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IDENTIFICATION TITLE AND NUMBER
Characterization of Oil and Gas Waste Disposal Practices and Assessment of Treatment Costs
Engineering
DE-AC22-92-MT92007

PARTICIPANT NAME AND ADDRESS:
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US/DOE Patent Clearance is not required prior to publication of this document.

DATE: April 25, 1994

Contract Number	DE-AC22-92-MT92007
University	Rice University
Date of Report	April 15, 1994
Contract Date	July 1, 1992 - June 30, 1994
Anticipated Completion Date	September 30, 1994
Government Award	$137,510
Program Manager	Philip B. Bedient
Principal Investigator(s)	Philip B. Bedient
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Reporting Period	January 1, 1994 - March 31, 1994

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ACQUISITION & ASSISTANCE DIV.

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DATE: April 26, 1994

TECHNICAL PROGRESS REPORT

March 1994

Attached

Table of Contents

Page

Executive Summary 1

Introduction 3

Project Description 3

Project Status 4

Planned Activities 7

Summary 8

Report Distribution List 9

References 9

Publications 9

List of Tables and Figures

Table 1. Sludge Volumes 10

Figure 1. GAC Treatment Costs 11

Figure 2. PAC Treatment Costs 12

CHARACTERIZATION OF OIL AND GAS WASTE DISPOSAL PRACTICES AND ASSESSMENT OF TREATMENT COSTS

Executive Summary

This project consists of 3 tasks: 1) Developing a Production Environmental Database (PED) with the purpose of investigating the current industry waste storage and disposal practices by different regions, states, and types of waste and investigating the environmental impacts associated with these practices; 2) Evaluating the suitability of available and developing technologies for treating the waste streams identified in Task 1 and identifying unit process configurations; and 3) Evaluating the costs associated with various degrees of treatment achievable by different treatment configurations.

Information pertaining to the environments surrounding oil and gas activities has been collected through various public agencies for the state of Texas. Examples of the type of information collected include hydrography, transportation, soil types, floodplains, subsurface geology/hydrogeology, precipitation, locations of water supply wells, landuse/landcover, and parklands. Much of this data has already been assimilated into the GIS while some is currently being collected/digitized.

A data analysis effort is underway for much of the data that has been collected to date. Annual volumes of produced water have been assembled from state agency records for 20 of the 31 producing states surveyed. As in EPA's report to Congress, produced water volume estimates may be generated for the remaining states by developing water/oil (or water/gas) production ratios using data from nearby states. Because no records are kept, information on volumes of drilling wastes generated is not available from state agencies. Using a method similar to that used by EPA and API, these volumes are to be estimated on an annual basis based on the amount of drilled footage. The amount of drilled footage is to be obtained from the WHCS database.

The WHCS database will form the basis of the environmental analysis of drilling activity. This database contains information on all wells drilled in the United States in the years 1988, 1990, and 1992. Pertinent data items to be extracted from the WHCS database include API number, location, completion date, total depth, class, producing formation and elevation. The Well Bore Database, containing information on production, injection, and abandoned wells for eight counties within the state of Texas will serve as the basis for the environmental analysis of production activity.

Much of the effort relating to the treatment of produced water was spent in looking at the treatment of residual wastes such as sludges. The method in which some of the residual waste streams will be dealt with was determined. The amounts of sludges that would be produced during the treatment of the representative produced waters have been estimated. The costs associated with the treatment and disposal of these sludges have been calculated. The procedure for the treatment and disposal of the sludges produced by package complete treatment will be gravity thickening and

drying in sand beds. The PAC sludge does not require thickening and will be deposited onto the sand drying beds with the thickened sludge from the other unit process. Unthickened sludge typically contains about five percent solids by weight and this percentage can rise to between twenty and forty once it has been thickened. All sludge will be landfilled once it has been dried. This disposal by landfilling will be the most expensive portion of the residual waste stream management, in most cases.

The impacts of some of the disposal practices have been examined. Deep well injection into the underground formation from which the produced waters came is one method that is currently being used to dispose of the waste stream. Discharge to surface waters is also practiced in certain parts of the country. In Texas, this type of disposal is practiced and limited to tidally influenced water bodies. There is little documentation, but growing concern over the potentially degrading effects that the produced water discharges might have on these coastal habitats.

Introduction

This report covers work completed during the sixth quarter for the project. The project consists of three tasks: the first relates to developing a database of waste volumes and disposal methods used by the industry; the second and third tasks are aimed at investigating technologies that could be used for the treatment of produced waters and developing cost estimates for those technologies.

The remainder of this report describes progress related to the three tasks in the project. Overall, construction of the PED is ongoing. While much of the data has been collected and entered into the database, a few data categories are still missing, for example, soils and geology and geohydrology. Work is currently under way to collect these data. In addition, a detailed data analysis has begun in order to develop relationships between oil and gas activities and environmental characteristics. In terms of the treatment of produced water, much of the work in the past quarter was focused on analyzing the costs associated with the treatment and disposal of waste residuals such as sludges.

Project Description

The proposed effort consists of 3 tasks:

Task 1. Developing a Production Environmental Database (PED) with the purpose of investigating the current industry waste storage and disposal practices and investigating the environmental impacts associated with these practices. Task 1 is composed of subtasks as follows:

1. Estimate quantities of waste generated by oil and gas extraction by state, region, and type.

2. Develop a profile for the waste characteristics by state, region, and type.

3. Determine current industry waste storage and disposal practices by state, region, and type.

4. Develop the environmentally significant characteristics of the disposal methods used.

5. Determine the hydrogeologic, surface water and exposure point characteristics of "receptor environments".

6. Investigate the predominant landuse patterns surrounding oil and gas activities.

7. Assess the environmental impacts of oil and gas activities on a state and regional basis.

8. Assess the differences in environmental impacts analyzed on a statewide and regional basis from those determined from site-specific data.

9. Analyze the data statistically to develop distributions for some of the parameters on a state, regional and nationwide basis.

10. Assimilate all the data in a database.

Tasks 2 and 3. Tasks two and three of this project address the impacts and costs of coproduced water disposal. Different disposal practices may require different levels of water treatment to avoid negative environmental impact. Physicochemical treatment unit processes for waste water will be evaluated with respect to their suitability in treating water that has been coproduced with oil and gas. Several treatment scenarios representing various configurations and combinations of unit processes will be evaluated. The costs of these scenarios will then be compared with the environmental impact associated with a designated disposal practice or use for the treated water. Water quality, will be expressed by the concentrations of specific target contaminants as well as several composite parameters. Contaminants of concern will be grouped based on the likely similarities of both the unit processes required to remove them, and their chemical makeup. Thus, an assessment of treatment technologies and costs for one parameter within such a group may be useful in assessing the treatment and cost for another contaminant.

Composite parameters, such as TOC, give an indication of the total concentration of several contaminants in water. In some instances , it may be useful to estimate treatment costs by attributing the chemical characteristics of a representative constituent compound (e.g. benzene) to a given composite parameter (e.g. total organic carbon). Alternatively a solution weighted average of the characteristics of several constituent contaminants might be used. Process performance, in terms of removal efficiency and effluent concentration, will be evaluated using simulation models for candidate processes. Existing cost information for these processes will be used in conjunction with performance calculations to generate trade off curves for water quality (environmental impact) and treatment cost.

Project Status

Task 1. The past quarter was spent building the various elements of the PED and developing a strategy for data analyses. In terms of the PED, much progress was made. Digital Line Graph (DLG) hydrography and transportation information was obtained for the eight counties in Texas and the data were processed into the PED. County boundaries as well as major and minor aquifers and a map of the DRASTIC regions in Texas also have been integrated into the PED. The detailed geology and hydrogeology of the eight counties is under development. Information on water wells, injection wells and abandoned wells and data on surface discharges have been obtained and processed into the PED. A 1:1.5 million scale map depicting oil and gas fields within the state of

Texas was obtained from the Mid-Continent Oil and Gas Associates and forms the base map for much of the analyses. Finally, information on floodplains, wetlands, landuse and other environmental characteristics are also being integrated into the database.

Detailed planning for data analyses related to the information assembled to date has been completed as follows:

Quantities of Wastes Generated. Annual volumes of produced water have been assembled from state agency records for 20 of the 31 producing states surveyed. A number of these volume totals represent injection volumes and not produced volumes as this is the only type of data reported. As EPA's report to Congress, produced water volume estimates may be generated for the remaining states by developing water/oil (or water/gas) production ratios using data from nearby states.

Because no records are kept, information on volumes of drilling wastes generated is not available from state agencies. Using a method similar to that used by EPA and API, these volumes are to be estimated on an annual basis based on the amount of drilled footage. The amount of drilled footage is to be obtained from the WHCS database.

Waste Characteristics. Data on the characteristics of oil and gas wastes are limited. The EPA/API waste sampling database remains the best source for this type of information. An attempt was made at gathering produced water chemical data during assembly of the produced water database. However, only 7 of the 31 states inventoried were able to provide brine chemical analyses and the majority of these represented individual well grab samples. The EPA/API databases are to be supplemented with the limited waste characterization data reported in the literature for use in the PED.

Types and Characteristics of Waste Disposal Practices. Due to the unregulated status of oil and gas wastes and the lack of reporting requirements, information on disposal practices is generally unavailable. The one exception is the disposal of produced water via deep well injection which is regulated under the Federal UIC program. In compiling the produced water database, 17 of the 31 states surveyed were able to classify the brine disposal practices used within the state but only by 'used' or 'not used' and not by 'how much goes where'. The API survey remains the only source of statistical information on drilling waste disposal practices.

Environmental Characteristics. The WHCS database will form the basis of the environmental analysis of drilling activity. This database contains information on all wells drilled in the United States in the years 1988, 1990, and 1992. Pertinent data items to be extracted from the WHCS database are the following:

API number
Latitude/Longitude
Completion date
Total depth (ft)

Final class (oil, gas, dry, etc.)
Producing formation
Elevation (ft, MSL)

The Well Bore Database, containing information on production, injection, and abandoned wells for eight counties within the state of Texas will serve as the basis for the environmental analysis of production activity. Pertinent data items to be extracted from the WBDB are the following:

API number
Latitude/Longitude
Completion date
Elevation (ft, MSL)
Classification (oil, gas, injection, or plugged)
Total depth (ft)
Depth of packer (ft)
Depth of casing (ft)
Interval of water quality protection required by TDWR

Tasks 2 and 3. The costs of produced water treatment are made up of several components. Some of the most important are those associated with residual waste. During treatment, residual waste streams are produced as a result of the separation and or concentration of undesirable constituents from and out of the produced water, respectively. The unit processes chosen to treat the produced water that generate relevant amounts of residual waste are package complete treatment for the removal of suspended solids and heavy metals, powdered activated carbon (PAC) adsorption to rid the water of undesirable organic constituents, and reverse osmosis (R/O) to separate dissolved solids from the waters. The backwash cycle of both the conventional filtration process and the granular activated carbon (GAC) adsorption bed will produce small amounts of sludge that will not be considered in this analysis.

The method in which some of the residual waste streams will be dealt with was determined. The amounts of sludges that would be produced during the treatment of the representative produced waters have been estimated. The costs associated with the treatment and disposal of these sludges have been calculated. Table 1 contains a listing of the amounts of sludge that will be produced during conventional treatment and PAC adsorption. The procedure for the treatment and disposal of the sludges produced by package complete treatment will be gravity thickening and drying in sand beds. The PAC sludge does not require thickening and will be deposited onto the sand drying beds with the thickened sludge from the other unit process. The PAC sludge consists of only the actual carbon that is added to the waste stream and the water that is entrapped within it's pores. The sludge that accumulates in the sedimentation basin, where most of the solids are removed during conventional treatment, consists of the suspended solids found in the waste stream, the coagulant added (alum and polyelectrolyte) along with it's precipitate and the waste water congealed around and within these constituents. Unthickened sludge typically contains about five percent solids by weight

and this percentage can rise to between twenty and forty once it has been thickened. All sludge will be landfilled once it has been dried. This disposal by lanfilling will be the most expensive portion of the residual waste stream management, in most cases.

Diagrams describing the way that the performance and cost evaluation have taken place for several of the unit processes have been created. Figures 1 and 2 show these diagrams for GAC and PAC adsorption. These diagrams should enable anyone to understand where the costs associated with these two treatment unit processes come from. The amount of carbon that must be added to the waste stream in powdered form in order to remove the organic contaminants is the carbon feed mentioned in Figure 2. The costs associated with disposing of the dried sludges into a landfill are simply unit costs per amount of sludge depending on the nature of the sludge. The costs of landfilling sludge range from about twelve to two hundred and fifty dollars per cubic meter ($/cu m).

The impacts of some of the disposal practices have been examined. Deep well injection into the underground formation from which the produced waters came is one method that is currently being used to dispose of the waste stream. Discharge to surface waters is also practiced in certain parts of the country. In Texas, this type of disposal is practiced and limited to tidally influenced water bodies. There is little documentation, but growing concern over the potentially degrading effects that the produced water discharges might have on these coastal habitats.

Planned Activities

Task 1. Proposed questions to be answered by the PED may be divided into two categories, those that pertain to drilling activities and those that pertain to production activities.

Drilling activities
What types of landuses surround oil and gas drilling operations?
How many drilled wells are within a given distance of a water supply well?
What types of groundwater usages exist in the vicinity of drilling activities?
How many drilled wells are within a given distance of a surface water body?
How much drilling activity occurs within freshwater aquifer regions?
How much drilling activity occurs within parklands?
How much drilling activity occurs within floodplains?
What is the relationship between drilling activity and DRASTIC regions?
What is the depth to groundwater in the vicinity of drilling activities?
Given a surface soil type and a level of precipitation, what is the potential for the leaching of contaminants from reserve pits in a given area?

Production activities
What types of landuses surround injection/abandoned wells?
How many injection/abandoned wells are within a given distance of a water supply well?

What types of groundwater usages exist in the vicinity of injection/abandoned wells?
How many injection/abandoned wells are within a given distance of a surface water body?
How many injection/abandoned wells are located within freshwater aquifer regions?
How many injection/abandoned wells are located within parklands?
What is the relationship between injection/abandoned wells and DRASTIC regions?
What are the ranges of depths of injection wells in relation to the depths of groundwater protection zones?
Where are surface discharge points located?

Tasks 2 and 3. A summary will be presented containing the philosophy and goals of the treatment of the produced water. The strategy envisioned to reach said goals, and a detailed description of the methods used to implement this strategy will also be presented. The problems created by produced waters will be stated as they have been defined. Potential solutions will be offered that have been evaluated with respect to feasibility and cost.

Diagrams similar to those presented in Figures 1 and 2 will be made for all of the unit processes. Graphs comparing costs vs. unit process design capacity will be constructed for a typical set of circumstances for each of the unit processes. The costs for various levels of treatment for all of the representative waste streams will be calculated and compared. Cost curves will also be constructed that will depict the costs associated with the removal of all relevant waste stream constituents to specific levels as a function of the amount of each constituent found in the raw waste stream. For example, a curve will exist that will provide the cost of desalinating produced waters with levels of TDS ranging from 1 to 300,000 parts per million (ppm) down to drinking water standards. These charts will enable an individual to get a rough estimate of what it would cost to treat a specific produced water with well defined objectives for the quality of the finished product. Analysis of these costs will include an explanation of the decision making process used when the choices regarding types and levels of treatment were made.

Summary

In summary, collection and analysis of data for the PED is still ongoing. Much of the data collection effort is complete and most of the data have been incorporated into the GIS. Few gaps in the data remain and those are currently being filled. A data analysis plan has been developed to correlate the industry's activities with environmental characteristics. Cost estimates for the treatment and disposal of residuals from waste streams related to the treatment of produced water (e.g., sludges) have been developed.

Report Distribution List

Document Control Center
U. S. Department of Energy
Pittsburgh Energy Technology Center
P. O. Box 10940, MS 921-118
Pittsburgh, PA 15236-0940

References

None at this time.

Publications

A journal article is currently under preparation.

Table 1. Sludge Volumes

Conventional Package treatment with alum and polyelectrolyte addition.

Sludge Volume (Cubic Meter/Day)

Flow (MGD)	Wastestream/TSS R1 62.00	R2 60.00	R3 4.00	R4 68.00	R5 8800.00	R6 16.00
0.0100	0.0962	0.0947	0.0527	0.1007	6.6453	0.0617
0.1000	0.9616	0.9466	0.5269	1.0066	66.4534	0.6168
1.0000	9.6161	9.4662	5.2690	10.0659	664.5336	6.1684

PAC

Sludge Volume (Cubic Meter/Day)

% Removal of Organics		10.00	20.00	30.00	40.00	50.00	60.00	70.00	80.00	90.00	95.00	99.00
.01 MGD	R1	0.0007	0.0007	0.0007	0.0008	0.0008	0.0009	0.0010	0.0011	0.0013	0.0016	0.0027
	R2	0.0001	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0003	0.0004	0.0007
	R3	0.0015	0.0016	0.0017	0.0018	0.0019	0.0021	0.0023	0.0026	0.0034	0.0043	0.0073
	R4	0.0015	0.0016	0.0016	0.0018	0.0019	0.0020	0.0023	0.0026	0.0033	0.0041	0.0069
	R5	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0002	0.0003	0.0004
	R6	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002	0.0004
.1 MGD	R1	0.0067	0.0070	0.0073	0.0076	0.0081	0.0087	0.0095	0.0108	0.0134	0.0165	0.0266
	R2	0.0015	0.0015	0.0016	0.0017	0.0018	0.0020	0.0022	0.0025	0.0032	0.0040	0.0068
	R3	0.0152	0.0159	0.0167	0.0177	0.0189	0.0205	0.0228	0.0264	0.0337	0.0428	0.0733
	R4	0.0148	0.0156	0.0165	0.0176	0.0188	0.0204	0.0226	0.0260	0.0328	0.0412	0.0688
	R5	0.0010	0.0010	0.0010	0.0011	0.0012	0.0013	0.0014	0.0016	0.0020	0.0025	0.0042
	R6	0.0007	0.0008	0.0009	0.0010	0.0011	0.0012	0.0013	0.0015	0.0019	0.0024	0.0038
1 MGD	R1	0.0670	0.0696	0.0727	0.0764	0.0810	0.0869	0.0952	0.1079	0.1336	0.1649	0.2663
	R2	0.0146	0.0153	0.0160	0.0170	0.0181	0.0196	0.0217	0.0250	0.0317	0.0401	0.0679
	R3	0.1524	0.1592	0.1673	0.1771	0.1894	0.2054	0.2280	0.2636	0.3366	0.4277	0.7327
	R4	0.1480	0.1560	0.1650	0.1755	0.1882	0.2043	0.2263	0.2601	0.3282	0.4118	0.6880
	R5	0.0096	0.0100	0.0105	0.0110	0.0117	0.0127	0.0140	0.0160	0.0202	0.0253	0.0422
	R6	0.0072	0.0079	0.0087	0.0096	0.0106	0.0118	0.0133	0.0153	0.0191	0.0236	0.0380

Figure 1. GAC Treatment Costs

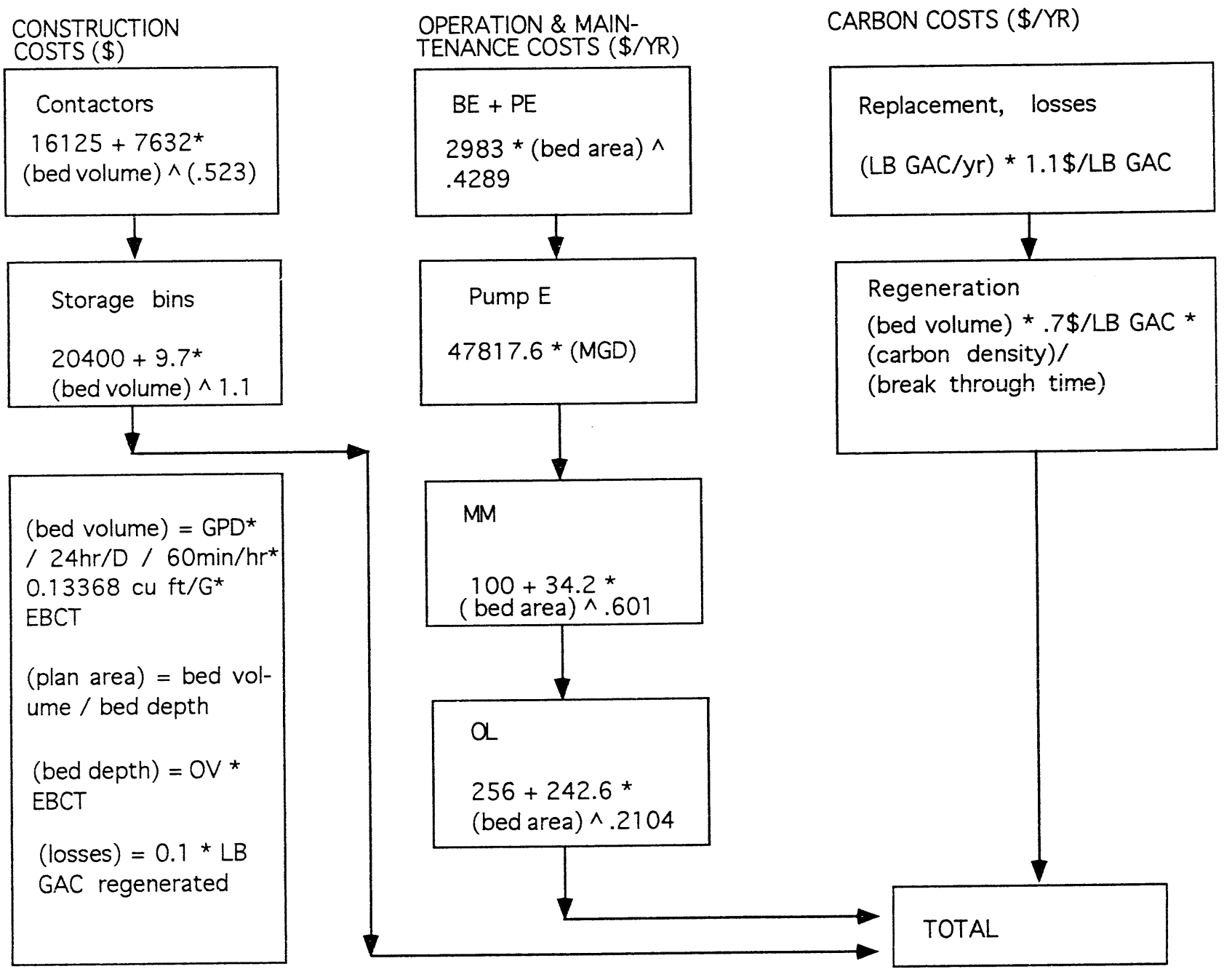
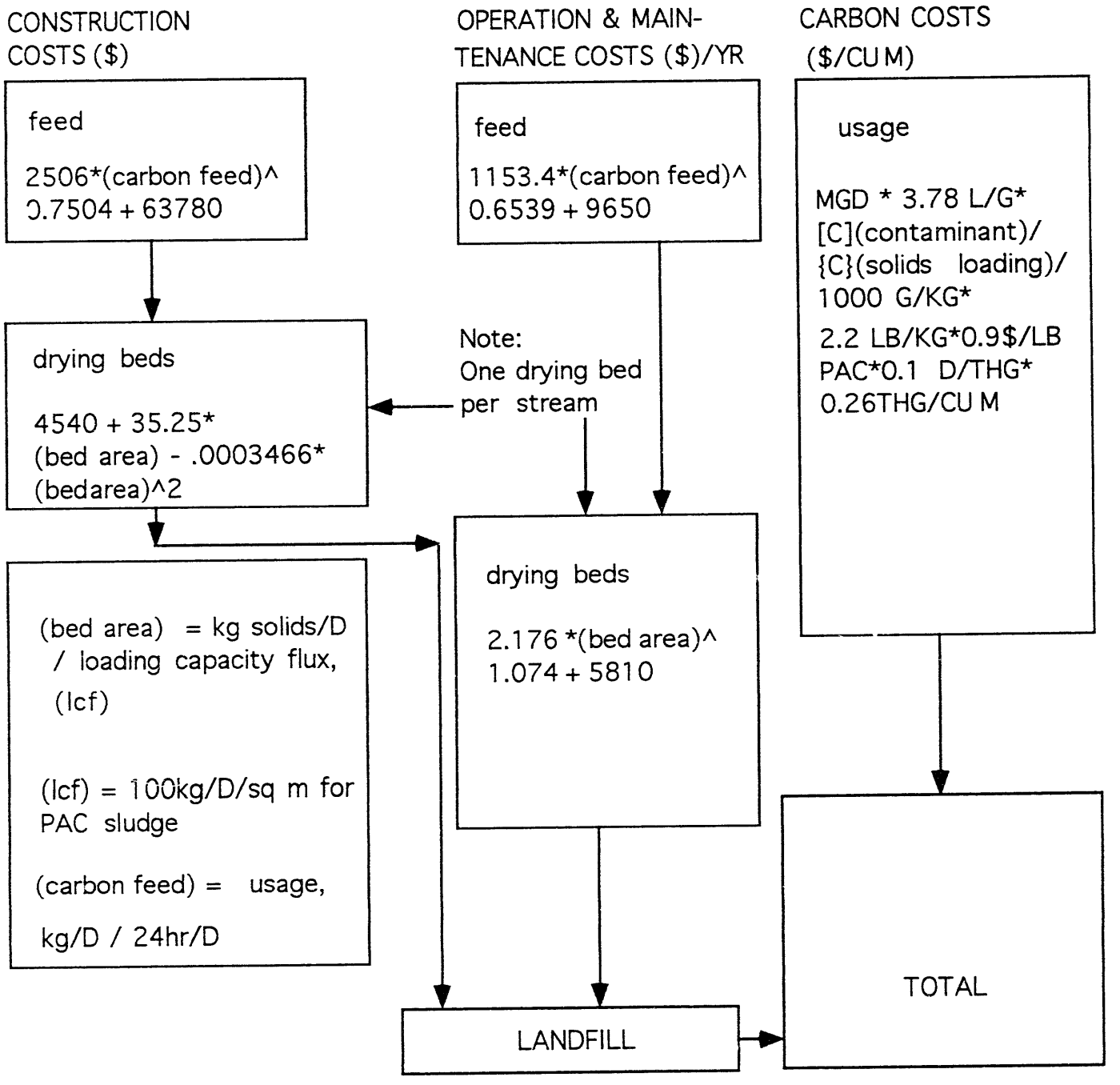


Figure 2. PAC Treatment Costs



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