) Type of Cultivation: The base soils should never be left with a finer surface texture than is absolutely necessary thus if harrowing provides a sufficiently fine seed bed for germination but too rough for mowing it may be better to allow germination to take place on the rough seed bed and roll thoroughly after germination rather than creating a very fine erosion prone seed bed with a chain harrow. This technique also applies to areas susceptible to wind erosion. Deep chiseling or ripping as a cultivation technique can temporarily improve the water intake rate of the soil. 3) Zero Cultivation Technique or Minimum Cultivation Technique: where landforms are at excessive grades but it is desired to change the vegetation cover, cultivation may be quite unnecessary. Existing vegetation may be killed when growing strongly with the total contact herbicide. It is preferable to disk harrow at least once. This cuts existing vegetation into the soil where it acts as a mulch. Reseeding can then be carried out at the same time with the appropriate fertilization.

Advantages	**Disadvantages**
- careful attention to cultivation techniques will pay developer. - one of cheapest and simplest methods of erosion control on site with only slight erosion hazard and a worthwhile supplementary measure on more critical sites.	

Cost Implications

This technique cannot be readily incorporated as a development cost. It is generally used by field supervisors on a as-needed basis and as a management technique. No great additional construction costs are incurred since the measure makes use of existing equipment and personnel nor are maintenance costs involved as this is an interim measure.

Previous Experience

This technique is applicable throughout the Great Lakes Basin and should be widely practiced. However, due to short term nature of problem such prevention techniques are often overlooked in favour of some type of "in transport" technique, such as a sedimentation basis.

Source of Information 182, 110, 119, 102, 120, 137, 92.

Title Temporary Diversions on Steeply Sloping Sites & Temporary Chutes	14

Keywords Urban, Transportation, Agriculture, Sediments, Erosion, Extractive

Applicable Land Use	**Pollutant Controlled**
Lakeshore & Riverbank Urban Erosion Transportation (construction) Agriculture Forest, Extractive	Sediments

Description

Temporary diversions may be of several types:

1) Temporary diversion channel consisting of a channel and a ridge usually across sloping land to convey runoff laterally at a reduced velocity to a safe discharge point.
2) A diversion berm is a compacted earthfilled ridge which effectively creates a channel on its upslope side. This measure is often installed temporarily at the top of slopes where regrading and seeding is taking place.
3) An interceptor berm intercepts concentrated runoff and diverts it to a safe discharge point.

4) Temporary chutes are examples of safe discharge routes referred to for diversion channels. Temporary chutes are constructed of a wide range of materials including flexible irrigation tubing, asphalt lined swales, half sections of corrugated metal pipe, concrete sewer pipe, etc. Erosion protection at the base of the chute or an energy dissipator is normally required often via the use of rip rap or concrete outfall structures.

Advantages	**Disadvantages**
- prevents damage where final grading is completed and reduces siltation of partly completed storm drainage systems - minimizes damage caused by severe storms during the construction period - minimizes the amount of regrading necessitated by erosion during construction period	- these techniques are temporary and their removal will entail some costs - removal can cause additional disturbance and possible minor damage to permanent facilities - diversions can increase seepage and may cause slope instability.

Cost Implications

Temporary diversion berms, chutes, downpipes, etc. are very site-specific in their design and therefore costs are difficult to estimate. Since the diversion berms are minimal earthwork structures, costs in the order of $1.30 to $2.00 per lin.m. appear reasonable. Chutes, downpipes, etc. may range in costs from $9.00 to $65.00 per metre and upwards depending on the flow requirements and soil conditions. Chutes may be reused. Some maintenance is required to prevent the buildup of sediment at either the top or the bottom and to prevent localized scouring problems.

Previous Experience

A popular technique which is widely used throughout the Great Lakes Basin.

Source of Information 49, 38, 102, 108, 110, 120, 128, 137, 232, 92, 106.

Title Temporary Check Dams on Small Swales and Watercourses	15
Keywords Urban, Transportation, Erosion, Extractive, Agriculture, Sediments.	

Applicable Land Use		**Pollutant Controlled**
Urban	Agriculture	Sediments
Transportation (construction)		
Extractive	Lakeshore & Riverbank Erosion	

Description

The purpose of this technique is to prevent gully erosions occurring during the construction period either in temporary channels or in permanent channels which are un-vegetated and therefore susceptible to high sediment flow. This technique consists of constructing a barrier of relatively pervious material perpendicular to the flow in order to impede the runoff and create an upstream pool where sediments will settle out. Straw bales, straw bales supported by gravel filters, wire fence and straw bales or a combination of all three have successfully been used in small temporary applications. The width and height of the check must be sufficient that the expected flows will have sufficient cross-section areas to filter through without creating excessive upstream ponding or overtopping or circumventing of the check dam. Removal of upstream accumulated sediments and replacement of clogged straw bales is a necessary maintenance activity. Installations must be removed prior to final channel stabilization. Sediment control efficiencies may range upwards of 75% for low intensity storms. If maintenance is not frequent, a risk will exist that a high intensity storm will wash out a portion of the accumulated sediment.

Advantages	**Disadvantages**
- not only prevents gully erosion but also cause the precipitation of high proportion of the sediment load in the runoff. - in some cases, if carefully located and designed these checks can remain in a semi- permanent installation with minor re- grading, at least until final revegetation.	- because of temporary nature many measures are visibly unattractive - removal of the item may be a significant cost in some areas - suitable for limited drainage areas since failure could result in an increased slug of the accumulated sediments being washed downstream
Capital Costs	**Operating and Maintenance Costs**
Costs for these temporary facilities are site specific but for a typical 10 m. wide by 0.5 m. high check dam the costs are estimated in the range of $300 to $500.	Minimal

Previous Experience

This technique is gaining acceptance as efforts to control short term sediment production during construction are made.

Source of Information 42, 38, 87, 102, 108, 110, 120, 128, 137, 232, 92,106.

Title Seeded Areas Protected with Organic Mulch	16

Keywords Urban, Transportation, Extractive, Forestry, Agriculture, Sediments.

Applicable Land Use		**Pollutant Controlled**
Urban	Lakeshore & Riverbank	Sediments
Transportation	Erosion	
Extractive	Agriculture	
Forestry		

Description

The application of plant residues or other suitable organic material can reduce the impact of rainfall, chedc runoff, prevent onset of erosion and prevent compaction or crusting. It will also help conserve soil moisture thus stimulating growth of plant cover. It may be used in conjunction with other techniques and critical area planting. Organic mulches may require anchoring with netting or chemical binders.

1) Site Preparation: Grading if possible to allow use of conventional machinery in application of mulch and anchoring.This usually means a maximum slope of 3 horizontal to 1 vertical.Steeper slopes require hand work or hydroseeding.
2) Types of Mulch: These incude the following list; compost or straw manure; corn stocks shredded or chopped; hay or straw; peat moss; pine straw or needles; peanut hulls or cocoa beans; sawdust, green or composted; shredded sugarcane bagasse; tanbark; wood chips or shaVings; wood excelsior; wood fibre cellulose. Application rates vary from 1125 kg to 55 metric tons per ha depending on the desired effect whether it be for soil conditioning, surface protection or erosion resistance.Mulch anchoring includes peggingand twine, mulch netting, soil binder sprays and mechanical crushing and incorporation by harrowing, disking, etc.

Advantages	**Disadvantages**
- grass coverage developed at twice the rate in mulched areas vs unmulched - the moisture containing capacity of organic mulches, and particularly straw, was found to be superior to chemical mulches. - many commercially available products now on market.	- if seeding is not carried out at the same time as application of a thin layer of finely chopped mulch it must be done only after partial decomposition of the mulch material.This may involve a separate work cycle after up to a year - straw mulch, generally cheapest and most effective is potential fire hazard and may be subject to wind blow in some areas and may result in intro. of undesirable seeds

Capital Costs	**Operating and Maintenance Costs**
Seed, fertilizer, straw mulching and tack- ing can range from $265/ha to $1250/ha. Additional asphalt emulsion may increase the cost by $625 to $750/ha. Other mulches range in cost from $1.20 per sq.m. for corn stock to $1.50 per sq.m. for wood chips.	seeds

Previous Experience

A popular, widely used technique with high degree of effectiveness.

Source of Information 108, 38, 87, 102, 92, 106, 110, 120, 126, 137, 133, 10, 101, 221, 232.

Title Seeding Areas protected by Netting or Matting	17

Keywords Urban, Transportation, Extractive, Forestry, Sediments, Erosion.

Applicable Land Use	**Pollutant Controlled**
Urban Transportation Extractive Forestry Shoreline and Riverbank Erosion	Sediments

Description

The purpose of matting and netting is to stabilize the surface of the soil and to pre- vent erosion during establishment of vegetation. Most mattings do not have any soil moisture retaining benefits but there are a few exceptions. It is used almost exclusively on steep slopes and for the protection of swales and channels to be vegetated. Generally used where soil moisture conditions are good and where a mulch is unnecessary to retain moisture and yet where some soil stabilization is required. Used in swales where high velocity of runoff during the period of establishment of vegetation is likely to cause scouring. Materials include: jute; twisted paper mesh; fiberglass; finely woven plastics; excelsior; and woven metal wire.

For maintenance, the protected area should be regularly inspected. Any clods holding the matting off the ground should be tamped into the soil and matting should be stapled down in any depressions. Following severe storms the installation should be inspected for undercutting. After a year a top dressing of fertilizer will help improve coverage of vegetation and the degradation of the temporary matting. A high percentage of gully erosion could be controlled in this manner.

Advantages	**Disadvantages**
- less expensive than most other stabilization techniques - easily placed by unskilled labour - any seed mix can be used without necessity to consider the decomposition period of an organic mulch - not subject to wind blow as are organic mulches but must be well anchored to pre- vent slippage during rainstorms.	- lack of soil moisture retention benefits of netting and matting in comparison to organic mulches.

Cost Implications

Installation costs vary considerably due to the type of material used.
eg. Woven Metal $500/ha
Jute Matting $1000/ha
Periodic inspection and patching and replacement of undermined areas should be carried out.

Previous Experience

Technique's applicable throughout the Great Lakes Basin however use has been limited to critical area treatments.

Source of Information 49, 38, 87, 102, 108, 110, 120, 126, 92.

Title Single Family Aerobic Treatment Systems	18

Keywords Urban, Agriculture, Recreation, Nutrients, Chemicals.

Applicable Land Use	**Pollutant Controlled**
Urban Agriculture Recreation	Nutrients Chemicals

Description

Aeration tanks can be used in place of septic tanks for sewage decomposition using aerobic bacteria. This is accomplished by injecting air into the tank through a pipe with a small compressor timed to run for certain periods every day mixing air bubbles with the sewage. Some of the aeration equipment on the market can be installed directly into a septic tank thus converting it to an aerobic unit. It is, however, recommended that a 3 compartment tank be used. Solids are settled out in the first compartment, aeration takes place in the second compartment and the third compartment is a clarifier where the remaining solids are settled out and returned to the second compartment. Effluent is not normally discharged to surface water but to a tile field for soil absorption or to other land disposal facility. Treatment efficiencies are in the 85% to 95% range for BOD and suspended solids depending upon the loading of the system and the retention time within the aeration tank.

Advantages	**Disadvantages**
- higher quality effluent than septic tank - possible use of sites with shallow or impervious soil layer where tile field - disposal is limited - use of smaller land areas for disposal of effluent	- aerobic systems require more maintenance therefore they may be less reliable for private home owners. - higher costs than conventional septic tanks
Capital Costs	**Operating and Maintenance Costs**
Capital costs of typical single family aerobic treatment systems can be expected to range from $2000-$5000 including tile bed.	Annual service (by contract) $150 to $250 dependent on location Power (per year) $100 to $150

Previous Experience

Widespread use throughout the Great Lakes Basin. Used particularly in recreational districts where shallow soils require importation of tile bed filter median and where reduction of tile bed requirements becomes a major economic consideration.

Source of Information 140, 207, 237, 92.

Title Contour Listing	19

Key/Ponds Agriculture, Sediments

Applicable Land Use	**Pollutant Controlled**
Agriculture	Sediments

Description

The rows are planted in contour furrows which reduce the velocity of water movement down the slope. Row break over and crossing during crop establishment is much less likely than with standard contour. If the corn is cultivated for example, the furrows are gradually closed. An implement called a "lister" is used to keep the furrows open. The need for open furrows is less critical after the corn has developed a canopy cover. The practice is most effective during the crop establishment period which is the time when erosion hazards are the greatest.

Contour listing is a form of conservation cultivation but it was developed in the past to the extent that a specific implement was developed for that single purpose. Its limited use on long slopes and its incompatibility with highly mechanized large acreage farming operations has resulted in a decline in usage of the techniques. Sediment reduction for very low intensity storms is estimated in the 25% to 50% range. Technique is of little benefit for high intensity storms.

Advantages	**Disadvantages**
A type of contour furrow which is effective in reducing sediment discharges for low intensity storms.	Not effective on long slopes unless support- ed by terraces or run off diversions. May interfere with the use of large mechanized equipment. On poorly drained soils it may aggravate wetness problems.

Cost Implications

This practice may require an additional tillage operation. Additional costs should be recognized for additional tillage operations, equipment and possible inconvenience. The implement is now of limited availability.

Previous Experience

This is one of the early soil conservation techniques but it has received less attention in recent years in favour of other methods.

Source of Information 237, 137, 182, 207.

Title Disposal of Treated Sewage Effluent by Spray Irrigation	20

Keywords urban, Recreation, Agriculture, Nutrients, Chemicals, Sediments.

Applicable Land Use		**Pollutant Controlled**
Urban	Liquid Waste Disposal	Nutrients
Recreation	Solid Waste Disposal	Chemicals
Agriculture		Sediments

Description

Spray irrigation is used to renovate and dispose of treated sewage effluent by applying it to land utilizing the soil for infiltration and filtration and vegetation for its transpiration effect. Effluent may be used to irrigate open space, agriculture, crops, etc. Effluent should normally undergo a secondary treatment prior to application. Availability of land and public acceptability are two important factors in determining feasibility. The benefits of this system are important in providing irrigation water, increasing groundwater yield and by providing a relatively cheap tertiary treatment of effluent particularly for small isolated communities. Equipment used ranges from conventional spray irrigation, using portable aluminum piping systems to high pressure fixed water guns which cover areas up to 5 hectares per spray nozzle. This technique should not be used on slopes over 15% or on soils with a shallow water table or poor drainage. Consideration of wind drift of the aerosol created should be taken into account. The water must not be toxic to vegetation and must not contain excessive concentrations of sodium or heavy metals that will result in long term soil damage. Typically 2.5 cm per week can be irrigated during the growing season. Treated leachates, from sanitary landfills have been disposed of in this manner but close monitoring of toxicity and heavy metals build up is required.

Very high pollutant control efficiency if properly applied since there is zero effluent discharge.

Advantages

- inexpensive tertiary treatment where land costs are low
- upstream disposal may improve dry weather stream flow
- groundwater yields may be improved
- source of irrigation water and nutrients for crop and open space areas - results in a savings in use of artificial fertilizer
- avoids construction of costly outfalls to receiving waters

Disadvantages

- extensive parcels of land required - possible health hazard
- storage facilities for effluent required during winter period
- chemicals in effluent may cause toxicity problems
- may be problem with buildup of nutrients potential accumulation of nutrients

Cost Implications

Land acquisition including land for buffer zone and storage ponds, application and distribution equipment, underdrains (if used) etc. Most of the U.S. and Canada use land of low value much of which costs less than $2000 per hectare. This method may be considerably cheaper than conventional tertiary treatment if low cost land of suitable quality is available nearby, especially for small communities where construction of long outfalls to receiving waters is necessary. In estimating costs some value should be placed on benefits which may include increased crop yield, increased groundwater yield, improved stream flow. There has been little success in selling effluent for irrigation.$3000/typical single family unit or $0.85/litre/day design capacity.

Previous Experience

Many installations throughout Canada and the United States. Extensive research being carried out at University of Pennsylvania and University of Guelph. A 1973 report (91) documented 60 installations in Ontario.

Source of Information 114, 80, 78, 72, 81, 82, 137, 140, 138, 92.

Title Surface Water Diversion	21

Keywords Urban, Agriculture, Transportation, Extractive, Forest, Sediments.

Applicable Land Use	**Pollutant Controlled**
Urban Agriculture Transportation Extractive Forest	Sediments

Description

Diversion is the process of collecting and channeling the water before it reaches erodible material or slopes. Size and gradients of the ditches are designed to carry expected flows estimated by knowledge of historical storm intensities and drainage areas. Flume, culverts, rip rap and various forms of matting can be used in channels conveying water down steep slopes to prevent erosion. Dikes can be used in the same manner as ditches and are often used together when material excavated from a ditch is used to form a down slope dike.

Diversions are also used to prevent runoff from entering areas where it will become contaminated and the resultant volume of effluent becomes hard to handle. Prevention of runoff from entering livestock confinement areas, or into mine sites and tailings areas are frequent applications.

Advantages	**Disadvantages**
In most cases diversion is an economical form of erosion control. It is often less expensive than constructing settling ponds for the repair of erosion damage. Similarly, it is often more economical to handle and treat concentrated effluents than to work with high volume low strengths waste streams.	- utilizes a portion of the land area for a single purpose.

Capital Costs	**Operating and Maintenance Costs**
Diversion ditches cost from $1.30 to $3.90 per cubic metre. Dikes range from $0.45 to $0.85 per cubic metre.	- Periodic removal of accumulated sediments which may decrease hydraulic capacity of diversion and cause overtopping and failure.

Previous Experience

A widely used technique in many types of application.

Source of Information 22, 34, 61, 115, 119, 66, 179, 107, 108, 110, 137, 145, 180, 221, 237.

Title Terraces (Diversion Terraces)	22

Keywords Agriculture, Urban, Forest, Extractive, Transportation, Sediments.

Applicable Land Use	**Pollutant Controlled**
Agriculture Urban Forest Extractive Transportation	Sediments

Description

These techniques support contouring and agronomic practices by reducing effective slope length and runoff concentration thereby reducing erosion due to lower velocities. Soil moisture conserved by greater impedance and therefore an increase in infiltration. Terraces can be constructed in areas where the slope of the land can be increased in short areas and decreased over larger areas so that the steep areas are reduced or restricted to tolerable amounts and the intensive practices are carried out on the larger area on the terrace. Some large hillside agricultural scheme terraces may be tens of metres wide, where in some rugged parts of the 'world the terraces themselves may not achieve even 5 metres. This technique is generally considered impractical on land slopes over 10 - 12% because the steeper back slopes tend to negate the benefits of the terrace at higher slopes.

Advantages	**Disadvantages**
Reduction of effective slope length there- fore reduction of velocity and therefore reduction of erosion. Adaptable to most sloping land conditions.	May impede the use of large machinery.
Capital Costs	**Operating and Maintenance Costs**
Estimated at $120 to $250 per hectare. Higher capital costs if terraces are narrower and steeper.	

Previous Experience

This technique is used throughout the world.

Source of Information 240, 107, 108, 110, 120, 121, 128, 137, 181, 239, 237 , 233, 92

Title No-Tillage Cultivation (Shot Planting, Zero Tillage)	23
keywords Agriculture, Sediments.	

Applicable Land Use	**Pollutant Controlled**
Agriculture	Sediments

Description

No-tillage cultivation is a method of planting crops that involves no seed bed preparation other than opening of soil for the purpose of placing the seed at the intended depth. This usually involves opening a small slit or punching a hole into the soil. There is usually no cultivation during crop production. Chemical weed control is normally required. This practice is effective in dormant grass or small grains and in row crop residues. The technique minimizes spring sediment surges and provides year round erosion control. The technique, however, has had a tendency to reduce crop yields on the finer textured, poorly drained soils due to a slowing of the soil temperature increase caused by the mulch effect of the previous crop residue. A lack of adequate planting equipment which will produce good soil-seed contact has hindered the yields on some soils with this technique. Lack of tillage during application of fertilizer may result in high soluble phosphorous loadings during runoff events.

Reduction of sediment loss in the order of 90% has been measured on loam soil with 8% slope and in continuous corn, at the University of Guelph (86).

Advantages	**Disadvantages**
Crop residues remain undisturbed on soil surface. Greatly reduce soil erosion. Energy saving because of reduced man/machine/fuel requirements.	Delays soil warming and drying. Increased use of chemicals and pesticides. Under some conditions, decreased yields are experienced. Some climatic and soil restrictions. Increased loss of soluble phosphorus.
Capital Costs	**Operating and Maintenance Costs**
$7.20 per acre was estimated by one researcher (239) as the potential loss due to yield reduction on the fine textured soils. Costs would be less on more favourable soils. Can result in up to 16% increase in yield over conventional clean tillage on coarser textured soils.	Increased herbicide insecticide and fertilizer costs.

Previous Experience

Limited use in Canada and the United States. Research being conducted at University of Guelph.

Source Of Information 88, 137, 249, 181, 182, 239, 237.

Title Pesticide Application Methods	24

Keywords Agriculture, Urban, Recreation, Forestry, Transportation, Pesticides.

Applicable Land Use	**Pollutant Controlled**
Agriculture Urban Recreation Forestry Transportation	Pesticides

Description

The amount of pesticides entering lakes and streams is influenced by the methcbd of application, the solubility and volatility of pesticides.Pesticides incorporated into the soil rather than left on the surface of soil and plants are less subject to evaporation and to movement by runoff waters.Pesticides are applied in liquid forms as a spray or in a solid form as a dust or granule. Present methods of application are imperfect and some of the pesticide reaches non-target organisms by wind drift, and volatilization of the water carrying the pesticide. The pesticide material may enter open bodies of water directly or after fallout and wash out. Dusted and sprayed pesticides are subject to drift which is related to particle size, wind speed climatological inversion and height of pesticide emission.In certain circumstances such as application against foliage or treatment of the underside of leaves, drift is needed to provide complete coverage. Drifting can be reduced by spraying and dusting when wind and other conditions are most suitable.Research shows potential of techniques to produce particles of more uniform size and thus reduce the number of small particles apt to drift.Various emulsifiers and oils can be added to the spray to increase droplet size and reduce drift.Granular pesticides drift the least, however their value in certain above ground uses is limited because they do not provide as complete physical coverage as a spray or a dust.Estimated 50% to 75% reduction of pesticides in runoff if best practical application rates and methods practices were employed.

Advantages	**Disadvantages**
- controlled application should result in less wastage and more effective treatment - minimize pollution by drift and washoff	- slower operation

Cost Implications

- chemical costs should be lower
- application costs could increase to allow for special equipment or more careful application

Previous Experience

Most application methods are well documented and encouraged by the pesticide manufacturers. Good quality machinery is available with continuing improvements.

Source of Information 181, 137, 133, 150, 182, 203, 205, 253, 239, 237, 97, 34, 11, 273, 266.

Title Alternatives to Chemical Pesticides	25

Keywords Agriculture, Forestry, Transportation, Urban, Recreation, Pesticides

Applicable Land Use	**Pollutant Controlled**
Agriculture Forestry Transportation Urban Recreation	Pesticides

Description

Non-chemical methods of pest control can reduce the use of pesticides and thus their entering into the environment. However, for the foreseeable future there will be a continuing need for pesticides in combination with these methods. These non-chemical methods include the following:

1) Agricultural practices: These practices includechanges in methods of cultivating ie. the removal of crop debris which provides host sites to pests.

2) Biological control: A substantial number of devastating and extensive pest problems have been resolved by introducing or conserving natural pest enemies. This technique is still in the research stage and not fully reliable.

3) Insect sterilization: The use of sexual sterilants for the suppression of insect population.

4) Insect toxins and pathogens: A form of germ or virus warfare against pests using organisms which are highly specific to the target pest.Very few toxins or pathogens are yet licensed for use in any part of North America.

5) Insect attractants: Includes fluorescent light rings, sexual attractants, etc. which attract alien insects for destruction or sterilization, etc.

Advantages	**Disadvantages**
- decreased use of pesticides	- increased production costs, time and inconvenience - techniques still in developmental stage - less controllable and site specific techniques.

Cost Implications

- potential savings in pesticide costs.
- alternative costs not sufficiently identified.

Previous Experience

Only cultural practices, inséct attractants and insect sterilization are beyond the research stage.

Source of Information 181, 182, 137, 239, 266.

Title Slow Release Fertilizers	26
Keyword Agriculture, Forestry, Chemicals, Nutrients.	

Applicable Land Use	**Pollutant Controlled**
Agriculture Forestry	Chemicals Nutrients

Description

Slow release fertilizers may be used to minimize possible nitrogen losses on soils subject to leaching. Chemical inhibitors, that can be incorporated with nitrogen fertilizer have been developed to delay nitrification.Presently, the general use of these inhibitors in agriculture is restricted by the high costs. Nitrification is very slow at lower soil temperatures hence, anhydrous ammonia can have slow re- lease properties if the soil temperature is low.

A slow release nitrogen fertilizer is also a long release fertilizer and therefore this may not be the total answer to controlling nutrient pollution. If nutrients are not adequately used by a crop during a growing season high levels of nitrate may result in the soil during non crop months and nutrient pollution may result. These materials are most effective on pastures or with plants having a long growing season.

Advantages	**Disadvantages**
- reduction of fertilizer use - better utilization of fertilizers	- if excess nutrients are not entirely used up during the growing season, they will be available during a longer time for washoff.

Cost Implications

There is an increased cost in the fertilizer applied which would be partially offset by the increased efficiency of use.Two types of slow release nitrogen fertilizers are currently available. Urea formaldehyde and Sulfur-coated Urea. For comparable nitrogen availability the slow release fertilizers cost about $275 to $350 per tonne more than the conventional ammonium nitrate fertilizer.

Previous Experience

Slow release fertilizers are widely available and have been used in recent years.

Source of Information 182, 137, 149, 181, 190, 237, 239.

Title Placement of Fertilizer	27

Keywords Agriculture, Forestry, Chemicals, Nutrients.

Applicable Land Use	**Pollutant Controlled**
Agriculture Forestry	Chemicals Nutrients

Description

The method of application and placement of fertilizers in relation to root distribution and moisture is important in increasing the effectiveness of fertilizers. General methods for applying fertilizer include broadcasting and disking, plowing before planting and top-dressing after the crop has been established. Placement of phosphate fertilizer with respect to the plant root system is critical because of its limited movement. If the phosphorus is not utilized by the plant it is subject to erosion with soil particles. On soils of low or moderate fixing capacities broadcasting the fertilizer on the surface and plowing it under is one of the most economical methods of application but nutrients may be lost if the fertilizer is not plowed under. Fertilizer should be incorporated into the soil by such methods as disking or when seed drilling. Placement of fertilizer in bands under the surface is an efficient use of nutrients and minimizes losses by surface erosion. Top dressing of phosphate fertilizer is often the only method of fertilizing established pastures and some foliage crops.

Advantages	**Disadvantages**
- potential saving in fertilizer costs - better utilization of nutrients	- none

Cost Implications

The use of better application methods may require new or additional equipment. Application techniques are normally adaptable to the tillage practices in use. Increased yields and better fertilizer utilization are expected to more than offset any increased application costs.

Previous Experience

A widely used technique which is effective and well documented.

Source of Information 182, 137, 116, 149, 181, 190, 219, 230, 231, 254, 239, 237, 92, 245, 27,2.

Title Timing of Fertilizer Application	28

Keywords Agriculture, Forest, Nutrients, Chemicals.

Applicable Land Use	**Pollutant Controlled**
Agriculture Forest	Nutrients Chemicals

Description

The timing of application is much more important for nitrogen fertilizers that are easily leached than for phosphorus which is absorbed by soil particles. The leaching of nitrates below the root zone may be more prevalent on sandy soils during period of precipitation. During cooler periods of low evapotranspiration, unused nitrates move downward into the soil. These factors should be considered in timing fertilizer application to maximize the efficiency and utilization by crops and to minimize nutrient losses by erosion and leaching. In general, phosphate and potash fertilizer must be applied at seeding time or earlier for satisfactory results. Nitrogen may be applied in the fall or in the spring for fall sown grain crops. For row crops, a portion of the nitrogen may be applied at planting time, and additional amounts may be side-dressed. The best time should be determined on the basis of soil, climatic conditions, and the crop being grown. In areas of high winter precipitation where leaching or denitrification losses may occur, spring application is usually best. Nitrogen fertilizers should never be broadcast on frozen land.

Advantages	**Disadvantages**
- potential savings of fertilizer costs due to better utilization	- timing of optimum fertilizer application may coincide with highest frequency of runoff events

Cost Implications

- potential savings

Previous Experience

- common "good farming" practice

Source of Information 182, 33, 100, 137, 116, 181, 239, 237.

Title Roughening of the Land Surface	29

Keywords Agriculture, Sediments.

Applicable Land Use	**Pollutant Controlled**
Agriculture	

Description

The most effective roughening depth for combating wind erosion for soil is 5 to 13 cm. The minimum stubble-mulch tillage leaves the soil in a rougher condition than conventional tillage. Special planters such as deep-furrow or hoe drills produce a roughness in the 5 to 13 cm. range and are especially effective in providing wind resistant surfaces. Emergency tillage in which land is roughened with chisels or listers is used as a last resort when vegetative cover is not adequate to provide control. This technique can be used for both fall and spring tillage operations depending upon the occurrence of wind erosive conditions. Chisel and disk ploughs are also useful implements to achieve a rough land surface.

Although primarily a wind erosion oriented technique, surface roughening is beneficial with respect to reducing sheet erosion as well.

Advantages	**Disadvantages**
- effective low cost method of wind erosion control - secondary benefits due to increased infiltration and surface detention of runoff	- seed bed preparation may not be optimum

Cost Implications

- low cost technique
- may be incorporated into other tillage operations

Previous Experience

- wide spread use in areas prone to wind erosion which includes parts of the northern states and southwest Ontario.

Source of Information 182, 137, 180, 237, 106.

Title Promotion of Soil Clods or Aggregates	30

Keywords Agriculture, Sediments.

Applicable Land Use	**Pollutant Controlled**
Agriculture	Sediments

Description

Soil clods or aggregates larger than 0.8 mm. in diameter are not moved by winds under 50 kilometers per hour.The degree of cloddiness needed to control wind erosion depends on the level of the other factors that affect wind erosion. The size of clods required under various circumstances can be calculated by a wind erosion equation (see ref. 182).The degree of cloddiness produced by tillage depends on such factors as soil texture, soil moisture, organic matter content, speed of operation and kind of tillage tool.Generally the most cloddiness is achieved by using 5 cm. chisels with 80 cm. sweeps followed in order by disks, rod weeders with shovels and large V-sweeps.Soil aggregation and cloddiness are also effected on the long term basis by crop residue management.For example, 1,100 kilograms per hectare residue per cropping period will reduce the wind erodable soil fraction about 4%.(137)

Although primarily a wind erosion oriented technique, promotion of soil clods and aggregates is beneficial in reducing sheet erosion from runoff. Infiltration and surface detention is increased.

Advantages	**Disadvantages**
- low cost method for reducing wind erosion	- may not be conducive to some fine seed beds

Cost Implications

- requires planning of tillage practices
- may involve one or two additional tillage operations during year to maintain roughness

Previous Experience

Common use in areas subject to wind erosion which includes parts of the northern states and southwestern Ontario.

Source of Information 182, 137.

Title Strip cropping	31

Keywords Agriculture, Forest, Extractive, Sediments.

Applicable Land Use	**Pollutant Controlled**
Agriculture Forest Extractive	Sediments

Description

Strip cropping is practiced as a means of reducing erosion on tilled soils. The intent is to break the length of the slope into segments by laying out strips across the natural slope of the land.Strips of close growing crops or meadow grasses are planted between tilled row crop strips to serve as sediment filters or buffer strips in controlling erosion and reducing soils loss up to 85%.The practice effectively reduces the velocity of water as it leaves the tilled area.Runoff is absorbed and soil particles are retained in the buffer strip.The system of cropping where the strips are laid out nearly perpendicular to the direction of the slope, is referred to as contour strip cropping. The buffer strips can vary in width across the fields to make them compatible with modern farm equipment use.

This technique is also used for wind erosion control where strips are placed across the prevailing wind direction.

Advantages	**Disadvantages**
- encourages crop rotation practices - does not affect fertilizer and pesticide rates if adjacent crops are compatible	- not compatible with the use of large farming equipment on many topographies unless sufficiently wide - less realized income from forage or hay crop areas as compared with short term returns for row crops on similar sloping land

Capital Costs	**Operating and Maintenance Costs**
$25.00/ ha for capital costs. This cost represents potential loss in profit, installation, and inconveniences in planting tillage and harvesting procedures.	$14.00/ha for amortization of capital costs, operation and maintenance. Also accounts for differences in types of crops and yields. The farmer should realize that yields will decrease rapidly on steep land if erosion is not controlled. This benefit should also be evaluated when considering the 0 & M costs.

Previous Experience

Wide spread use throughout Canada and the United States for many years.

Source of Information 181, 119, 116, 137, 182, 239.

Title Miscellaneous Tillage Alternatives	32

Keywords Agriculture, Sediments.

Applicable Land Use	**Pollutant Controlled**
Agriculture	Sediments

Description

Tillage systems are often used in combination with other erosion control measures and in many cases may be the only control measure needed or used.Tillage in which the soil is inverted generates the highest possible potential for erosion by water and wind. The systems listed below have all been used and have shown to be effective in reducing water erosion.

1) Till plant - with this system wide sweep and trash bars clear a strip over the old row and a narrow planter shoe opens a seed furrow into which seed is dropped, a narrow wheel presses the seed into firmer soil; covering disks place loose soil over the seed, this system controls erosion most satisfactorily when done on the contour or across the slope. $4.50/ha for operation beyond standard type of planting.

2) Strip tillage - a narrow strip is tilled with rototiller gang or other implement. Seed is planted in the same operation.This system is applicable on soil where some tillage is desirable in the row zone. $12.50/ha for operation beyond standard planting techniques.

3) Sweep tillage - this practice is used on small grain stubble to kill the early fall weeds, it shatters and lifts the soil while leaving the residue in place for water and wind erosion control.

4) Chisel planter - this system breaks or loosens the soil without inversion, most of the crop residue remains on the surface for control of water and wind erosion.

5) Plow-plant - planting is done directly into plowed ground with no secondary tillage this system increases infiltration, water storage in the plow layer, surface storage and surface roughness.Surface drying is delayed because of the large clods in the interrow zone.

6) Wheel Track plant - this system is similar to plow-plant but is not restricted to freshly plowed ground, planting is done in the wheel track of the tractor or planter. Advantages are the same as for plow-plant.

See also catalogue sheets Nos.23, 38, 33 and 19 for additional tillage systems.

Source of Information 181, 182, 137, 86, 237, 239.

Title Conservation Tillage	33
Keywords Agriculture, Sediments.	

Applicable Land Use	**Pollutant Controlled**
Agriculture	Sediments

Description

The objective of conservation tillage is to loosen the soil, distribute residue on the surface between the rows to be seeded, to place the seed in a firm bed of moist soil that will warm quickly to promote germination and establish vigorous seedlings. The current trend in agriculture is away from sod based crop rotations to a greater proportion of row crops and it has created serious erosion increases and problems. It is a matter of great concern.Research verifies the benefits of special agricultural practices combating these problems.Runoff plots show that rotation with corn, cereals, and hay can significantly reduce soil and water losses.Yield benefits may also result from improved soil physical conditions and nutrients supplied. Residues maintained on or near the soil surface improve water infiltration and reduce soil loss to less than 1/10th of that on fields without residues.Disk and chisel plows or heavy duty cultivators effectively keep residues near the surface. For large fields subject to erosion a combination of field stripping and mulch tillage can be effective.

White beans, soybeans and some corn are grown on more level, fine textured soils where runoff is not serious, nevertheless, surface runoff deposits sediments and nutrients in drainage ditches to the extent that grass bordering strips are recommended. Fields planted to corn in rotation with sod or green manure crops and plowed under, suffer less than a third of the soil loss.

Advantages	**Disadvantages**
Chisel plowing is popular and appears to have benefits in energy saving and reduction of erosion & maintenance of yields, particularly if used in conjunction with moldboard plowing on some soils. Alone, chisel plowing can reduce yields compared tc moldboard plowing, but not to the extent experienced with no till practices on the fine textured poorly drained soils.	For a time low tillage was considered a practical means of saving time and energy as well as soil in corn production.The problem with this is often lower crop yield. Lower soil temperatures and poorer tilth, particularly on medium and fine texture soil, is believed to be responsible for the yield decline.

Cost Implications

- varies from \$3.75/hectare to \$18.75/hectare dependent on tillage technique, soil type and crop.

- cost is a function of crop loss due to poorer yield,less land utilization and consequent change in crop yield.The decreased yields are more significant on the fine textured soils.

Previous Experience

Applicable technique to the Great Lakes Basin which is increasing in popularity.

Source of Information 137, 148, 154, 86, 88, 274, 275, 276, 181, 182, 239, 237.

Title Sod-Based Crop Rotation	34

Keywords Agriculture, Sediments.

Applicable Land Use	**Pollutant Controlled**
Agriculture	Sediments

Description

Good meadows lose virtually no soil and reduce erosion from succeeding crops. Total soil loss is greatly reduced but losses unequally distributed over the rotation cycle. This technique aids in control of some diseases and pests and provides a green manure for incorporation into the soil adding soil conditioning benefits related to the use of the sod rotation.

Advantages	**Disadvantages**
- reduction of erosion - control of some diseases and pests - more fertilizer placement options	- less realized income from hay crop year - possible greater potential transport of water soluble phosphorus - some climatic restriction
Capital Costs	**Operating and Maintenance Costs**
- $3.50 to $4.00 per hectare for reduced short term yield (profits) from sod crop in comparison to row crops for the same field. - cost of seeding field to meadow approximately $500 to $700/hectare.	

Previous Experience

Common practice in most areas of Great Lakes Basin particularly with Dairy and Mixed Farming operations. Not popular with cash crop farmers due to potential reduction of profit.

Source of Information 137, 148, 154, 34, 181, 182, 237.

Title Winter Cover Crops	35
Keywords Agriculture, Sediments.	
Applicable Land Use Agriculture	**Pollutant Controlled** Sediments

Description

Winter cover crops are temporary revegetation of the fields with a low cost narrow row cover crop which is often referred to as green manure when it is ploughed under. The soil conditioning benefits of the cover crop are incorporated into the soil to increase the residue content.The basic philosophy behind the technique is to maintain a vegetative cover for as extensive a period of time as possible while also providing secondary benefits as a soil conditioner when incorporated into the soil.

Advantages	**Disadvantages**
- provides good base for planting of the next crop - reduction of erosion - some improvement of soil characteristics - may reduce the leaching of nitrate	- usually no advantage over heavy cover of chopped stalks or straw - use of winter cover may reduce yield of following cash crop if spring tillage operations are delayed due to increased drying time of field caused by mulch effect of residues left in spring.
Capital Costs $30/ha for planting and $12.50/ha or inconvenience (239).	**Operating and Maintenance Costs**

Previous Experience

Used widely for its green manure benefit rather than for sediment control but acceptance by agricultural community should be relatively easy.

Source of Information 181, 182,137, 239, 237.

Title Improved Soil Fertility	36

Keywords Agriculture, Sediments.

Applicable Land Use	**Pollutant Controlled**
Agriculture	Sediments

Description

This technique is a vague management practice wherein the effectiveness of the vegetative cover in the prevention or control of erosion is directly related to the fertility of the soil i.e. increased fertility, which includes nutrient availability, moisture retention, tilth etc., helps directly to increase vegetative vigor and growth thus indirectly causing a reduction in the availability of unprotected soil particles prone to erosion and washoff.

Advantages	**Disadvantages**
- within reasonable economic conditions this technique can substantially increase crop yield if a carefully managed soil fertility control program is carried out	- none

Cost Implications

Technique is low cost to implement and should result in short term, cost effective reduction of erosion and increased productivity.

Previous Experience

This is the objective of most progressive farmers.

Source of Information 182, 137, 181, 237.

Title Timing of Field Operations	37
Keywords Agriculture, Sediments.	

Applicable Land Use	**Pollutant Controlled**
Agriculture	Sediments

Description

Research has found that timing of field operations greatly affects the discharge of sediments given the climatic conditions of the Great Lake areas. Fall plowing facilitates more timely planting in wet springs, but greatly increases the winter and early spring erosion hazards by exposing vulnerable soil surfaces to the spring runoff and spring rainfalls, thus higher sediment yields result. By leaving the field undisturbed over the winter period and timing the cultivation practices after spring runoff a substantial decrease in the sediment contribution to water courses can be achieved.

Advantages	**Disadvantages**
- Optimum timing can reduce erosion and increase yield	- accomplishment of spring cultivation and planting becomes even more dependent upon weather conditions and hence a greater risk must be assumed by the farmer

Cost Implications

It has been estimated that a cost of $0.25 per hashould be assigned due to increased inconvenience. Cost is difficult to quantify. Cost of delayed planting can be several dollars per hectare and may even result in making planting impractical or requiring a change in crops.

Previous Experience

A well documented concept but farmers reluctant to take increased risk of spring planting difficulties.

Source of Information 182, 88,137,181, 219, 239, 237.

Title Contouring or Contour Cultivation	38
Keywords Agriculture, Sediments.	

Applicable Land Use	**Pollutant Controlled**
Agriculture	Sediments

Description

Contour cultivation i.e. contour ploughing practice done parallel to the contour of the land. Runoff which would normally flow perpendicular to the contour is now diverted laterally to take much longer, milder routes to its eventual outlet thereby reducing erosion and hence reducing soil loss. This technique can reduce average soil loss by 50% on moderate slopes but less on steep slopes. There is a danger if cultivation rows break over and cause a cascading effect on lower contour ridges.On a macro scale this can be supported by terraces on long slopes if the climatic and topographic limitations allow.A modification to restrict the cascading effect can be made by graded rows which is a variation of contouring wherein periodically much higher rows or ridges are created along the contours. This technique is often used in conjunction with terraces or diversions where effective slope lengths are excessive.

Advantages	**Disadvantages**
- Relatively simple method to allow more intense cropping without a decline in productivity	- Additional convergence of rows causes some inconvenience and decreased efficiency during planting, tillage and harvesting operations, therefore more time and cost is required.

Cost Implications

$6.00 per hectare for operational inconvenience has been estimated by one researcher. (239)

Previous Experience

Extensive utilization of this technique is the United States for many years. Limited previous experience in Canada.

Source of Information 240, 87,137, 181, 182, 207, 237, 239.

Title Grassed Outlets | 39

Keywords Agriculture, Urban, Transportation, Lakeshore & Riverbank Erosion, Sediments.

Applicable Land Use		Pollutant Controlled
Agriculture Urban Transportation	Lakeshore & Riverbank Erosion	Sediments

Description

The purpose of grassed outlets is to provide an erosion resistant covering of areas vulnerable to the high velocity flow exiting from drainage conduits. The sodding or seeding around the outlet should be done to a sufficient extent to reduce the exposed areas subject to erosion.Grassed outlets may also be utilized as side slope drains to facilitate the drainage of graded roads and terrace channels and downslopes with minimal resultant erosion. Such grassed outlets involve establishment and maintenance costs and may interfere with the use of large implements.If grassed outlets are used to control active gullies, however, it may be more convenient to drive through a smooth grassed channel than to work around a gully.

Grassed outlets are also useful in reducing erosion of banks around tile outlets and at junctions of small drainage ways.

Advantages	Disadvantages
- prevention of gully erosion and resultant soil loss. - potential convenience compared to working around a gully	- possible conflict with the use of large implements - will not stand prolonged flow - must be mowed to maintain conveyance efficiency and to control weeds.

Cost Implications

Sodding/seeding costs in the order of $1.00 per square metre. Loss of small areas of productive land

Reduction of dredging costs in drainage channels.

Previous Experience

- design aspects well documented
- in common usage in many areas of erosive soils

Source of Information 182, 107, 38, 87, 108, 110, 120, 126, 137, 180, 181, 237, 232, 92, 106.

Title Direct Dosing of Alum to a Septic Tank	40

Keywords Recreation, Urban, Agriculture, Nutrients

Applicable Land Use	**Pollutant Controlled**
Recreation Urban Agriculture	Nutrients (Phosphorus)

Description

An electrically operated dosing device is used such that with each flushing of the toilet, a predetermined portion of alum solution is injected into the inlet of the septic tank. Mixing of the alum and septic tank influent takes place in the sewer. At a rate of Al:P = 2, the concentration of the total phosphorus in the septic tank effluent dropped from 19.6 to 0.72 mg/1 as PO_4 ie. a 96% removal of Phosphorus (Test Results). Dissolved phosphorus levels dropped to 0.13 mg/L. Slight increases in sulphates were observed but no adverse effect on the concrete septic tank or on the soil of the leaching bed was observed. Phosphorus precipitates, sludges, etc. increased sludge accumulation rates from 621/person/year to 146 1/person/year

Advantages	**Disadvantages**
- simplicity of system - relative low cost - useful in areas where proper soil mantle or optimum separation to watertable is not available and where phosphorus will be readily carried to a water body	- more frequent removal of sludge accumulations required - requires maintenance by homeowner.
Capital Costs	**Operating and Maintenance Costs**
The cost of installing the alum dosing system is estimated at about $120 per dwelling.	The required amount of dry alum is avg. 20.33 kg/per/year at a price of $0.22/ kg of dry alum the annual cost of alum is about $4.47/person/year.

Previous Experience

Use of alum for phosphorus removal from lagoon effluents is well established in Ontario and the United States. Ontario Ministry of the Environment has done extensive research on alum use in private systems.(211)

Source of Information 112, 140, 211.

Title Swirl Concentrator for Runoff Treatment	41

Keywords Urban, Agriculture, Sediments, Nutrients.

Applicable Land Use	**Pollutant Controlled**
Urban Agriculture	Sediments Nutrients

Description

A device for the partial removal of suspended solids in storm water runoff or combined sewer overflow. The swirl concentrator converts a linear flow motion into a rotary motion and through its configuration the solids settle to the bottom for alternate discharge or further treatment. The treated effluent is discharged over a weir on the top of the tank. To avoid pumping of the foul underflow it is recommended that the regulator be fitted between the hydraulic gradients of the inlet sewer and the interceptor receiving the foul flow. The device is useful as an overflow regulator for combined sewers to maximize the quality of the overflow discharge. Full scale testing has shown that at flow rates from 10 to 220 litres/second, suspended solids and BOD_5, removals based on concentrations were in the order of 18% to 55% and 29% to 79% respectively. Removal of Suspended Solids on a mass basis ranged from 43% to 65%.

Advantages

- effective in removing settleable and floatable solids and BOD_5
- cost effective for removal of first 20% to 80% of solids in storm water/combined sewer overflows
- very simple, non mechanical device and pumping is not required

Disadvantages

- requires significant available hydraulic gradient
- subject to clogging of outlet pumps or gravity outlet by coarse objects such as bottles, rags, bricks
- require normal hosing of chamber walls and floor after each overflow
- dry weather flow may not be great enough to carry accumulated solids to the floor and through the foul sewer outlet

Capital Costs

Flow Capacity	Estimated Total Costs	Cost Per L/sec
220 L/sec	$27,000	$125
2600 L/sec	103,000	40
4000 L/sec	144,000	35

Capital Costs are a function of flow, available hydraulic gradient, accessibility & proximity to foul water and effluent receivers.

Operating and Maintenance Costs

- literature suggests 0 & M costs at about $0.55 per cu.m. per day capacity per year
- maintenance costs include allowance for clogging, chamber cleaning, servicing of pumps and removal of solids deposited in foul water receiving conduits
- maintenance generally increased with longer between storm periods

Previous Experience

- detailed design methodology has been published for the Swirl Concentrator - field tested 3.75 m. in Syracuse New York
- others constructed in Toronto and elsewhere

Source of Information 18, 185, 186, 188, 48, 104, 135, 138, 184, 210, 248, 249.

Title Retention Basins for the Treatment of Wet-Weather Sewage Flows	42
Keywords Urban, Sediments, Nutrients.	

Applicable Land Use	**Pollutant Controlled**
Urban - (Combined Sewer Overflows)	Sediments Nutrients

Description

The basic function of a retention basin is to retain excess wet-weather flows that would otherwise be discharged untreated and to return them, following a storm, to a sewage treatment plant.The volume of combined sewage produced by large storms is so great that a retention basin is ordinarily sized to reduce rather than eliminate overflow.

Concrete retention basins with detention times of one-half to three hours accomplished suspended solids removal of an estimated 30 to 70 percent. Retention basins are also constructed as open earthen ponds and often are combined with disinfection of the outflow. A concrete retention basin is fitted with a coarse screen and designed so that the roof beams would be submerged when the tank was full in order to function as **a** skimmer.The screen and skimmers were useful in retaining the particulate trash and debris in the surface runoff.

Advantages	**Disadvantages**
Depending upon hydrology and desired effluent standards, a detention basin in conjunction with a combined sewer system can yield smaller pollutant load discharges than with separate sewer systems.	- not necessarily cost effective - highly dependent upon local hydrology and effluent requirements.
Capital Costs	**Operating and Maintenance Costs**
Costs for covered concrete tanks and associated local piping are approximately $50/cu.m./d capacity. Additional costs must include oversizing of sewage treatment plant if required.	- removal of debris and large solids from screens and basin floor - additional treatment plant operating costs

Previous Experience

City of Halifax, Nova Scotia has two retention basins in operation. Welland, Borough of York (Toronto).

Source of Information 188, 48, 104, 135, 138, 185, 207, 210, 246, 243.

Title Stationary Screens	43

Keywords Urban Runoff, Sediments, Nutrients.

Applicable Land Use	**Pollutant Controlled**
Urban Runoff	Sediments Nutrients

Description

The stationary screen is designed on the basis of flow rates and removal performance required.The screen assembly and configuration requires about 2 to 2.5 metres of hydraulic head loss, however, recent lower head models are available which require only 1 to 1.25 metres of hydraulic head loss.Collection flumes for sludge and screened effluent are required.The sludge is of sufficient concentration that it will not flow and it must be sluiced to return it to the sewer.

Advantages	**Disadvantages**
- energy efficient technique	- equal hydraulic distribution to multiple units is problematical - pumping may be required
Capital Costs	**Operating and Maintenance Costs**
Including housing, flow equalization channels, etc. construction costs are approximately $250/L/sec.	No moving parts or energy consumption, therefore, operating and maintenance costs are low.Only occasional cleanouts requir- ed.

Previous Experience

Design methodology and criteria well developed.Equipment is readily available from many suppliers.

Source of Information 186, 53, 111, 48, 104, 135, 138, 248, 249.

Title Horizontal Shaft Rotary Screen	44
Keywords Urban, Sediments, Nutrients.	

Applicable Land Use	**Pollutant Controlled**
Urban	Sediments Nutrients

Description

The screen is installed in a chamber designed to permit entry of the wastewater to the interior of the drum and collection of filtered (or screened) wastewater from the exterior side of the drum. Inlet and outlet piping is typically arranged in a fashion similar to granularmedia filters.Different aperture fabrics provide for removal of large solids to small solids as desired.This permits use of screens for purposes ranging from pretreatment to final treatment. Appurtenances include ultraviolet slime growth control, backwash sprays, and backwash storage and pumping facilities.

Advantages	**Disadvantages**
- requires less physical area than conventional clarifiers - useful tool to pretreat effluent prior to a particular treatment process - reduction in treatment chemicals required.	- less energy efficient than conventional clarifiers - periodic maintenance required
Capital Costs Approximately $170-$180/L/sec. (186)	**Operating and Maintenance Costs** - Estimated to be in the order of $0.01/10001.

Previous Experience

Syracuse, New York has 9-23 MLD rated installations. Several commercially available models exist.

Source of Information 186, 48, 104, 135, 138, 237, 249.

Title Vertical Shaft Rotary Fine Screen	45

Keywords Urban Runoff, Sediments, Nutrients.

Applicable Land Use	**Pollutant Controlled**
Urban Runoff	Sediments Nutrients

Description

A tightly woven wire mesh fabric fitted around a drum is used to strain the waste water flow. The drum of the rotary fine screen rotates about a vertical axis at high speeds (0.5 to 1.0 cycle/s) and the influent is introduced into the centre of the rotating drum.

- largest unit available (1975) was 130 L/sec. capacity
- includes hot and cold water sprays and detergent cleaners to clean screen
- removal efficiencies range from 60 to 90 percent for settleable solids, 30 to 32 percent for suspended solids and 16 to 25% for COD.

Advantages	**Disadvantages**
- less physical area required than for conventional clarifiers - reduction in process chemicals required if used as pretreatment device.	- uses special backwash solution - low flow rates, high costs - some limitations with highly variable flows - relatively high space requirements
Capital Costs	**Operating and Maintenance Costs**
$180/L/sec.(186)	Estimate for Seattle installation $0.01/1000 L.

Previous Experience

Fort Wayne, Indiana	1600 L/sec. installation
Seattle, Washington	1100 L/sec. installation
Portland, Oregon	125 L/sec. installation

Source of Information 186, 135, 48, 135, 138, 237, 249.

Title Treatment Lagoons	46

Keywords Urban, Agriculture, Recreation, Sediments, Nutrients.

Applicable Land Use	**Pollutant Controlled**
Urban Agriculture Recreation	Sediments Nutrients

Description

Three basic systems of lagoons exist:anaeorbic, aerobic, and facultative depending upon the type of biological activity that takes place within. Several types and sizes of treatment lagoons have been used in combined sewer overflow treatment demonstration projects sponsored by EPA.In most cases these treatment lagoons offer multiple uses and benefits as dry weather plant effluent polishing ponds, as inflow equalization basins, as settling basins, and as part of the urban open space/recreation systems. Removal efficiencies range from 27 to 90% for BOD5, 20 to 90% for SS and 20 to 65% for phosphorus and nitrogen.The main factor affecting removal efficiencies for all types of lagoons is carry over of algae and other micro organisms in the effluent.

Livestock manures are commonly treated in this manner when direct field application is not possible and storage-treatment is necessary.

Advantages	**Disadvantages**
- multi use capability - simple to operate	- large land area required - mosquito problem - odours
Capital Costs	**Operating and Maintenance Costs**
$200 to $700 per L/sec depending upon type, ie. aerobic or anaerobic, excluding land costs.	$2.50 to $3.50/1000 cu. m.

Previous Experience

Several EPA demonstration projects. Accepted design criteria for storm water or combined sewer overflows is not yet established.

Source of Information 135, 48,104, 248, 233, 237, 92.

Title Rotating Biological Contactors	47

Keywords Urban, Agriculture, Recreation, Nutrients, Sediments.

Applicable Land Use	**Pollutant Controlled**
Urban Agriculture Recreation	Nutrients Sediments

Description

The R.B.C. is similar to a cross between a trickling filter and activated sludge system. It consists of a horizontal shaft supporting a set of rotating discs upon which a biomass is grown, and a shallow contact tank that houses the shaft disc assemblies. The rotating discs are partially submerged and baffles are used between each shaft-disc unit to prevent short circuiting. The removal of organic matter from the waste flow is accomplished by adsorption of the organic matter at the surface of the biological growth covering the rotating discs. The reported BOD_5 removal efficiencies range from 60 to 90%, Settleable Solids at 80 to 90%, Nitrogen and Phosphorus at 40 to 50%, 704 or better COD removal rates maintained up to 8 to 10 times dry weather flow. Linear reduction of COD removal efficiency from 70% down to 20% for a flow range of 10 to 30 times dry weather flow.

Advantages	**Disadvantages**
- relatively low power requirements - fair degree of flow variation can be handled - shock loads are handled effectively - no fly and odour problems	- requires base flow to keep biomass active - little control of biological process - design aspects not well advanced
Capital Costs	**Operating and Maintenance Costs**
$800/L/sec at a 455 L/sec installation in Milwaukee, Wisconsin. Total cost including classifiers sludge digestion, sedimentation tanks, etc. but excluding land costs(135)	$0.04 cu. m. for total treatment plant including R.B.C. (135).

Previous Experience

- Milwaukee Wisconsin demonstration project (455 L/sec)

Source of Information 135, 248, 237.

Title Trickling Filters	48

Keywords Urban, Agriculture, Recreation, Nutrients, Sediments.

Applicable Land Use	**Pollutant Controlled**
Urban Agriculture Recreation	Nutrients Sediments

Description

Trickling filters are widely employed for the biological treatment of municipal sewage. The filter is usually a shallow circular tank of large diameter filled with crushed stone, drain rock or similar media. Influent is distributed evenly over the surface by means of a rotating distributor. Removal of organic matter is the result of an adsorption process occurring at the surface of biological slimes covering the filter media. They are classified by hydraulic or organic loading into low rate, high rate and ultra-high rate. Removals during dry weather flows have been reported to be 85 to 95% for both BOD5 and SS, and 65 to 90% during wet weather. It is reported that removal efficiencies dropped when the hydraulic loading exceeded 1.56 cu. m./hr/sq. m. 432 cu. m./sq. m./sec for plastic media and 0.48 cu. m./hr/sq. m.,132 cu. m./sq. m./sec for rock media.

Advantages	**Disadvantages**
- handle varying hydraulic and organic loads - simple to operate - can withstand shock loads - can recover rapidly from high flows	- require continuous base flow to keep the biomass active - problems may be encountered when treating more dilute combined sewer overflow or storm sewer discharge - no significant reduction of total nitrogen or phosphorus
Capital Costs	**Operating and Maintenance Costs**
Approximately $19,000/L/sec which includes cost of plastic filter media, final clarifier, piping, electrical work, chemical feed, site work but excluding land costs for a 260 L/sec installation (135)	$.02 to $.05/cu.m.

Previous Experience

Many in operation

Source of Information 133, 135, 138, 248, 237.

Title Contact Stabilization	49

Keywords Urban, Recreation, Nutrients, Sediments.

Applicable Land Use	**Pollutant Controlled**
Urban	Nutrients
Recreation	Sediments

Description

Contact stabilization is considered in lieu of other activated sludge process modifications for treating combined sewer overflows, because it requires less tank volume to provide essentially the same effluent quality. The combined sewer overflow is mixed with returned activated sludge in an aerated contact basin for approximately 20 minutes at the design flow. Following the contact period, the activated sludge is settled in a clarifier and the concentrated sludge then receives additional treatment.

BOD_5 and SS removals on combined sewer overflow achieved 83 and 92 percent respectively.

Advantages

- high degree of treatment
- reduction of the loadings on dry-weather facilities, by dual use of facilities during normal operations and emergency shutdown of the main plant

Disadvantages

- high initial cost
- the facilities must be located next to a dry weather activated sludge plant
- adequate interceptor capacity must exist to convey the storm flow to the treatment plant

Capital Costs

$19,000/L/sec. for 1000 L/sec. plant

Operating and Maintenance Costs

$.02/1000 1 for a 1000 L/sec. plant

Previous Experience

Kenosha, Wisconsin - 900 L/sec Installation

Source of Information 135, 104, 248, 237.

Title Air Flotation	50
Keywords Urban Runoff, Sediments, Nutrients.	

Applicable Land Use	**Pollutant Controlled**
Urban Runoff	Sediments Nutrients

Description

Dissolved air flotation is a unit operation used to separate solid particles or liquid droplets from a liquid phase. Separation is brought about by introducing fine air bubbles into the liquid. The bubbles attach to the solid particles or liquid droplets, the buoyant force of the combined particle and air droplet is great enough to cause the particle to rise. Once the particles have floated to the surface they are removed by skimming. Higher overflow rates and shorter detention times are achieved for dissolved air flotation than for conventional settling. Moderately good BOD and SS removal(both about 50%).

Advantages

This process has a definite advantage over gravity sedimentation when used on combined overflows or storm drainage in that particles with densities both higher and lower than the liquid can be removed in one operation. It also aids in the removal of oil and grease which are not as readily removed during sedimentation.

Disadvantages

- dissolved material is not removed without the use of chemical addition
- operating costs are relatively high compared to other physical processes
- greater operator skill required
- provisions must be made to prevent wind and rain from disturbing the float.

Capital Costs

For plants between 0.2 cu. m./sec. to 45 cu. m/sec. capital cost eqn is:

$Ca = 4,200 (Qa)^{0.84}$

where Ca = capital cost
Qa = plant capacity in L/sec.

Operating and Maintenance Costs

For plants between 0.2 cu. m./sec. and 45 cu.m./sec. Operating and maintenance costs range $.01 to $.04 per cubic metre.

Previous Experience

Well advanced methodology and design experience many installations, Racine, Wisconsin.

Source of Information 135, 31, 48, 104, 186, 210, 248, 249, 237.

Title Physical-Chemical Systems	51

Keywords Urban, Recreation, Nutrients, Sediments.

Applicable Land Use	**Pollutant Controlled**
Urban Recreation	Nutrients Sediments

Description

When a high quality effluent is required, such as may be expected in storm water reclamation and reuse, physical-chemical treatment systems may become both feasible and desirable. Physical-chemical systems are those means of treatment in which the removal of pollutants is brought about primarily by chemical clarification in conjunction with physical processes. The process string generally includes preliminary treatment, chemical clarification, filtration, carbon adsorption, and disinfection. During the last 12 years, research has advanced physical-chemical treatment technology to the point where it is becoming competitive in cost with biological treatment, especially for situations where significant phosphorus removal is required. Removal efficiencies; BOD- 90 - 97%; TOC - 74 - 94%; SS - 85 to 100%, Phosphorus 90 - 99%, Nitrogen 45 - 98%.

Advantages	**Disadvantages**
- very high quality effluence achieved - can reduce loading on dry weather plant	- very high capital costs

Capital Costs	**Operating and Maintenance Costs**
$50.00 to $175.00 per cu. m./d of plant capacity for flows ranging from 40,000 to 400,000	$0.01 to $0.06/cu. m.- 40 million litres/day plant $0.01 to $0.05/cu. m.-100 million litres/day plant $0.01 to $0.03/m. m-- 400 million litres/day plant

Previous Experience
- technology well developed
- South Lake Tahoe, California - 30 million litres/day installation
- Albany, New York - 0.1 million litre/day pilot installation (stormwater)

Source of Information 53, 48, 83, 104, 135, 138, 187, 248, 237.

Title Reverse Osmosis of Mine Tailings Effluent	52

Keywords Extractive, Chemicals.

Applicable Land Use	**Pollutant Controlled**
Extractive	Chemicals

Description

Contaminated water is forced under high pressure through cellulose acetate membranes. Water molecules pass through while most dissolved chemical molecules are retained and concentrated. Resultant fluid yields are variable according to the design of apparatus, required passage rates and degree of membrane fouling allowable. Iron, manganese and pH are only partially controlled. Filtration may be required to remove suspended solids prior to reverse osmosis.

Advantages	**Disadvantages**
- very high quality effluent - removes most dissolved solids - possibility of recovery of valuable minerals	- fouling of membranes is a problem that is being investigated - high volume of concentrated waste to dispose of - sophisticated operation

Cost Implications

No cost data was given in the literature on this technique since it is primarily in the developmental stage. Process is very expensive because of sophisticated equipment required and high operating costs.

Previous Experience

Still in experimental/developmental stage for this application. Technology of reverse osmosis is well developed and documented.

Source of Information 32, 142, 145.

Title Chemical Adsorption onto Clays in Experimental Environment	53
Keywords Agriculture, Forestry, Pesticides.	

Applicable Land Use	**Pollutant Controlled**
Agriculture Forestry	Pesticides

Description

Research studies have been done on the adsorption of organochloride insecticides onto natural clays. Attention is focused to the point that adsorption of these materials onto clays does not necessarily follow in exchange capacity. Desorption was also mentioned and found to be a prominent factor in remobilization of insecticides particularly when more demanding exchange elements are present. Temperature did not significantly vary the results. Depending on concentration, type of pesticide, type of clay adsorbant and the turbidity, up to 98% of the amount dissolved can be held on the clays.Thesis values of cone of clay - bentonite.1, 5,10 gm/1 remove 44, 48, DDT from water respectively initially containing 100 µgm/L. Same amount of bentonite removed 14, 23 and 30% respectively of HEOD (dieldrin) from water of the same concentration. Although organochloride insecticides are no longer widely used, this principle of adsorption of chemicals onto clays finds usage with other chemicals and is probably one of the mechanisms inherent in vegetative buffer strips around fields which increases pollutant removal efficiencies.

Advantages	**Disadvantages**
- A natural phenomenon which is inherently present when runoff filters through soils, or when sediments are contained.	- Desorption and remobilization is a real problem and desorption concentrat- ion of 3 µgm/L and 1 µgm/L for clay concentrations of 1.0 and 10.0 gm/L respectively - still in research stage

Cost Implications

No costs available at this time.

Application appears treatment plant oriented due to potential aggravation of turbidity problems in natural watercourses.

Previous Experience

Research study results are available but no actual installations revealed by literature research. Method gives insight into natural phenomenon of attenuation/purification by soils.

Source of Information 95, 99, 101.

Title Surface Water Diversion	54

Keywords Extractive, Solid Waste Disposal, Agriculture, Sediments, Nutrients, Chemicals

Applicable Land Use	**Pollutant Controlled**
Extractive Solid Waste Disposal Agriculture Forest	Sediments Nutrients Chemicals

Description

Water diversion involves collection of water before it enters the working area and then conveying it around the site.This procedure decreases erosion, reduces pollution and reduces water treatment costs by reducing the volume of water that needs to be treated.

Ditches, flumes, pipes, eaves trough downspouts, trench drains and dykes, are all commonly used for water diversion.

See also 14, 21, 22, 94.

Advantages	**Disadvantages**
- prevention of suspension or dissolution of pollutants - technique applicable to most locations - reduction of water volume for treatment if required.	- potential erosion associated with diversion
Capital Costs	**Operating and Maintenance Costs**
Cost a function of method of conducting water. Must include erosion control measures.	- minimal - dependent upon accumulation rate of or the repair of scoured areas in the diversion.

Previous Experience

This technique is widely applicable and is used commonly to control the direction of surface runoff.

Source of Information 142,145,221,234, 232, 92,106.

Title Reducing Ground or Mine Water Influx	55

Keywords Extraction, Solid Waste Disposal, Nutrients, Chemicals.

Applicable Land Use	**Pollutant Controlled**
Extraction Solid Waste Disposal	Nutrients Chemicals

Description

An impermeable liner can be placed against the high wall of a surface mine to prevent the influx of groundwater. This application is seldom used except where there are auger holes that require sealing, or a surface mine has broken into an underground mine work area.Underground mine openings encountered during stripping are often sealed with clay or concrete block walls.Impermeable barriers are often used in parallel with dewatering techniques to avoid the buildup hydrostatic pressure.

Advantages	**Disadvantages**
- prevention of the dissolution of minerals from workings or landfills. Clay liners have some attenuative effects as well as being relatively impermeable.	- have not had wide usage to date and documentation to judge effectiveness is very limited

Cost Implications

Because of high variability of technique application only unit prices are given. Clay ranges from $2.30 to $7.80 per cubic metre including installation depending upon source and haul distance.Concrete in place costs approximately $100 to $200 per cubic metre depending on area, labour, materials, farming requirements, and haul distance. Site preparation viill include additional costs depending upon present site conditions.

Previous Experience

This technique is known to be practical in some United States mining operations, but no examples were cited in the literature.

Source of Information 142, 145.

Title Underdrains for Mineral Stockpiles or Tailings	56

Keywords Extractive, Nutrients, Chemicals.

Applicable Land Use	**Pollutant Controlled**
Extractive	Nutrients Chemicals

Description

Underdrains of rock or perforated pipe can be placed below the pollution forming material to quickly discharge infiltrating water.These devices shorten the flow path and residence time of the water in the waste material. Underdrains are designed to provide zones of high permeability to collect and transport water from the bottom of the spoil piles. A common method of construction is to use trenches filled with rock commonly called French Drains.Should effluent and water from these drains require treatment, the underdraining provides a convenient method of collection, facilitating conveyance to a treatment facility.

Advantages

- reasonably economic means of containing possible contaminated seepage from new installations
- often used in conjunction with mineral recovery processing of resultant leachate.

Disadvantages

- difficult to implement for existing deep spoil piles
- monitoring of quality of the effluent should be a requirement

Cost Implications

Costs are extremely variable and should be developed for the particular usage factors such as depth, type of pipe material required for the particular loading and chemical condition. Estimate of cost range for this type of drainage is approximately $5.00 to $33.00 per lineal metre depending upon the type and size of pipe used.

Previous Experience

Design methodology and criteria are well documented.Mining operations in Northern Ontario are using this technique.

Source of Information 145,142.

Title Evaporation Ponds	57

Keywords Extractive, Nutrients, Chemicals.

Applicable Land Use	**Pollutant Controlled**
Extractive	Nutrients Chemicals

Description

Large holding/evaporation ponds may be used to prevent discharge of mine wastes. Mine discharges can be collected and conveyed to a large holding pond or series of holding ponds. This system is designed to provide that all influent water is lost to the atmosphere through evaporation and no discharge occurs. The bottom of the pond should be lined where impoundment materials are permeable. Clay liners may be particularly useful because of their ability to adsorb pollutant forming materials such as the arsenic compounds. The system must be designed with capacity for flow retention during periods of high rainfall and low evaporation rates. Settled solids will have to be removed from the pond periodically in order to maintain proper capacity.

Advantages	**Disadvantages**
- on site retention of pollutants	- highly dependent upon local hydrologic conditions - solids remain to be disposed elsewhere

Capital Costs	**Operating and Maintenance Costs**
The cost of pond dikes range from $0.45 to $0.85 per cubic metre. Lining costs depend upon materials used, availability and area coverage. Clay liners cost $2.30 to $7.80 per cubic metre including material and installation. Indigenous soils, availability and haul distance of lining materials, size and site preparation required affect costs.	Minor except for occasional clean-out of accumulated sediments.

Previous Experience

Only applicable in mid-western states where climate is suitable or where an external heat source is available.

Source of Information 145, 190.

Title Street Cleaning	58
Keywords Urban, Transportation, Sediments, Chemicals, Nutrients.	

Applicable Land Use	**Pollutant Controlled**
Urban Transportation	Sediments Chemicals Nutrients

Description

Street surface contaminants, which represent a major portion of urban land contaminants, can be partially removed by street sweeping operations prior to being exposed to runoff. Municipal street cleaning practices may be improved by increasing the frequency of street sweeping and/or increasing the removal efficiency of the equipment used. Motorized street sweepers are designed to loosen dirt and debris from street surfaces, transport it onto a moving conveyor and deposit it temporarily into a storage hopper. Three major types of existing street sweepers include the broom-type sweeper, the vacuum-type sweeper, and a third type of sweeper which uses a regenerative air system to "blast" dirt and debris from the road surface into a hopper. Sweepers are most efficient in the removal of large size particles with overall average efficiency at about 50%. Vacuum type sweepers have highest efficiency on dry streets with broom-type sweepers prone to difficulty in removing small particle sizes. Street surface contaminant accumulation is a function of street sweeping frequency, street sweeping removal effectiveness, and antecedant rainfall events.The removal effectiveness can be improved by sweeping an area more than once but repeated sweeping passes over the same area is essentially mutually exclusive from sweeping frequency unless more vehicles are acquired for the same area.

Advantages

- reduced loadings of watercourses due to flushing effect of rainfall on urban streets
- source collection and treatment of contaminants is usually only method used to control pollution of receiving water- courses from street runoff.
- associated benefit of improved public health and aesthetics of clean streets.

Disadvantages

- can be obstruction to traffic during busy period.
- regular program required
- difficulties during winter months in Great Lakes Basin
- parked vehicles present a problem

Capital Costs

Street sweeper costs vary widely depending upon the individual model. The following capital costs are representative of the range:

3-wheel -	$23,000 to 28,000
4-wheel -	$35,000 to 38,000
Vacuum -	$35,000 to 45,000

Operating and Maintenance Costs

A rough estimate of total cost for a given street sweeping program would be in the order of $8 to $12 per curb kilometer cleaned per year.

Previous Experience

Common practices in most urban area.Many types of vehicles widely available from many suppliers.

Source of Information 138, 185, 248, 237, 146, 92.

Title Interception of Aquifers	59

Keywords Extractive, Solid Waste Disposal, Nutrients, Chemicals.

Applicable Land Use	**Pollutant Controlled**
Extractive Solid Waste Disposal	Nutrients Chemicals

Description

This technique involves the use of bore holes, casing and pumps to transfer water from one point to another in order to reduce groundwater flow into a mine or landfill. A complete hydrological site evaluation of the area to determine the aquifer characteristics in water flow system is required prior to installation .The groundwater flow system is intercepted prior to movement of water through the site in question and water is prevented from contacting the pollutant forming material. The uncontaminated water is then discharged down gradient from the mine or landfill. The use of these systems is highly technical therefore groundwater geologists should be consulted to perform site evaluation to determine the feasibility to design the system. This technique is also referred to as "purge wells" or "counter pumping" when used for the control of leachatemigration from solid waste disposal sites.

Advantages	**Disadvantages**
- prevention of the contamination of groundwater, reduction in the volume of water to be treated if required	- relatively costly - will work under favourable conditions only - system designed to be variable depending on local hydrogeological factors

Cost Implications

Costs can only be developed on an individual application basis.Costs will be a function of geologic strata, casing size, number of wells, hydraulic characteristics of the aquifers, volume of flow to be pumped, energy costs, chemistry of the groundwater which in turn may lead to corrosion of well streams, periodic replacement and/ or maintenance of well stream or pumping system may be required.

Previous Experience

This technique is used commonly for dewatering of excavations and foundations and to a limited extent for the control of landfill leachate migration.

Source of Information 145.

Title Neutralization of Mine Acid Waste	60

Keywords Extractive, Chemicals.

Applicable Land Use	**Pollutant Controlled**
Extractive	Chemicals

Description

When mine drainage is acid the acidity can be neutralized by the addition of an akaline material.By properly selecting the alkaline agent, many metals (cations) can be removed during neutralization as insoluble hydroxide. Anions such as phosphates, fluorides, and sulphates can also be removed by calcium alkalies using this insolubility principal.Several alkaline materials are available for neutralization, including lime, hydrated lime, limestone, caustic soda, soda ash, magnesium carbonate and ammonium hydroxide.The selection of the neutralizing agent is highly dependent upon the minerals or ions to be precipitated.

Advantages	**Disadvantages**
- effective - reliable	- requires collection of waste streams, collection and removal of precipitate

Cost Implications

Costs per metric ton of basicity range from $10.00 per tonne to $67.00 per tonne of basicity. The basicity factor is defined as grams of calcium carbonate (Ca CO_3) equivalent per gram of alkaline agent.Costs must then be related to the amount required which is a function of the pH and flow of the mine drainage to be treated.

Previous Experience

Methodology and design criteria are well developed.Several installations for the treatment of mine wastes in the United States and Ontario.

Source of Information 145, 19, 36, 84, 141.

Title Stream Neutralization		61
Keywords Mining, Nutrients, Chemicals.		
Applicable Land Use Mining	**Pollutant Controlled** Nutrients Chemicals	

Description

The Pennsylvania Department of Environmental Resources has constructed an automatically operated hydrated lime neutralization system for treatment of streams affected by acid mine drainage. This system is applied to streams which are mildly acidic but may contain little iron, aluminum, manganese or other compounds that will precipitate as insoluble compounds. The system consists of a lime storage bin with a variable speed factor. Stream flows are measured by a float behind a weir. Flow and upstream pH both control the lime feed rate. Lime is introduced dry behind the weir and an electric mixer and baffles ensure rapid dissolution.

Advantages	**Disadvantages**
These plants have operated with little problem and have returned several streams to a quality that supports aquatic life.	Does not remove contaminant but transforms its effects. Probable downstream impact due to increased mineral content of sediments.
Capital Costs	**Operating and Maintenance Costs**
Several plants installed by Pennsylvania have capital costs ranging from $40,000 to $54,000 and have treated flows ranging from 568 to 21,764 cubic metres per day.	Operating costs have ranged from $300 to $741 per month or about 1.5 per cubic metre in periods of low flow and 1.84 per cubic metre in periods of high flow.

Previous Experience

Generally still in research stage. Several installations in Pennsylvania.

Source of Information 142, 145.

Title Improved Methods of Sludge Disposal on Land	62

Keywords Liquid Waste Disposal, Urban, Agriculture, Nutrients, Chemicals.

Applicable Land Use	**Pollutant Controlled**
Liquid Waste Disposal Urban Agriculture	Nutrients Chemicals

Description

Disposal of digested liquid sewage sludge is commonly via land application by tank truck. During the autumn and spring months when soils are soft and wet due to precipitation conventional sludge handling vehicles are unable to drive over the fields without becoming mired or causing excessive rutting and compaction of soil. Various types of vehicles have been examined to determine their suitability for spreading sludge on fields under adverse conditions. These included a tank truck, a sludge injector, a bulldozer, a front end loader and an all terrain vehicle. Not one of the vehicles or methods investigated proved to be ideally suitable and effective; however, the all terrain vehicle showed the most promise.

Added consideration should be given to the winter application of sewage sludges to the land with regard to potential runoff contamination during the spring melt. Storage facilities may be used during periods when spreading is not desirable ie. wet periods, winter, etc.

Advantages	**Disadvantages**
- the all terrain caused minimal field damage and was judged most appropriate for land disposal of sludge; however a larger tank would be required on the all terrain vehicles to improve efficiency.	- the bulldozer is too slow and heavy and causes excessive damage to topsoil and turf. Front end loader too cumbersome and also causes field damage. - tank truck becomes easily inoperative - injector frequently clogs with soil and is ineffective in hard soil or frost - spreading slow with all terrain vehicle
Capital Costs	**Operating and Maintenance Costs**
Dependent on type. Ranges from $20,000 to $45,000.	

Previous Experience

Various types of vehicles are used throughout the Great Lakes Basin for the land application of sludges. Improved vehicles or associated equipment are normally well received.

Source of Information 228, 78, 79, 80, 145, 218, 225, 235.

Title Annual Storage and Land Application of Livestock Wastes	63
Keywords Agriculture, Nutrients.	

Applicable Land Use	**Pollutant Controlled**
Agriculture	Nutrients

Description

Studies have been undertaken to compare daily spreading of manure on the land with annual storage where manure is applied several days prior to crop planting and is plowed down within 24 hours after application. Less manure phosphorus was lost through storage and direct plow down but nitrogen losses were greater with storage than with daily spreading. It was also found that for given restrictions on Nitrogen losses from the agricultural areas the reduction in net farm income per pound of decreased nitrogen loss was higher with annual storage and direct plow down, than with daily spreading technique. Similarly, it was found that it is more costly to reduce phosphorus losses with annual storage and direct plowing, if storage facilities had to be built.

Advantages	**Disadvantages**
- controlled application - minimum loss by runoff - better use of nutrients - elimination of daily spreading	- cost - storage problems, odour - success is dependent on soil, crop and climatic conditions
Capital Costs	**Operating and Maintenance Costs**
Annual storage and direct plow down of livestock wastes is estimated to increase farm operation costs by about 15% as compared to frequent application, no significant stockpiling and incorporation only when convenient to a tillage operation.	

Previous Experience

This is a practice applicable to and currently practiced in the Great Lakes Basin. It has been adopted as a good farming practice by many agricultural agencies and is eligible for grant/loan assistance in many jurisdictions.

Source of Information 203, 89, 102, 33, 121, 124, 225, 239, 237, 152, 190, 206, 219.

Title Sewer Flushing	64

Keywords Urban, Sediments, Nutrients.

Applicable Land Use	**Pollutant Controlled**
Urban	Sediments Nutrients

Description

In many cases the high pollutional load of combined sewer overflows is the result of pipe line deposits being scoured by the high velocity of storm flows. These deposits are solids that settle out or that are trapped within the line during antecedent dry weather. Systematic sewer flushing is designed to remove the material periodically as it accumulates and to convey it hydraulically to the treatment facilities. It was found that removal efficiency of deposited material by periodic flush waves is dependent upon flush volume, flush discharge rate, sewer slope, sewer length, sewer flow rate, and sewer diameter.

Advantages	**Disadvantages**
- provide proper treatment to pipe line deposits during dry weather - maintain full sewer hydraulic capacity	

Capital Costs	**Operating and Maintenance Costs**
$1,750.00 per hectare to $3,530.00 per hectare for sewer cleaning equipment.	$32.00 per hectare to $64.00 per hectare annual cost.

Previous Experience

Common practice in most urban areas.

Source of Information 146, 237, 104, 117, 135, 207, 221, 248.

Title Combined Sewer Overflow Regulators	65
Keywords Urban Drainage, Nutrients, Sediments.	

Applicable Land Use	**Pollutant Controlled**
Urban Drainage	Nutrients Sediments

Description

Regulators are designed to divert average dry weather and maximum flows to the interceptor leading to the treatment plant with the excess overflowing to a receiving water. Recent research has resulted in several regulators that appear capable of providing quality and quantity control via induced hydraulic flow patterns that tend to separate and concentrate the solids from the main flow. Other devices promise excellent quantity control without troublesome sophisticated design. Research results are available on the following types: Broad-Crested inflatable fabric dam, cylinder operated gate, cylindrical gate, float operated gate, fluidic device, high side-spill weir, horizontal fixed orifice (drop inlet), internal self priming syphon, leaping weir, vertical gate, side-spill weir, swirl concentrator, tipping gate, etc.

Advantages	**Disadvantages**
- wide range of options depending on sophistication required - can be designed to contain as much contaminated water for treatment as possible - maintains optimum sewage treatment operation	- limited control of pollution in overflow.
Capital Costs	**Operating and Maintenance Costs**
Capital costs are dependent upon diameter inlet and outlet pipes, accessibility, mechanical nature of equipment, etc. Costs range from $1,000 to $4,000 for static non-mechanical devices to $200,000 to $600,000 for large dynamic mechanical regulators.	O & M costs range from $600 to $700 for static non-mechanical devices to $1,200 to $2,100 for the dynamic mechanical devices.

Previous Experience

Many municipalities in the Great Lakes Basin with combined sewers are updating their regulations. The development of regulators to maximize overflow quality has resulted in new consideration being given to the return to combined sewers in some circumstances.

Source of Information 135, 207, 210, 248, 246.

Title Overburden Segregation	66

Keywords Extractive, Transportation, Sediments, Nutrients.

Applicable Land Use	**Pollutant Controlled**
Extractive - Open Cut Urban - Construction Transportation	Sediments Nutrients

Description

Overburden that must be removed to expose a mineral is seldom homogeneous. This overburden is usually a mixture of soil and rock that has varying physical and chemical properties. From a water pollution standpoint there are three classes of overburden material: 1) Topsoil - material conducive to plant life, 2) Clean Fill, 3) Pollution-Forming material. The purpose of segregating overburden is to keep the three classes of material separated during mining or construction so that they can be effectively utilized later for regrading.

Spoil segregation was rarely practiced by miners in the past because it was cheaper to pile all material together. Reclamation of these old abandoned mines is difficult because good soil is lost and pollution-forming materials occur throughout the soil. One of the primary purposes of overburden segregation is to stock pile soil for later establishment of vegetation. Soil from all surface mine sites should be removed, stock piled and temporarily vegetated to control erosion.

Urban and transportation construction has a better record of topsoil segregation for regrading of disturbed area however, little attempt is made to reconstruct original soil horizons. The replacement of successive soil horizons is required for full restoration of the soil's productivity.

Advantages	**Disadvantages**
Has been successfully utilized many times in the coal fields of eastern United States, When utilized with regrading and revegetation it is believed to be one of the most successful methods of controlling water pollution from surface mines. A necessity with both urban and rural earthwork for complete restoration.	Only applicable to surface activity. May not be sufficient material conducive to vegetative growth to save. Costly if operations not carefully planned.

Cost Implications

Costs vary in accordance with the amount of different overburden types present, terrain, geometry of the mine site, mining method, and equipment available. The cost of using this technique will have to be developed on an individual site basis. Costs cannot be determined from past application of this technique because it is used in conjunction with other techniques. Costs of this technique have never been isolated from costs Of the entire mining operation, but in urban and transportation earthworks, scraping and stockpiling of earth may run in the $.75 to $1.50/cu. m. range depending upon volume and haul distance

Previous Experience

Commonly used technique in its simplest form however, increased benefits can accrue if technique more rigorously applied.

Source of Information 145.

Title Mineral Barriers or Low Wall Barriers	67
Keywords Extractive, Sediments, Nutrients, Chemicals.	

Applicable Land Use	**Pollutant Controlled**
Extractive	Sediments Nutrients Chemicals

Description

Mineral barriers are portions of the mineral and/or overburden that are left in place during mining. These barriers are common in the coal industry. Approximately a 9 m width of coal outcrop is left in place during contour strip planning. The basic function of this "low wall barrier" is to provide a natural seal along the outcrop. This seal helps retain surface and mine water within the mine during the mining operation, after mining the barrier helps to confine groundwater within the regraded mine spoil. Mineral barriers are also left between surface mines and adjacent deep mines to prevent the free passage of water between the mines.

Mineral barriers appear applicable to the dredge mining industry. A barrier could be left between the dredging operation and an adjacent stream or body of water in order to contain large amounts of sediment often generated from the mine area.

Advantages	**Disadvantages**
Low wall barriers are applicable to most types of contour mining. They function best when mining has been performed to the rise of the mineral seam. Effectiveness of the barrier depends upon the integrity of the formation and local hydrologic conditions. The barrier should be utilized in the context of a reclamation plan.	Can provide obstruction and inconvenience to vehicle movement. All of mineral deposit is not utilized.

Cost Implications

The costs of this technique are a function of the site conditions of the individual mine site. They have not in the literature been separated therefore estimation is difficult. Unfortunately a low wall barrier used in contour mining contains the most easily extractable mineral in the mine. The minerals remaining in the barriers are not likely to be mined in the future because of their geographic distribution over large areas.

Previous Experience

Design methodology and criteria well developed. In current use by some coal extraction operations.

Source of Information 145.

Title Longwall Strip Mining	68
Keywords Extractive, Sediments, Nutrients, Chemicals.	

Applicable Land Use	**Pollutant Controlled**
Extractive	Sediments Nutrients Chemicals

Description

This concept is an adaptation of longwall underground mining. It is being investigated for mining of seam-type mineral deposits such as coal as an alternative to strip mining. A vertical trench is cut into the hill perpendicular to the coal outcrop then automatic mining equipment is inserted in this trench and progresses through the coal seam in a direction parallel to the outcrop. Coal is cut by machine and transported to the outcrop with a conveyor belt. The mine roof is held up with hydraulic jacks that progress forward with the cutting equipment allowing the roof to collapse behind the miner.

Advantages	**Disadvantages**
This type of mining does not leave underground void spaces. It does not disturb the overlying material as in strip mining and could provide a high percentage of coal recovery. Equipment is controlled remotely keeping people out of the danger area.	In view of limited application to date it must be considered experimental.

Cost Implications

Costs are not yet available.

Previous Experience

A few installations in the coal fields of Pennsylvania.

Source of Information 145.

Title Modified Block Cut or Pit Storage	69

Keywords Extractive, Sediments, Nutrients, Chemicals.

Applicable Land Use	**Pollutant Controlled**
Extractive	Sediments Nutrients Chemicals

Description

This method was developed as an alternative to standard contour strip mining, to facilitate contour regrading, minimize overburden handling, and to contain spoil within the mine areas. An initial cut is made from a crop line into the hillside for the maximum high wall depth desired and suitably cast in a low area or placed in a suitable pit or hollow fill area. This cut is usually three times wider than each succeeding cut in order to accommodate spoil material from succeeding operations after removal of the mineral vein from the open block. Spoil from the succeeding cut is backfilled into the previous cut proceeding in one or both directions from the initial cut. This step simultaneously allows resource recovery and provides the first step in strip mine reclamation.

Advantages	**Disadvantages**
- overburden is handled only once, grading and revegetation areas are reduced - concurrent reclamation , relatively small disturbed area, use of contour regrading and confinement of most of the spoil to the mine area	- limited at present to terrain slopes of less than 20^0 and average high wall height of 18 m. - problem placing material from first cut of overburden
Capital Costs	**Operating and Maintenance Costs**
It appears that this method is no more expensive than any other method where contour regrading is required and could eventually prove to be less costly.	

Previous Experience

Utilized in the coal fields of Pennsylvania.

Source of Information 145.

Title Head-of-Hollow-Fill	70

Keywords Extractive, Sediments, Nutrients, Chemicals.

Applicable Land Use	**Pollutant Controlled**
Extractive	Sediments Nutrients Chemicals

Description

This technique is essentially an overburden storage method. Overburden material from adjacent contour or mountain top mines is placed in narrow steep sided hollows. The material should be properly placed in compacted layers of 1.2 to 2.4 meters and graded so that surface drainage is possible. The natural ground should always be cleared of woody vegetation. Site should be selected where natural drainage exists or may have existed except in areas where inundation occurs. This permits ground water and natural fertilization to exit fill areas without saturating the fill, this reduces potential landslide and erosion problems.

Advantages	**Disadvantages**
Provides a means of cleaning up islands of land left with no access resulting from in complete prior mining. Can reduce landslide potential and allow for full recovery of one or more mineral seams. Effectiveness depends upon good design and construction of drainage facilities.	Leaves behind a large amount of disturbed soil. Underdrainage containing high concentrations of pollutants sometimes results and may require treatment.

Cost Implications

Cost of head-of-hollow filling will depend upon the method of mining it supplements. Haul distances, site preparation and equipment used must be taken into account at each proposed site. Costs could be reduced in some applications where box cut or modified block cut mining methods are used, due to a consequent reduction in material to be discarded outside the mine bench.

Previous Experience

Utilized in the coal fields of Pennsylvania.

Source of Information 145.

Title Box Cut Mining	71
Keywords Extractive, Sediments, Nutrients, Chemicals.	

Applicable Land Use	**Pollutant Controlled**
Extractive	Sediments Nutrients Chemicals

Description

The box-cut method, utilizing only one cut, is essentially a normal form of contour strip mining which leaves an undisturbed bench over a low wall. Overburden is discarded down slope, using an acceptable slope control technique and eventually regraded. With two cuts, vegetation is removed and suitable top soil overburden material stock piled. Remaining overburden is removed to a pre-determined elevation and cast down slope. The box cut operation then begins nearest the exposed high wall with this overburden cast over the low wall area, the mineral is then extracted from the first cut opening. A second cut is then made toward the low wall barrier with the spoil material cast into the first cut trench.

Advantages

- generally applicable to surface mining on rolling to steep terrain
- may be applied to multiple seam vein resource recovery
- progressive restoration

Disadvantages

- unless some very careful planning is done and operations carefully controlled further problems may develop
- steep slope conditions could severely limit the application
- problem of preventing slide conditions, spoil erosion, and resultant stream sedimentation from occurring.

Cost Implications

This is a relatively inexpensive mining technique. Costs have not been broken out for this specific aspect. Costs will vary according to the mining plan, local factors at each mine site.

Previous Experience

Open pit mining areas of Pennsylvania, Ohio and Minnesota.

Source of Information 145.

Title Area Mining	72

Keywords Extractive, Sediments, Nutrients, Chemicals.

Applicable Land Use	**Pollutant Controlled**
Extractive	Sediments Nutrients Chemicals

Description

Area mining involves removal of large blocks of material whereas contour mining removes narrow bands of material. An area mine is usually started with a box cut or trench extending to the limits of the property or vein deposit with a concomitant parallel spoil bank. Spoil material from each successive parallel cut or trench is placed in a preceding trench. Last cut or trench is bounded by overburden material on one side and an undisturbed highwall on the other side.

Advantages	**Disadvantages**
Has fewer associated problems than contour mining. A large portion of sedimentation occurs within the mine and never reaches external surface flow channels. Spoil landslides are rare. Regrading of area mine land usually less expensive.	Area mining has greater potential for ground water pollution. Overburden segregation, water diversion, regrading and revegetation are necessary in conjunction with area mining to eliminate water pollution and improve aesthetics.

Cost Implications

This is a mining technique and not a reclamation technique. Costs of reclamation are an integral part of the total mining operation and therefore have not been broken out.

Previous Experience

Common open pit mining technique.

Source of Information 145

Title Auger Mining	73

Keywords Extractive, Nutrients, Chemicals.

Applicable Land Use	**Pollutant Controlled**
Extractive	Nutrients Chemicals

Description

This mining method is used to recover coal behind a high wall of a surface mine. Large augers are driven horizontally about 60 metres into a pole seam. Coal is recovered in a manner similar to wood chips from a drill bit, successive parallel holes are driven into the pole seam until the operation becomes unfeasible. The strip mine is then back-filled over the auger hole openings. Recovery is often less than 40%.

Advantages	**Disadvantages**
If carried out properly pollution potential can be minimized.	Special compaction procedures are required when backfilling auger holes, if auger operation is carried out in acid producing seams of coal, problems of adequate sealing may occur.

Cost Implications

This is a mining technique rather than a remedial technique therefore costs have not been determined.

Previous Experience

Generally in developmental stage.

Source of Information 145.

Title Reducing Surface Water Infiltration	74

Keywords Extractive, Solid Waste Disposal, Chemical, Nutrients_

Applicable Land Use	**Pollutant Controlled**
Extractive Solid Waste Disposal	Chemical Nutrients (through groundwater)

Description

This technique involves reducing surface permeability of pollution forming materials. This can be achieved by placement of impervious materials such as concrete, soil cement, asphalt, rubber, plastic, latex and clay. This effect can also be achieved by surface compaction and by chemical surface treatment such as carbonate bonding.

The impervious material is applied in a layer on the pollutant forming material to form a water tight seal over it. The remaining materials and overburden above are left exposed depending upon the material and the future land use. Each particular technique has very specific procedures that must be followed in order either to protect the integrity of the material or to ensure that proper mixing and therefore resultant qualities are developed.

Advantages

- Reduction in water percolating through pollution forming materials therefore, resulting in decrease in leachate production - less volume of higher concentration

- leachate is usually easier to handle and treat if required.

Disadvantages

Wide range of costs often in proportion to efficiency. Some materials very prone to damage, possible effects of settlements, quality control must be strict.

Cost Implications

The costs of these techniques vary widely due to the nature of the sealant materials. Individual costs are dependent upon such factors as volume of material required, thickness and area of application, labour, material and equipment costs. Clay $2.30 to $7.80 per cubic metre. Gunite $19.00 to $22.00 per sq. metre. Asphalt $2.40 to $6.00 per sq. metre. Carbonate bonding $.95 to $3.00 per sq. metre. Synthetic membranes varying in thickness and in composition range from $2.70 to $10.75 per sq. metre.

Previous Experience

Materials are widely available and technique is applicable and used throughout the Great Lakes Basin.

Source of Information 145.

Title Road Planning $ Design	75

Keywords Forestry, Transportation, Sediments.

Applicable Land Use	**Pollutant Controlled**
Forestry Transportation	Sediments

Description

Roads, both during construction and while in service, are the largest single cause of sedimentation in water courses in forested areas. No amount of design or construction expertise will eliminate sedimentation as well as a thorough planning and reconnaissance program. At this stage the potential for mass earth movement, high unstable soils, soil erodability, unstable stream channels, etc. should be identified. Also, activity should be limited in areas adversely affected by landform, climate, topography, etc. and assessments should be made of land capabilities to recover. Considered to be the most important phase of logging road development.

Advantages	**Disadvantages**
- reduces costs not anticipated when roads are located in an improper manner. - allows anticipation of erosion problems before they occur therefore, resulting in preventative measures being taken.	

Cost Implications

Increased design costs and time to implementation. Possible savings in construction and restoration costs.

Previous Experience

Advocated by logging companies and government agencies in Canada and U.S. Methodology and criteria well developed.

Source of Information 130, 128, 129.

Title Blocking	76

Keywords Extractive, Chemicals,

Applicable Land Use	**Pollutant Controlled**
Extractive	Chemicals

Description

Blocking is any process that reduces amount of oxygen entering the mine sulphide environment and thereby reduces amount of sulphide acid produced. Various methods of oxygen exclusion have been tried. Among the less successful are latex surface barriers, groundwater-aquifer control, filling, and removal of solids. The most successful - blocking with grouted limestone blocks, also provides a measure of neutralization and retards groundwater movement. Oxygen contents of 16-17% have been achieved with 50-60% reduction in H_2SO_4 production.

Advantages	**Disadvantages**
- moderately effective - reduces acid production and leaching of other chemicals	- unforeseen fractures and irregularities cause groundwater movement and re- oxygenation

Cost Implications

Not available from literature sources.

Previous Experience

Field Experimental

Source of Information 8, 142, 145.

Title Check Dams	77

Keywords Urban, Transportation, Agricultural, Recreation, Sediments, Erosion.

Applicable Land Use		**Pollutant Controlled**
Urban Transportation Agricultural Recreation	Lakeshore $ Riverbank Erosion	Sediments

Description

A check dam is a structure used to reduce the gradients in channels to thereby control headward and streambank erosion. By reducing gradients in the channel flow, velocities are reduced and therefore erosion is reduced. At the drop structure an abrupt change in grade is created in a localized area which is protected from erosion. Check dams are used where the capability of the earth and/or vegetative measures are exceeded in the safe handling of water at permissible velocities, where excessive grade or over- fall conditions occur, or where water is to be lowered from one elevation to another. Structures can be made of concrete, metal, rock, gabions, fabriform, wood, etc. depending upon site conditions. Widely used for watercourse stabilization.

Advantages	**Disadvantages**
- indirect control of nutrients, pesticides, re-aeration of stream	- site specific design required - upstream and downstream effects must be considered - fish movement restricted

Cost Implications

Capital - Site specific, dependent on design

Design Life - Varies depending on materials, 5 to 50 years

Operating & Maintenance - 1% to 2% of capital cost per year

Previous Experience

Widely used in all parts of Canada and U.S.

Source of Information 92, 108, 110, 120, 126, 106.

Title Retaining Walls for Road Construction for Steeper Slopes	78
Keywords Forestry, Transportation, Sediments.,	

Applicable Land Use	**Pollutant Controlled**
Forestry Transportation	Sediments

Description

Retaining walls bring about an abrupt change in grade or enable the utilization of a steeper overall slope than otherwise possible. Three types of walls are used and each has a limited height design.

1. Gravity walls or buttresses are suitable for moderate soil pressures and are designed for the height of 2.4-3 metre walls.

2 Crib walls can be built up to 6 metre to withstand moderate soil pressure

3. Cantilever walls allow a 7.6 metre height to counteract most soil conditions.

This has proven to be an effective method to eliminate most soil movement.

Advantages	**Disadvantages**
- allows roads to be built across steeper slopes than normally possible	- very costly - may be susceptible to soil erosion unless otherwise designed
Capital Costs	**Operating and Maintenance Costs**
Capital Cost in the order of $300 to $1000 per metre depending upon height and soil conditions.	- Maintenance should be minimal if properly designed and constructed.

Previous Experience

Methodology and design criteria well developed. Prefabricated sections available from many suppliers. In common usage.

Source of Information 130, 108, 110, 128.

Title Revegetation - Reforestation of Cut Areas and Bare Slopes	79

Keywords Forestry, Transportation, Extractive, Urban, Sediments.

Applicable Land Use		**Pollutant Controlled**
Forestry Transportation Extractive Urban	Lakeshore & Riverbank Erosion	Sediments

Description

The greatest amount of erosion from roads (after construction) occurs during the first year after completion and decreases thereafter. Vegetative establishment (grasses and/ or trees) should be initiated immediately after soil disturbance. If necessary, revegetation should be accompanied by fertilizers, mulches, chemical soil stabilizers, watering or mechanical measures to ensure quick vegetative growth and limit high initial rates of soil loss. It should be carried out at an optimum time of year to ensure maximum amount of growth during the first season.

This technique is also applicable to lakeshores and riverbanks left bare by erosion or following slope lowering, construction of road or utility crossings, etc.

Advantages	**Disadvantages**
- one of the cheaper and most effective methods of soil stabilization - decreased overland flow, increases infiltration and is aesthetically pleasing - also advantageous to wildlife	- dependent upon climatic conditions
Capital Costs	**Operating and Maintenance Costs**
- Grass revegetation costs could range from $250/hectare for hand broadcasting of seed with no mulch, to $3000/hectare for hydro-seeding and mulch. Tree planting - seedlings often available from gov't sources - installation $400 to $750 per hectare - many gov't installation programs available.	Maintenance Costs are dependent upon species planted, thinning and pruning required.

Previous Experience

Wide spread common use. Design criteria and guidelines easily available and well documented.

Source of Information 119, 38, 107, 108, 110, 120, 126, 128, 133, 145, 237, 106.

Title Vegetative Buffer Strips	80

Keywords Forestry, Agriculture, Urban, Liquid Waste Disposal, Sediments, Nutrients.

Applicable Land Use		**Pollutant Controlled**
Forestry Agriculture Urban	Liquid Waste Disposal	Sediments Nutrients

Description

Where vegetation is being cleared adjacent to a watercourse, a strip of riparian vegetation should be left along the streambank. The wider the strip the more effective it will be in filtering out sediment. In agricultural lands, grass buffer strips between row crop areas and watercourses have been found very effective. Not only does a vegetative strip filter out sediment carried in overland flow, it also reduces and slows down overland flow that causes rilling and gullying on streambanks. Vegetative (buffer strips add to the stability of the upper zones of the bank. This is a useful practice as cultivation up to the edge of the bank leads to a weakening of the top of the bank and contributes to bank failure.

Advantages

- economical method of reducing sediment entering the stream course
- important to aquatic life, retains water temperatures, does not increase BOD

Disadvantages

- often leaving a strip of vegetation may lead to its demise due to sudden exposure thus this method may prove ineffective unless well planned
- small areas taken out of production

Cost Implications

Installation costs can range from $250/hectare for minimal tillage and manual broadcasting of seed to $3000/hectare for hydroseeding with mulch, however, costs due to land removed from production must also be considered.

Previous Experience

The retention of vegetative buffer strips around fence lines and adjacent to streams and wet lands occurs naturally, however, the intentional widening of these buffer strips is not difficult.

Source of Information 181, 182, 38, 87, 107, 108, 110, 120,126, 133, 180, 239, 237, 92, 106, 129.

Title Sediment Basin	81

Keywords Forestry, Transportation, Urban, Agriculture, Solid Waste, Sediments.

Applicable Land Use		**Pollutant Controlled**
Forestry	Solid Waste	Sediments
Transportation	Extractive	
Urban	Lakeshore & Riverbank	
Agriculture	Erosion	

Description

Where sediment laden ditches or conduits discharge into watercourses, or prior to discharge into recharge facilities, the reduction of sediment load is desirable. Storage areas and flow velocities are significantly reduced and retention times sufficient for settling are the basic design requirements. Stokes Law for the settling velocities of particles in fluids is used as the fundamental design formula. Sedimentation basins can be designed to remove all particles larger than the specified design size. The retention time and surface area vary inversely with the design particle size. These facilities require maintenance and removal of debris and accumulated sediments if the basin is to remain effective.

Advantages

- a method suitable for many structures which would certainly enhance the quality of water entering natural streams
- decreases turbidity and BOD

Disadvantages

- not adaptable to all situations
- costs may be too great in relation to the project
- difficult and expensive to remove fine particles in this manner.

Cost Implications

Varies according to depth, area, availability of materials, type of control structure, accessibility, etc. from $2000 up.

Previous Experience

In common use. Design methodology well developed and documented.

Source of Information 180,120,119,107,110,108, 38, 81,126, 134, 92, 106, 190, 239, 237, 232, 207, 210, 221, 231, 248, 249.

Title Rip Rap Bank Protection	82

Keywords Urban, Transportation, Agricultural, Shoreline Landfilling, Sediments.

Applicable Land Use		**Pollutant Controlled**
Urban Transportation Agricultural	Lakeshore & Riverbank Erosion Shoreline Landfilling	Sediments

Description

Rip rap is broken angular rock which when placed in ditches and on streambanks provides physical protection against the scouring action of flowing water and provides resistance to surficial sloughing of the bank material. The rip rap rock should have a size gradation to allow packing of the layer to minimize voids. It should be sized to withstand the shear forces exerted by the stream velocities to which it will be exposed.

When rip rap sizes exceed about 0.5m in diameter, it is also referred to as "armour stone". Such large rip rap or armour stone is used extensively for shoreline protection and shoreline landfilling as protection against wave action.

Advantages	**Disadvantages**
- economical method of providing localized or lengthy protection against stream- bank erosion - control of undermining or loss of structures and useable land	- requires sloping surface of 2H to 1V to 4H to 1V depending upon soil conditions and stream hydraulics
Capital Costs	**Operating and Maintenance Costs**
$9.00/sq. m. to $18.00/sq. m. depending upon size of rock required.	Periodic : replacement or regrading of localized areas where extreme event exceeds design capability of installation is required.

Previous Experience

Widespread throughout North America.

Source of Information 92, 38, 81, 107, 108, 110, 120, 126, 232, 106.

Title Protection of Culvert Outlet, Chute Outlets, etc.	83
Keywords Urban, Transportation, Agriculture, Sediments.	

Applicable Land Use	**Pollutant Controlled**
Urban, Transportation Agriculture Lakeshore & Riverbank Erosion	Sediments

Description

The velocity of flow is nearly always speeded up during passage through a culvert or tile outlet and always when passing down a chute. A scour hole or plunge pool will develop unless the end of the culvert or chute is protected. Should such develop, the risk of failure of the entire structure is increased. Three basic types of protection are suggested:

1) Plunge Pool: The plunge pool that is anticipated to develop can have its effect protected against by deepening the head wall of the outlet below the probable scour depth. Initial loss of local materials will occur and then stabilization will result.

2) Protected Apron of Riprap, Gabion, Concrete, etc.: If the plunge pool is not acceptable, dumped rock, hand placed riprap, rock filled gabion baskets, concrete mat, etc. may be used to provide an erosion resistant, energy dissipating area adjacent to the culvert or to outlets, thereby protecting the area subject to erosion with an artificial. covering.

3) Stilling Basins: Where flow is excessive for the economic use of dumped stone or other energy dissipaters, stilling basin can be used. The function of a stilling basin is similar to that of a plunge pool.

Advantages	**Disadvantages**
- if a plunge pool forms at culvert mouth, it may severely weaken a culvert embankment thus threatening its stability - scouring in a culvert mount can start gully erosion which may gradually extend upstream and destroy all the lateral support of the culvert, therefore causing failure.	
Capital Costs	**Operating and Maintenance Costs**
The size and type of structures required are dependent upon the design flow, soil conditions and available areas for the construction of the facility. Costs may range in the order from $50 for dumped rock in small applications to many thousands of dollars for sophisticated stilling basins for large flows.	Extreme runoff events may require some restoration or repositioning of rip rap.

Previous Experience

Common practice. Design methodology and criteria well established.

Source of Information 110,107,180,120,181,81,108,126,232,92, 106.

Title Dolos (Offset asymmetric tetrapods)	84
Keywords Shoreline Landfilling, Sediments.	

Applicable Land Use	**Pollutant Controlled**
Shoreline Landfilling	Sediments

Description

Dolos are offset tetrapods size designed to prevent wave action from causing erosion by providing a barrier against which waves break. The barrier may be on or offshore. Delos are designed to be placed in an interlocking manner so that they do not move independently, but act in unison against impinging wave energy. They may be constructed out of steel or concrete.

Advantages	**Disadvantages**
This expensive procedure is usually undertaken on high energy shorelines presented to open oceans, however, can be used for lower energy shorelines by scaling down the size of the dolos	Maintenance must be carried out to ensure broken dolos are either repaired or replaced as broken units allow movement that can become destructive. Large crane equipment required for emplacement and maintenance.
Capital Costs	**Operating and Maintenance Costs**
\$980/15 cu. m. unit.	- periodic replacement of damaged units.

Previous Experience

Used in many places around the world for harbour protection in high energy wave zones.

Source of Information 238

Title Engineering, Design E Management for Shoreline Landfilling	85

Keywords Shoreline Landfilling, Sediments, Chemicals, Nutrients.

Applicable Land Use	**Pollutant Controlled**
Shoreline Landfilling	Sediments Chemicals Nutrients

Description

By design and engineering of both the shoreline plan and beach profile based on a knowledge of storm-wave direction it is possible to plan filling operations to minimize turbidity from eroded fill and thereby minimize muddy bottoms where undesirable. Management of filling operations should be undertaken to place non-contaminated, coarse, resistant materials in sensitive locations where wave action is expected to be at a maximum from a preceding design programme. Using this approach it is possible to locate contaminated fill where erosion and hence dispersal is to be non-existent or at a minimum. Filling should be undertaken in calm weather when forecasts are favourable. Filling in designated sensitive areas should be only behind protection structures and headlands with suitable filter methods to prevent escape of fine material. Logical and rational design and management probably the best way to minimize turbidity, loss of fill material and spread of possible contaminated fill.

Advantages	**Disadvantages**
- more economy of fill because of lower loss of material	- limited to effectiveness of structures used in design and the design itself.

Cost Implications

Higher cost of engineering and construction management but should be offset by lower maintenance and less environmental damage.

Previous Experience

Various shoreline modifications some of which are exceptionally long lasting. This technique is now required by most appropriate regulatory agencies.

Source of Information 127

Title Revegetation of Mine Tailings: Stablization	86
Keywords Extractive, Sediments.	

Applicable Land Use	**Pollutant Controlled**
Extractive	Sediments

Description

Various seed densities and plant types are applied to various slopes on a tailings dump at Erie Mine Company in the Mesabi Iron Range. The tailings are basic Off 7.4 -8.4 with sufficient potash to sustain growth. Nitrogen 60 kg/ha and phosphorus 36 kg/ha are placed and mixed into the top 1.5 to 2 cm of the tailings. Seeding times were found to be important with optimum results in May and October. Two mixtures were found to work well:

Intermediate Wheatgrass	17 kg/ha	Smooth Brome	22.5 kg/ha
Red Fescue	17 kg/ha	Perennial Rye Grass	5.5 kg/ha
Alfalfa	11 kg/ha	Alfalfa	5.5 ka/ha
Birdsfoot Trefoil	5.5 kg/ha	Birdsfoot Trefoil	11 kg/ha
	50.5 kg/ha		44.5 ka/ha

Mixture is applied in mulch or tack on straw. Mulch should be a hay mulch on slopes of 3:1 or less. Opportunities for a high percentage of successful seedings exist if the following six principles are followed: 1) use of adapted plant materials for land use desired; 2) proper seedbed preparation; 3) mulching; 4) proper seed placement; 5) planting date to coincide with the season of highest precipitation probability unless to be irrigated; and 6) proper management during establishment and after a stand is established.

Advantages	**Disadvantages**
The procedure is useful in controlling erosion & therefore sediment loss to streams. Slope & pH have to be considered in designing the mixture. Maintenance is essential food chain for first 3-4 years otherwise causes large scars and sediment discharges. Returns a scarred landscape to aesthetic greenery again. Frequent use is made by wildlife deer, rabbit, fox and birds.	- slope limitations - may require pH adjustment - may introduce toxic elements into - a partial management practice only.
Capital Costs	**Operating and Maintenance Costs**
$2000 to $3000 per ha cost for Lime addition if low pH is encountered.	cutting of grass - fertilizing until well established

Previous Experience

Many mining companies have some experience with revegetation.
Sudbury, Elliot Lake.

Source of Information 197, 198, 38, 145, 200.

Title Slope Lowering of Spoil and Tailings Stockpiles	87
Keywords Extractive, Sediments.	

Applicable Land Use	**Pollutant Controlled**
Extractive	Sediments

Description

Normally stockpiles of spoil are made high with slopes approaching the angle of repose of the material.

Lowering of slopes has several advantages:

1) Increases the stability to prevent gross movements of soil

2) Decreases the susceptibility of the soil to particulate erosion

3) A further bonus is the rapidity of vegetative growth with a minimum of maintenance because of sheet wash and gullying.

Slopes in excess of 3:1 have been found difficult to work and maintain while slopes of 5:1 are considered ideal for controlled runoff and vegetative rehabilitation. Often low slopes can be achieved by planning in the final design.

Advantages	**Disadvantages**
- low runoff and siltation - aesthetic improvement	- extra cost incurred from grading - larger land area required
Capital Costs	**Operating and Maintenance Costs**
Unit Costs: $0.18 to $1.15/cu.m. with a mean of $0.48 for spoils moving Grading Costs: $530-$5000/ha with a mean of $2150/ha	

Previous Experience

Many examples in United States and Ontario for treatment of old tailings stockpiles. Most new tailings stockpiles are included in a restoration plan.

Source of Information 197, 200, 196, 38,145.

Title Package Sewage Treatment Plants (Multi-Family Use)	88

Keywords Urban, Agricultural, Recreational, Nutrients, Chemicals, Sediments,

Applicable Land Use	**Pollutant Controlled**
Urban Agricultural Recreational	Nutrients Chemicals Sediments

Description

These units provide waste water treatment typically through an extended aeration process to serve a small number of housing units or a livestock operation which cannot feasibly be served by municipal sewers due to isolation, economics of scale, or phasing of development. This is a sewage treatment method for residents or operations in locations that require high effluent quality. It can also be used to serve industrial and commercial uses or residential subdivisions temporarily until such time when public sewer connections may be made. Effluent is suitable for field disposal or for stream discharge in some cases where the assimilation capacity is sufficient. The package plants are usually made of a five part system; bar screens; grit chamber; aeration tank; settling tank; and chlorine contact chamber. Package plant (factory built) systems are typically in the five to one hundred unit capacity, but there are plants on the market to serve a population of up to 10,000 persons in small communities, resorts, large sub-divisions and other developments. These units are prefabricated for field assembly by a skilled crew.

Advantages	**Disadvantages**
- the extended aeration process eliminates the need for a primary settling tank and digester required in the conventional activated sludge process - extremely flexible to local conditions - may release urban development of an area from restraint of municipal sewer extension.	- ore expensive per unit than municipal treatment when central sewer system is feasible - regular skilled maintenance often not carried out resulting in failure and subsequent pollution - local authorities hesitant to issue permits for package treatment plants
Capital Costs $1,000 to $1,500 per family unit served excluding sewer costs. $0.40 to $0.65 per litre per day capacity.	**Operating and Maintenance Costs** $0.12 to $0.18 per 1000 litres treated

Previous Experience

Widely used in Ontario and United States. Many types of equipment/plants available from several suppliers.

Source of Information 53, 92.

Title Waste Exchange for Resource Recovery	89

Keywords Solid Waste, Chemicals.

Applicable Land Use	**Pollutant Controlled**
Solid Waste	Chemicals

Description

A coordinating body which actively promotes cooperation between and among industries who can accept and utilize waste materials. The body can act merely as a catalyst or an information exchange to alert industries of potential markets for waste residue or it can also be a materials handling body (a clearing house) which actually transfers waste materials from the producer to the consumer.

Advantages	**Disadvantages**
- may prove invaluable as source of raw materials for industries while solving waste disposal problems for others - reduction of industrial solid wastes, less land required for disposal - reduction in use of virgin materials	- requires extensive public relations work to be established and continual updating of information required

Cost Implications

Dependent on type of management setup. Costs are minor for information exchange only and this type of setup possibly requires one full-time technical advisor and several part-time secretaries. If the setup is a clearing house type, this would require warehouse, equipment, etc.

For information only type exchange: - $61,000 to $83,500 first year
$44,500 to $53,000 second and subsequent years

Previous Experience

St. Louis, Europe and Great Britain
Pilot project to be undertaken by Canadian Government.
Feasibility Study undertaken in Ontario.

Source of Information 179

Title Head Gradient Control	90

Keywords Solid Waste Disposal, Sediments, Chemicals, Nutrients.

Applicable Land Use	**Pollutant Controlled**
Solid Waste Disposal	Sediments Chemicals Nutrients

Description

This technique is underlined by the principle that water flow through a sanitary landfill site should be minimized in order to minimize the production of undesirable leachates and gas. Head gradient through a landfill can be controlled to an extent by the construction of some or all of the following: tight earth dam between refuse and water; intercept all surface and groundwater before it reaches fill area; equalize and maintain water level on all sides of the fill; compact refuse and cover with impermeable material with gas vents installed; seed cover material with high transpiration crops.

Advantages	**Disadvantages**
- protection of aquifer - reduces soil erosion	- may still require leachate treatment

Cost Implications

Site specific. Dependent on location, soil conditions, rainfall, types of wastes landfilled and operational characteristics. Gravity interception drains are usually more economic than dewatering wells but both are very geology dependent.

Previous Experience

Several installations in Canada and the United States.

Source of Information 267

Title Biological Treatment	91
Keywords Solid Waste Disposal, Sediments, Chemicals, Nutrients.	

Applicable Land Use	**Pollutant Controlled**
Solid Waste Disposal	Sediments Chemicals Nutrients

Description

Laboratory demonstration to show feasibility of adding landfill leachate (5% of flow) to domestic wastewater for treatment using activated sludge. Glass, cans, metals, bottles, stones, wood, plastics, plastic coated papers removed from mixed refuse prior to saturation and bleeding of leachate. Leachate mixed with domestic wastewater and various parameters monitored. Poor solid-liquid separation occurred at times and prime nutrients necessary for biological treatment were found to be missing.

The demonstration showed limited treatability of landfill leachates in activated sludge plants, but requires further studies on solid-liquid separation, nutrient addition, and optimum sewage-leachate mixing ratio.

Advantages	**Disadvantages**
- able to utilize municipal systems	- experimental

Cost Implications

Where suitable municipal system is available, leachate treatment costs likely to be more economical than construction of on site treatment facilities. Costs are municipally dependent upon particular treatment facilities and effluent standards required.

Previous Experience

Lycoming County, Penn. tried aerated lagoons.
Toronto, Ontario
Region of Peel, Ontario

Source of Information 76, 45.

Title Streambank Protection with Vegetation	92
Keywords Urban, Agriculture, Erosion, Sediments.	

Applicable Land Use		**Pollutant Controlled**
Urban	Lakeshore & Riverbank	Sediments
Agriculture	Erosion	

Description

This technique may be used to stabilize banks in swales, creeks, streams and rivers as well as man-made ditches, canals, impoundments, including ponds and storage basins. Streambanks may be divided into four zones: aquatic plant zone at the mean low water level; reed bank zones covered at peak flow stage; lower riparian zones or open flood- way zones naturally covered with willows and shrubbery plants; upper riparian or flood fringe areas that would naturally be covered with canopy forming trees.

Aquatic plants are often considered weeds and a nuisance though they do slow down stream flows and protect the stream bed.The reed bank zone forms a permeable obstacle slowing down current waves by friction. Suitable plants are the common reed, reed grass and bulrush. The lower riparian zone usually has a natural growth of willow, alder, buttonbush, small maples, sweet gum, etc. These vegetative types can be reintroduced on denuded flood plains to stabilize soil with roots. In periods of high water their upper branches reduce the velocity and erosive force of the water. Willows are the most commonly reintroduced and readily available for this use. The upper riparian zone is rarely flooded. Wood in this zone can include most species indigenous to the area.

A high degree of stabilization is possible in areas of low velocity flow.

Advantages

- stream bank vegetation can break wave action and the velocity of flood flows
- roots and rhizomes stabilize streambanks - reduction of velocity can lead to deposit of water borne soil particles
- certain reeds and bulrushes have capability of improving water quality by absorbing certain pollutants such as heavy metals, detergents, phenols and idols.

Disadvantages

- general reluctance of engineers to use natural material
- native plants are not carried by regular nurseries and often have to be obtained by hand or from special nurseries
- flow retardant aspects of vegetative waterways need to be taken into account

Capital Costs

Dependent on types of vegetation.
May range from $150/ha to $500/ha.

Operating and Maintenance Costs

- should only require minor restoration after extreme runoff events.

Previous Experience

Common practice throughout Great Lakes Basin. Criteria and plant material widely available.

Source of Information 191, 107, 180, 120, 110, 38, 87, 108, 126, 221, 239, 237, 232, 92.

Title Grass Channels or Waterways | 93

Keywords Urban, Transportation, Agriculture, Nutrients, Erosion, Sediments..

Applicable Land Use		**Pollutant Controlled**
Urban	Lakeshore & Riverbank	Sediments
Transportation	Erosion	Nutrients
Agriculture		

Description

For velocities up to 2.5 m per second for favourable soil conditions, runoff can be handled by grass channels if correctly graded and stabilized. They may be used on any site where flow velocities make the use of grass swales feasible based upon the hydraulic gradient. On highly erodible soils a lower design velocity must be used. Grass waterways may be built in parabolic trapezoidal. or V-shaped cross-sections. Parabolic cross-sections are most commonly found in nature and have proven most satisfactory. Waterways constructed of trapezoidal sections tend to revert to a parabolic shape. Side slopes should not exceed 3 to 1 to enable the channel to be maintained by mechanical means. A well developed design methodology should be used to match the permissible velocity with the soil conditions and the grass variety that is to be used.

Properly designed grass channels or waterways will provide a high degree of erosion control however, the period of innundation must not exceed tolerance of grasses used.

Advantages

- grass lined channels are cheaper than those lined with concrete or stabilized by a biotechnical measure
- grass will delay runoff and considerably reduce energy and consequently erosive capacity of runoff
- grass channels are visually more acceptable than those lined with other materials
- vegetative waterway allows infiltration thereby reducing runoff

Disadvantages

- very careful design and good maintenance program are necessary if channels with grass are to be effective without gully erosion
- installation of new impermeable surfaces in the channel drainage area may increase runoff velocity and exceed capacity of channel

Capital Costs

In place the cost of sod and channel lining is about $1.20/sq.m. Cost per hectare for seeding is around $2000, not including top soil but including fertilization. Wood and straw mulch about 18¢/sq.m. Seed, fertilizer and jute mesh costs about 60¢/sq.m.

Operating and Maintenance Costs

Careful maintenance can increase the capacity of grassed waterways. A yearly dressing of the proper fertilizer at about 5¢/sq.m. should be given to all grassed channels and they should be mowed regularly to encourage a tight sod.

Previous Experience

Common practice. Design methodologies and criteria well developed and documented.

Source of Information 232, 120, 110, 119, 181, 38, 87, 107, 108, 126, 207, 221, 239, 92, 177.

Title Permanent Diversions	94

Keywords Agriculture, Urban, Transportation, Forestry, Sediments, Nutrients, Erosion.

Applicable Land Use		**Pollutant Controlled**
Agriculture	Forestry	Sediments
Urban	Lakeshore F	Nutrients
Transportation	Riverbank Erosion	

Description

The purpose of a permanent diversion is to direct runoff from areas where it could cause erosion to areas where it can be disposed of safely. This measure is applicable to any site where there is an erosion hazard created by a concentration of runoff flowing over an unprotected area. The situation is most likely to occur on highly erodible soils on sites with a high proportion of steep slopes. Recently constructed fill slopes are most susceptible to damage in this manner. Permanent diversions are generally of three types:

1) Diversion Channel- Consists of a channel and a ridge across a sloping land surface which conveys water laterally at a slow velocity and discharges it into a protected area or outlet channel.

2) Diversion Berm - A well compacted earth fill ridge installed at the top of the slope or at top of steep slopes to divert storm runoff from these critical areas. For permanent installations a diversion channel is more common.

3) Bench Terraces: Relatively flat areas on sloping land constructed along the contour they can often be designed for width to allow for construction of roads or dwelling units following natural contour or for cropping purposes. In practice there will normally be a diversion channel at the lowest point of a bench terrace which may be constructed with a natural or reverse fall.

Advantages

- increased overland flow distance in diversion channels may significantly increase time of concentration of runoff from a drainage area

- his may reduce peaking of runoff allowing smaller culverts, etc. to be installed

- in many subdivisions, diversions may be incorporated into the pedestrian open space system

Disadvantages

- water seeps into diversion and sloughing may occur on unstable soil

- if slope is too steep, construction of diversion may cause erosion

- regular maintenance of channel vegetation is required

- where drainage area is steep or undergoing construction, channel may act as a sediment trap

Capital Costs

Varies with type. Ranges from $21.00/m. to $50.00/m.

Operating and Maintenance Costs

- mowing is required for weed control
- periodic removal of accumulated sediments that may affect hydraulic capacity.

Previous Experience

Common practice. Design methodology and criteria well established and documented.

Source of Information 92, 38, 107, 108, 110, 120, 126, 221, 239, 237, 232, 177.

Title Bank Protection by Jetties, Deflectors	95

Keywords Agriculture, Transportation, Urban, Shoreline Landfilling, Sediments, Erosion

Applicable Land Use		**Pollutant Controlled**
Agriculture Transportation Urban	Lakeshore & Riverbank Erosion Shoreline Landfilling	Sediments

Description

Jetties and deflectors are structures placed in watercourses or on lakeshores at an obstructive angle to normal flow or current thereby guiding flow direction to a less vulnerable or more desirable location. A jetty-deflector can deflect current or flow from an eroding bank and cause a buildup of sediments that can then restablize. Weirs and check dams, drop structures and falls are used to reduce the effective gradient of the stream to dissipate excess energy. It is often used in conjunction with jetties to reduce the erosive nature of a watercourse. These techniques should not be used on sites where the stream cannot safely compensate for restrictions in channel width either by bed scouring or by scouring the inside of the bend.

Advantages

- water falls dissipate excess energy which results from straightening of a channel and can reduce need for channel lining
- area of still water created by falls often increase recreational value
- deflectors and jetties cause areas of relatively still water where sediment loads are precipitated
- sediments deposited, help to stabilize bank.

Disadvantages

- areas of still water created by check dams cause stream to drop its sediment load and may result in siltation of the channel upstream from the fall
- deflectors will considerably restrict channel capacity and should only be used where the stream's natural tendency to compensate for this by scouring the bed or opposite bank will not cause problems.

Capital Costs

$9.00 to $18.00 per sq.m.

Operating and Maintenance Costs

- periodic replacement of damaged materials.

Previous Experience

Design methodology and criteria well developed and documented. Extensive works on some major United States rivers, some Ontario rivers, and a few examples on Great Lakes Shoreline.

Source of Information 233, 110, 38, 120, 126, 92.

Title Reduction and Elimination of Highway Deicing Salts	96

Keywords Urban, Transportation, Chemical.

Applicable Land Use	**Pollutant Controlled**
Urban Transportation	Chemical

Description

Deicing salts are a serious pollutant causing danger to vegetation, ground and surface water and serious corrosion to metal. Effective alternatives to calcium chloride and sodium chloride do not exist or else are not publicly accepted. The use of abrasives alone is not acceptable and results in great expense of cleaning curbs and catchbasins. Polyurethane tire chains which are quiet and don't damage road surfaces may be a future alternative. Other chemicals used as additives to salts also pollute. Sodium ferrocyanide decomposes by photochemical action to form cyanide. Control of drainage around stockpiles is important. Some agencies propose enclosure of all stockpiles.

Reduction of salt pollution can be effected by a) informing operators of proper techniques; b) establishing guidelines for application rates and optimum mixes; c) maintaining spreading equipment itself in first class condition to ensure even spreading; d) modifications to spreading equipment to improve effectiveness of application; e) applying salt in a fairly concentrated strip one to three feet wide on the middle one third of the pavement during storms; f) if chemicals are spread before a storm apply evenly over the whole area; g) new techniques such as pre-storm application of brine solution followed by the use of high speed snow blowers should be investigated; h) cautious applications in significant recharge areas; i) limiting application to critical steep slope and in intersections. Most corrosion inhibitors, such as sodium chromate or sodium hexametaphosphate significantly increase cost and further degrade runoff quality.

Advantages (of limiting deicing salts)	**Disadvantages**
- chloride ions move rapidly in soil E may pollute ground water $ surface water - chlorides cause serious corrosion to automobiles, highway structures etc - salt may damage roadside vegetation due to excessive chloride concentration	- use of deicing salts results from demand for "bare pavement" in periods of snow - policy is based on safety arguments, like stopping distances for icy roads is 145 meters; 55 metres for sanded $ 20 meters for salted, bare but wet roads. - delays due to snow storms may be costly. annual loss of an extra hour of time may result in millions of dollars of productivity - effective deicing is important
Capital Costs	**Operating and Maintenance Costs**
Reduction in amount of spreading equipment required but probable increase in damages due to accidents.	- decrease in Operating and Management cost! proportional to reduction in amount applied.

Previous Experience

Application rates are usually locally determined depending upon specific traffic intensity and accident frequency. Ontario Ministry of Transportation and Communications has done research in this area. They also have programs to enclose all salt stockpiles.

Source of Information 98, HRB Report, 134, 140, 196, 183, 207, 248, 92.

Title Septic Tank/Tile Bed Sewage Disposal	97

Keywords Urban, Agriculture, Recreation-Sewage Discharges, Nutrients,

Applicable Land Use	**Pollutant Controlled** Nutrients
Urban Agriculture Recreation - Sewage Discharges	

Description

Domestic sewage which carries nutrients can be effectively treated and disposed by the septic tank/tile bed system for low density urban, recreation and agricultural land uses. Sewage enters a one or two compartment tank where anaerobic biological activity degrades waste and traps both solids and grease. The still highly contaminated but solids-free effluent is sent to a tile bed for aerobic treatment in the soil and ultimate disposal by infiltration and evapotranspiration. Nutrients are generally contained by the soil. They have been used for larger establishments like schools and shopping centres.

Advantages	**Disadvantages**
- reliable, low maintenance, simple - adaptable to many soil conditions and topographies up to 25% slope.	- limited to porous soils, not good with shallow soil or high water table - very granular soils do not retain phosphorus - careful design required for poorly drained soils.

Cost Implications

Maintenance requirements include periodic pumping out of sludge and scum accumulations on a frequency of 5 to 10 years depending on the severity of use, products used in the home, care of disposal of insoluble materials and grease.

Pump out cost: $25 - $50.

Previous Experience

Common use throughout the suburban and rural areas of the Great Lakes Basin. Design methodology and criteria well developed and documented.

Source of Information 77, 140.

Title Miscellaneous Methods to Reduce Storm Runoff	98

Keywords Urban, Transportation, Sediments, Nutrients.

Applicable Land Use	**Pollutant Controlled**
Urban Transportation	Sediments Nutrients.

Description

1. Discharge of Roof Downspouts to Grassed Areas. Common practice in urban areas is to connect roof downspouts directly to storm sewers. This results in less water available for infiltration and causes faster overall runoff therefore, increasing runoff peak flows. Discharge to grassed areas slows the storm water runoff and increases the portion of rainfall lost to infiltration.

2. Foundation Drain Discharge to Grassed Areas. This practice eliminates the hazard to basements due to surcharging of storm sewers and allows more constrictive sizing of the storm system which would tend to reduce the peak storm runoff flows.

3. Use of Open Ditches - As an alternative to closed sewers to provide storm drainage to developed areas, use of open ditches would reduce runoff velocities and hence storm runoff peaks. Open ditches would also be beneficial in removing sediments and other materials washed from the streets. This technique of storm drainage is significantly less expensive than a piped system but requires more maintenance and in some cases is aesthetically less pleasing.

4. Reduction of Pavement Width - In residential areas, it is common practice to provide extra pavement width for parking purposes. The transferal of this parking area to gravelled driveways on each lot and the reduction in the impervious pavement areas will tend to reduce total runoff, areas of pollution accumulation and the peak flows of the runoff.

Title Exclusion of Livestock from Watercourses	99

Keywords Agriculture, Sediments, Nutrients.

Applicable Land Use	**Pollutant Controlled**
Agriculture	Sediments Nutrients.

Description

When livestock are allowed direct access to a watercourse for drinking, stream banks are broken down, bottom sediments disturbed and direct discharge of animal manures to the watercourse results. Depending upon the intensity of the livestock usage, the stability of the soils and stream bank and the ability of the watercourse to assimilate the contaminants, this activity can pose a serious problem.

Fencing off of watercourses and the provision of alternate sources of water supply are the most obvious methods of reducing this problem. In some cases, the use of concrete or gravel access ramps in controlled areas will sufficiently reduce the problem to still permit direct water usage from the watercourse.

Advantages	**Disadvantages**
- reduction of direct discharge of livestock wastes to watercourses - maintenance of stable streambanks	- increased cost and inconvenience if alternate water supply source is required
Capital Costs	**Operating and Maintenance Costs**
Construction of concrete or gravel ramps would be in the order of $250 to $500 each Fencing for the exclusion of livestock from an area costs approximately $1.50 - $2.75 per meter.	- regular cleaning of accumulated manure around and on access ramps

Previous Experience

Commonly used technique.

Source of Information 203, 173, 174.

Title Land Smoothing	100

Keywords Agriculture, Sediment.

Applicable Land Use	**Pollutant Controlled**
Agriculture	Sediment

Description

Land smoothing is the removing of irregularities on the land surface by the use of special equipment to rough grade fields to form continuous gradients. The purposes of land smoothing are to: improve surface drainage; provide for more effective use of precipitation; obtain uniform planting depths; provide for more uniform cultivation; improve equipment operation and efficiency; improve terrace alignment; and to facilitate contour cultivation. By improving the overall productivity and efficiency of cultivation of the field, the susceptibility to erosion is reduced, and the efficiency of other erosion control methods is increased.

This practice applies on lands where depressions, mounds, old terraces, turn rows and other surface irregularities interfere with the application of other needed soil and waste conservation and management practices.

Advantages	**Disadvantages**
- many indirect benefits	- care must be taken not to disturb or to preserve the natural soil horizons.

Cost Implications

Costs are very site specific depending upon the extent and magnitude of the irregularities, the need for multiple operations to reserve soil horizons grading tolerances, etc. Costs are estimated to be in the range of $100 - $200/hectare.

Previous Experience

Technique is applicable and widely used throughout the Great Lakes Basin.

Source of Information 240, 241, 242, 243, 244.

Title Gabion Baskets	101

Key words Urban, Agriculture, Lakeshore and Riverbank Erosion, Sediment.

Applicable Land Use	**Pollutant Controlled**
Urban Agriculture Lakeshore and Riverbank Erosion Shoreline Landfilling	Sediments

Description

Gabions are made of heavy gauge wire mesh fabric, wired into panels which together form rectangular baskets. These baskets are then wired together in various geometries to conform to the desired bank or shoreline height and slope and then filled with angular rock. When completed the gabion lining provides a continuous, flexible, erosion resistant structure of great strength. Gabions have been used as retaining walls, channel linings, drop structures, check dams, chutes, spillways, energy dissipates. etc. Soil material eventually fills the rock voids and provides a base for vegetative growth. Depending upon soil conditions a granular or fabric filter may be required behind the structure to prevent the loss of fines through the gabion.

Advantages	**Disadvantages**
- as building blocks, gabions can be designed to fit most channel geometries - strong and flexible - very stable	- key basket at toe of slope may be difficult to construct underwater and coffer damming may be required to allow construction in the dry.

Cost Implications

Installation is very site specific depending particularly upon water depth and velocity, and site accessibility. General costs range from $40 to $60 per cu.m.

Maintenance is very low.

Previous Experience

Very commonly used material with availability throughout the Great Lakes Basin.

Source of Information 125, 108.

Title Miscellaneous Erosion Control Fabrics and Materials	102
Keywords Urban, Agriculture, Lakeshore and Riverbank Erosion, Sediments.	

Applicable Land Use	**Pollutant Controlled**
Urban Agriculture Lakeshore and Riverbank Erosion Shoreline Landfilling	Sediments

Description

1. Biodegradeable Materials - The fabric materials provide a cover to protect the soil base from direct water flow, they act as a filter to restrict the washout of fine particles, yet they still allow seeded vegetation to germinate and grow. Jute matting, and excelsior blanketing are examples.

2. Synthetic fabrics - These fabrics are non biodegradeable and can be either woven or non woven. Woven materials usually have larger pore sizes than non woven fabrics. This class of fabric can be very thin with small pore size making them ideal for filter cloths behind gabions, around drainage tiles etc. as an alternative to granular filter material. At the other extreme, very tough, course fabrics up to several centimeters in thickness can be obtained for use in lakeshore erosion applications to resist wave action. Materials of a wide variety of plastic compounds, polyester, cellulose, fibreglass etc. are used. Common trade names are Bidim, Mirafi 140, Terrafix, Typar, Hold/oro.

3. Concrete filled fabrics - A nylon fabric mat looking much like an air mattress filled with concrete has been used successfully for channel lining and shoreline stabilization with success. This blanket, "Fabriform", can be placed on slopes, above and below the water line. The mat, once placed, is pressure filled with concrete grout This material can be obtained in both a cobbled or smooth surface and can be fabricated with spaces for the relief of hydrostatic pressure from under the mattress.

4. Mesh connected concrete blocks. A European firm has recently introduced a mattress for use in streambank and lakeshore protection. Small concrete blocks are formed around a wire mesh to form flexible units in excess of 1 metre x 2 metres in area. These heavy flexible units can be easily field connected and lifted into place with backhoe or crane equipment. These mattresses are particularly useful in underwater applications in excess of 2 metres of water. Common trade name is GOBI-MAT.

5. Interlocking Paving Stones - Very dense, frost resistant masonry bricks, commonly used for streets and sidewalks, have been successfully used for lining of channels to protect against erosion, maintain hydraulics and improve aesthetics. A bedding of sand is required for these hand laid bricks. Flexibility of end product is an asset. Repairs are relatively easy with little adjacent disturbance.

Title Miscellaneous Individual Wastewater Treatment Systems	103

Keywords Urban, Recreation, Agriculture, Nutrients.

Applicable Land Use	**Pollutant Controlled**
Urban Recreation Agriculture	Nutrients

Description

1. Jet Home Treatment Plant/Aquarobic System - Below ground extended aeration system with discharge to a soil absorption system. Optional upflow filtration and disinfection can be added. Effluent results: BOD=20 mg/L, SS= 25mg/L. Cost approximately $2,700 to $3,000 per unit. Sludge must be periodically removed, aerator maintained. $7 - $10 per month for electricity.

2. Incinolet - Incinerates waste in toilet. Septic tank and soil absorption system would be required for remaining household waste water. A zero discharge from toilet wastes results. Ashes must be periodically removed. $900 capital cost plus intermittent power consumption of 750 watts.

3. Ecolet - Humification with external heat source for mesophilio conditions. Urine and liquids evaporated. Electric fan provides oxygen for aerobic conditions. System only for toilet therefore, septic tank and soil absorption system required for remaining household waste water.$900 capital cost plus continuous power consumption of 160 watts.

4. Cycle Let - Underground extended aeration plus membrane filtration, activated carbon filtration and ultraviolet disinfection. Water can be recycled for flush water. System must be protected against freezing. $4,000 to $7,500 capital cost plus continuous power consumption of 350 watts. Ultraviolet light, filtration media require frequent replacement and outer unit requires annual/biennial cleaning.

Source of Information 207, 237.

Title Clivus Multrum	104

Keywords Urban, Recreation, Agriculture, Nutrients.

Applicable Land Use	**Pollutant Controlled**
Urban Recreation Agriculture	Nutrients

Description

The Clivus Multrum is a compartmentalized toilet in which the wastes are composted. Wastes are deposited into a tank with an inclined bottom. Aerobic conditions are maintained by connection within the tank and a degree of forced venting to control odours. A relatively inert ash of composted material results at the bottom of the inclined composting compartment which must be periodically removed.

Advantages	**Disadvantages**
- no discharge from toilet wastes - very low water consumption	- periodic cleaning - septic tank and soil absorption system still required for remainder of household liquid wastes
Capital Costs	**Operating and Maintenance Costs**
Depending upon remoteness of location each unit costs in the order of $1,400 and a $450 installation allowance should be added.	- Very little maintenance required due to absence of mechanical systems. - requires periodic cleaning.

Previous Experience

Used extensively in Scandinavia and recently introduced in Canada and the United States.

Source of Information 207, 237.

Title Controlling Feedlot Runoff	105

Keywords Agriculture, Nutrients.

Applicable Land Use	**Pollutant Controlled**
Agriculture	Nutrients

Description

The first step in the control of pollution resulting from feedlot runoff is to minimize the quantity of runoff by preventing external surface water from entering the lot. The drainage system should be designed to divert any drainage via diversions or terraces around the feedlot so that only drainage from the feedlot itself will have to be handled.

Manure on the feedlot surface provides protection to the soil from erosion, however, if a heavy load of manure is carried in runoff, difficulty in intercepting and handling the runoff will increase. Manure packs should be contained within the internal feedlot drainage area.

The runoff water can be collected and disposed of by several different systems. The economics of installing a retention type system will be site specific depending upon land availability, materials costs and site conditions. The runoff can be disposed of directly on the land provided that the application rate is low enough that runoff does not occur from the receiving land and the crop nutrient requirements are compatible with the nutrient content of the runoff. In general, feedlot runoff should not be used on fresh fruit and vegetable crops that may carry the contamination into the market product. Monitoring for salt and nutrient buildup in the receiving soils should be done.

The retention pond may take a number of forms depending upon the requirements of the individual installation. In some cases, a simple temporary storage will be sufficient from which the runoff will be spread on adjoining land. In other cases, a more extensive treatment system will be required. Treatment lagoons have been used for many years for the treatment of biologically degradable wastes. While lagoons are relatively inexpensive to construct and operate, they require a sizable land area to provide adequate treatment. Land disposal of the effluent is usually required unless treatment efficiency or receiving water capacity is sufficiently high to allow for disposal.

Most techniques used to control and/or treat feedlot runoff are adaptations of remedial measures for other purposes. See also catalogue entries 20, 21, 22, 42, 46,47,62,63,80,81.

Source of Information 208, 219, 237, 206, 152, 203.

Title Landfill Liners	106

Keywords Solid Waste Disposal, Chemicals.

Applicable Land Use	**Pollutant Controlled**
Solid Waste Disposal	Chemicals

Description

Several types of lining materials are available to artificially contain landfill leachate (contaminated seepage from solid waste) in sites which do not naturally afford the capability to attenuate the contamination prior to impairing a ground or surface water use. Natural materials such as native clay and bentonite clays have been used as well as several man made materials such as PVC, hypalon, butyl rubber, elasticized polyolefin, asphalt, soil cement, etc. Site conditions will determine the degree of contaminant required and then an engineering analysis must be done to select the best material for the purpose. A high degree of containment is possible if properly constructed. Degradation rates vary with materials and site conditions but generally accepted range is from 20 to 50 years. Most liners require a protective cover to avoid mechanical injury during landfilling.

Advantages	**Disadvantages**
- total on-site containment of pollutants is possible - containment of landfill leachate in more concentrated form for treatment if necessary - more controlled system than if allowed to enter groundwater flow system	- requires careful quality control and construction supervision to ensure integrity - requires large capital investment

Cost Implications

Costs for site preparation are site specific. Materials and installation costs vary greatly depending upon type, quantity, location, site conditions, climate, etc. Approximate costs range from $1.50 to $5.00 per sq.m.

Previous Experience

Several landfills in Pennsylvania, New York and Wisconsin.
Liverpool Road Landfill Site, Toronto, Ontario
Extensive research done in United States and Canada.

Source of Information

Title Hydroseeding	107

Keywords Urban, Transportation, Lakeshore & Riverbank Erosion , Sediments.

Applicable Land Use		**Pollutant Controlled**
Urban Transportation Lakeshore & Riverbank	Forestry Extractive Erosion	Sediments

Description

In hydroseeding, a mixture of seed, fertilizer and water is mixed together in a truck mounted reservoir and sprayed on to sloping or inaccessible areas in slurry form. Many types of hydroseeders also have capability to mix and spray an organic or fibrous mulch and a mulch tacking agent simultaneously. This method is effective on large areas, particularly slopes where preparation and multiple seeding operations may be difficult and undesirable. This is a very fast and effective method of revegetating disturbed areas and is not as dependent upon weather and soil moisture conditions as conventional agricultural seeding equipment.

Advantages

- suitable for steep slopes or inaccessible areas
- flexibility with application rates, materials and timing
- single operation is fast and effective with less additional disturbance of area

Disadvantages

Cost Implications

Hydroseeding costs are generally in the $.10 to $.25 per sq.m. depending upon size of area, application rate, materials and mulch used, travel distance of equipment soil quality, etc.

Previous Experience

Very popular method of restoration of sloping areas particularly for highway construction restoration.

Source of Information 92, 106, 146.

Title Catch Basin Cleaning	108

Keywords Urban, Transportation, Sediments, Nutrients, Chemicals

Applicable Land Use	**Pollutant Controlled**
Urban Transportation	Sediments Nutrients Chemicals

Description

When regularly cleaned, catch basins are found to be effective in removing particulate matter from runoff, including fine solids. However, few are cleaned regularly enough to be efficient, usually only once per year, and may become a significant source of organic sludge. Catch basins can be cleaned regularly in areas which are not serviced by street sweeping equipment, depending upon the remaining capacity of the catch basin and the rate of accumulation. Catch basins can remove approximately 56% of total solids and about 40% of BUD. (146)

There has been much discussion about the usefulness of catch basin sumps if there is no program or as an alternative to periodic cleaning. The absence of sumps would tend to reduce the "first flush" peak loadings from urban runoff, but it has yet to be established whether the long term effects of no-sump catch basins are beneficial.

Advantages	**Disadvantages**
- source removal of concentrated contaminants prior to entering transport system - regularly maintained catch basins and street cleaning may improve urban runoff quality by 25 to 50%.	

Cost Implications

The cost of various methods of catch basin cleaning are in the order of $3 to $4 per catch basin.

Several vacuum type street sweeping vehicles can be adapted for this purpose as well.

Previous Experience

Common practice in most municipalities. Many types of commercially available equipment.

Source of Information 146, 221, 248, 237.

Title Plant Materials for Bank and Slope Stabilization	109

Keywords Urban, Agricultural, Recreation, Forest, Extractive, Sediments.

Applicable Land Use		**Pollutant Controlled**
Urban	Forest	Sediments
Agriculture	Transportation	
Recreation	Lakeshore & Riverbank	
Shoreline Landfilling	Erosion	

Description

Ground Covers Other Than Grass	**Location of Use**	**Remarks**
Cotoneaster horizontalis Eunoymus coloratus Coronillia varia Pachysandra terminalis Vinca minor	. On steep slopes up to 1:1 or greater . Some species will do well on very sandy or rocky slopes where grasses might not grow . Many are very shade tolerant and can be used where turf is difficult to establish . used effectively where maintenance is difficult	. generally slow (1-2yr) to establish hut have good soil binding properties when established; . may be expensive depending on spacing, type, area to be covered . generally form a good mat which prevents pelting rain from eroding the soil . requires little or no maintenance once established . visually attractive . many broadleaf evergreen species available for winter effect
<u>Shrubs</u>		
Cornus alba Forsythia suspensa Rosa wichuriana	. generally useful on valley slopes up to 2:1 . should be used in conjunction with ground covers or grasses rather than alone . useful for naturalizing disturbed valley or highway slopes	. rooting systems have good soil holding properties . require little or no maintenance . require a deeper soil than ground cover to become established
<u>Vines</u>		
Clematis paniculata Hedra helix 'Baltica' Lonicera japonica 'Halliana' Parthenocissus quinquefolia	. similar to ground covers except most require full sun	. generally more rapid establishment . often display rapid growth covering large areas . rooting system holds soil well

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