Cost Reductions for Solid Waste Disposal in North Dakota Using Regional Landfills

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Managing municipal solid waste (MSW) is a growing problem in North Dakota and nationwide. Households, businesses, and industry generate MSW at a per capita rate of about four pounds per day (U.S. Environmental Protection Agency, 1990). The per capita rate of MSW generation is expected to continue increasing into the next century.

Even with the effective use of incineration, source reduction, and recycling, landfills will continue to be the principal disposal method (Lodge and Rayport, 1991). While additional landfill space is needed, mounting concern about protecting ground water and other environmental resources has led to increasingly stringent regulations governing landfill design and operation. The newest and most restrictive of these are Environmental Protection Agency design regulations (Subtitle D) which will become effective in October 1993. Among the most salient changes from previous requirements are those that mandate synthetic liners and leachate collection systems for most landfills (Walsh, 1988). Designed to prevent ground water contamination, these environmental protection devices also will make new landfills expensive to construct and operate compared to older designs. Thus, Subtitle D requirements should substantially increase economies of size cost advantages in landfill development and operation of larger landfills.

Rural communities in North Dakota will soon be confronted with replacing their existing landfills. However, the requirements of Subtitle D will make small, community-based landfills prohibitively expensive to develop and operate. North Dakota is currently examining a regional approach to MSW management.

While a variety of factors must be considered in developing regional plans for MSW management, the basic economic problem is selecting optimal locations and sizes of landfill facilities. This problem centers on the trade-off between facility operation costs and MSW transportation costs. Per ton waste disposal costs are lower for larger capacity facilities. However, MSW transportation costs increase directly with greater distances, potentially offsetting cheaper disposal costs. An additional factor in optimizing landfill site and size selection is the role of transfer stations.

Objectives

The objectives of this study were to: 1) develop a method of locating and sizing regional landfill facilities in North Dakota, and 2) evaluate the cost effectiveness of regional waste disposal plans in North Dakota.

The study estimated the amount of waste generated annually in North Dakota, fixed costs of establishing and variable costs of operating landfills given Subtitle D requirements, operating costs of transfer stations, and the costs of transporting MSW from generation location to disposal facility.

Methods

A computer model was used to optimize landfill sizes and locations. Transportation and disposal costs did not include the collection phase of solid waste disposal (i.e., curbside pickup costs).

Costs were minimized subject to four types of constraints. First, all MSW generated in North Dakota was disposed of in landfills. Second, all MSW incurred transportation costs and variable operating costs when delivered to a landfill. Third, landfills had five capacity constraints (i.e., 20, 75, 175, 250 or 400 tons per day). Finally, only one landfill could be built at any particular site.

Population multiplied by per capita waste generation equaled the quantity of MSW generated in North Dakota communities. Total generation of MSW in North Dakota was estimated at about 1,300 tons per day (TPD), based on 4 pounds of MSW per person per day (U.S. Environmental Protection Agency, 1990) and a state population of 638,800 (U.S. Bureau of the Census, 1991).

North Dakota was separated into 176 wastesheds to localize waste generation throughout the state. Of the 176 wastesheds, seven represented Native American jurisdictions, 17 were cities (over 2,500 in population), and the remaining 152 were subcounty areas. Each wasteshed had a central town or point from which distances were measured to surrounding landfills. Five counties had two possible landfill sites. The other 48 counties had one possible site. Possible landfill sites included all existing landfill sites. If no current site existed in a county, cities located next to major highways and central to the county were selected.

Disposal Costs

Landfill capital and operating cost estimates were developed for five discrete landfill sizes--20, 75, 175, 250, and 400 TPD. The cost estimates were collected from prior economic-engineering studies (Minnesota Department of Natural Resources, 1992; Halbach, 1990; Sebesta, 1989; and Joyce, 1990). Buell et al. (1990) developed a relationship of costs for different sized landfills, which was used to verify the cost estimates.

Fixed costs were categorized into three stages: predevelopment, construction, and annual operations. The predevelopment stage of a landfill project has five categories, which include landfill site, engineering design, public hearings, land acquisition, and other costs. The construction stage of a landfill includes road construction, site excavation, liner development, buildings and grounds development, erosion control, construction management, leachate control development, and final cover assembly. Five percent of predevelopment and construction costs were added for unanticipated expenses. Fixed costs of annual operations (the third fixed cost component) included insurance and postclosure.

Insurance and postclosure are considered fixed costs but actually represent expenses that occur each year. Predevelopment and construction costs also are considered fixed costs but only are incurred during landfill development. Because predevelopment and construction costs only occur once, they were amortized over the useful life of a landfill (20 years) to provide an annualized cost estimate. Average annual fixed costs per ton ranged from $22.19 for a 20-TPD facility to $7.48 for a 400-TPD facility (Table 1). Fixed expenses for landfills varied throughout North Dakota because of different land costs.

Daily operation of a landfill requires expenditures for labor, equipment maintenance, utilities, leachate maintenance, and well monitoring. Average variable costs ranged from $11.26 per ton for a 20-TPD landfill to $5.44 per ton for a 400-TPD landfill (Table 1).

Transportation costs were calculated for compaction trucks hauling from generation site to landfill location. Previous studies estimated the cost per ton-mile to be $0.16 to $0.36 (Buell et al., 1990 and Fischer, 1992). A loaded cost of $0.20 per ton-mile was used assuming a running cost per mile of $2.00 and a 10-ton payload.

Table 1. Fixed and variable costs for different sized landfills, North Dakota, 1992.

	Size of Landfill				
Item	20 TPD	75 TPD	175 TPD	250 TPD	400 TPD
	Lifetime fixed costs				
Predevelopment	$358,875	$437,820	$583,315	$671,955	$831,230
Construction	866,750	1,836,550	2,549,250	3,452,250	5,153,500
Contingency	61,281	113,719	156,628	206,210	299,237
Total development	$1,286,906	$2,388,089	$3,289,193	$4,330,415	$6,283,967
	Annual fixed costs				
Principal and interest	121,475	225,419	310,477	408,761	593,162
Insurance and postclosure	17,000	63,750	148,750	212,500	340,000
Total annual fixed cost	$138,475	$289,169	$459,227	$621,261	$933,162
Annual capacity (tons per year)	6,240	23,400	54,600	78,000	124,800
Average fixed cost ($/ton)	$22.19	$12.36	$8.41	$7.96	$7.48
Variable cost ($/ton)	$11.26	$9.45	$6.50	$5.92	$5.44

Semitrailers were assumed to haul waste only from transfer stations to landfills. Transportation cost per ton for semitrailers was estimated to be $0.04 per ton-mile, assuming a running cost per mile of $2.00 and a 45-ton payload.

Data on transfer station costs were not available, so four options were modeled to test the sensitivity of the cost estimates. First, transfer station costs were assumed to be $8.00 per ton with facility capacity of 12 TPD. Second, transfer station costs were assumed to be $12.00 per ton at the same capacity. Third, transfer station costs were set at $8.00 per ton, but capacity was increased to 18 TPD. Finally, transfer station costs were assumed to be $12.00 per ton with a capacity of 18 TPD.

Results

A computer model was used to solve three scenarios.[1] A baseline scenario was estimated for comparison purposes. The second scenario allowed the model to choose the optimal combination of landfill locations and sizes. The final scenario allowed landfills to receive waste either directly or via transfer stations.

Baseline Scenario

A baseline, which assumes a landfill in each county, was specified to provide a basis for comparison with other solutions. The baseline (Scenario A) represents an upper limit for comparing costs associated with other scenarios. The baseline is similar to North Dakota's current situation, given the state had 51 permitted landfills in 1991. It also can be viewed as a potential consequence of efforts by special interest groups to restrict movement of waste materials across jurisdictional boundaries.

In Scenario A, each county was assumed to have the smallest of the five landfill sizes needed to provide adequate capacity for annual waste disposal. Cass County needed a 250-TPD facility. Burleigh, Grand Forks, and Ward Counties each required a 175-TPD landfill. Thirteen counties had 75-TPD landfills. The other 37 counties had 20-TPD landfills.

The total annual cost of MSW disposal for the initial scenario was estimated to be $16.9 million (Table 2). Fixed costs, variable costs, and transportation costs accounted for 65, 23, and 12 percent of total costs, respectively (Table 2). The weighted average total cost (ATC) for the state was $36 per ton.

Variation in costs among counties is perhaps more important than the statewide ATC. The ATC for counties ranged from $17 to $229 per ton. Out of 54 jurisdictions[2], ATC was greater than $50 per ton in 33 counties, while four counties had ATC less than $21 per ton. Those with high ATC were counties with small populations (Table 3). The low-cost counties contained North Dakota's four urban centers. High ATC for the less populous counties support consideration of a regional approach in developing MSW facilities.

Optimal Size and Location Scenario

Waste shipments were unrestricted and the model was allowed to choose optimal locations and sizes for regional landfills in Scenario B. The solution to Scenario B represents the cost of waste disposal using regional landfills.

The optimal solution had 12 landfills. Ten were regional landfills and the other two served the Fort Berthold and Standing Rock Native American reservations[3]

[1]A number of scenarios were evaluated as part of an effort to support the planning process of the North Dakota State Department of Health and Consolidated Laboratories. Information on other scenarios is available (Dooley et al. 1993).

[2]Fort Berthold and Standing Rock Native American Reservations are considered separate jurisdictions and do not fall under control of the North Dakota State Government.

[3]Waste was not allowed to cross Fort Berthold and Standing Rock jurisdictions. Costs for these jurisdictions were constant in all solutions and will not be discussed in detail.

Table 2. Annualized cost estimates, landfill selection and average total cost for scenarios A, B and C, North Dakota, 1992.

Item	A: Baseline	B: Size and Location	C: Transfer Station
STATEWIDE COSTS		thousand dollars	
Fixed	10,908	4,694	4,550
Variable	3,934	3,184	4,003
Transportation	2,041	4,371	2,754
Totals	16,882	12,249	11,307
		percentage	
Fixed	64.6	38.3	40.2
Variable	23.3	26.0	35.4
Transportation	12.1	35.7	24.4
COUNTY COSTS		dollars per ton	
Weighted Mean	36.20	26.27	24.25
Minimum	16.65	15.74	15.74
Maximum	228.66	59.43	45.69
OUTPUT			
Number of Landfills	54	12	12
20 TPD	37	2	2
75 TPD	13	4	4
175 TPD	3	3	3
250 TPD	1	3	3
400 TPD	0	0	0
Landfill Utilization	60.0%	92.6%	94.3%

(Figure 1). Bismarck, Fargo, and Grand Forks each had a 250-TPD landfill. Dickinson, Jamestown, and Minot each had a 175-TPD landfill. Devils Lake, Rolla, Wahpeton, and Williston each had a 75-TPD facility.

All landfills combined operated at 93 percent of capacity (Table 2). Facilities at Bismarck, Devils Lake, Fargo, Minot, and Williston operated at 100 percent of capacity. Dickinson, located in the sparsely populated southwestern part of the state, had the lowest capacity utilization (71 percent). Average total costs of MSW disposal ranged from $16 per ton for Burleigh County to $59 per ton for Burke County (Table 3).

The total cost of MSW disposal for Scenario B was estimated to be $12.2 million (Table 2). Compared to the baseline solution (one landfill per county), costs in Scenario B declined 27 percent, with fixed and variable costs decreasing 57 and 19 percent, respectively. Transportation costs increased substantially (114 percent), reflecting the increased expense of shipping MSW to regional facilities.

The weighted average cost per ton for MSW disposal declined 27 percent in Scenario B and averaged $26 per ton compared to $36 per ton in the baseline (Table 2). The state's least populous counties enjoyed the greatest cost reductions given the regional approach to MSW management (Table 3). The maximum cost was $59 per ton instead of $228 per ton. ATC only fell slightly in the most populous counties.

Table 3. County-level waste disposal costs under baseline, optimal size and location, and transfer station scenarios, North Dakota, 1992.

County	Solid Waste	Scenario A	Scenario B	Scenario C	County	Solid Waste	Scenario A	Scenario B	Scenario C
	tons/year	$/ton				tons/year	$/ton		
Adams	2,317	73.0	44.3	34.4	Morton	17,301	42.6	21.3	20.5
Barnes	9,158	44.9	31.4	29.3	Mountrail	2,731	64.1	39.2	29.5
Benson	5,351	47.7	32.0	23.5	Nelson	3,219	60.9	36.3	32.4
Billings	809	182.6	32.0	30.5	Oliver	1,738	91.6	30.3	26.7
Bottineau	5,848	42.0	42.5	35.1	Pembina	6,744	62.3	42.7	38.0
Bowman	2,625	66.1	48.0	34.8	Pierce	3,688	53.3	46.6	31.1
Burke	2,191	82.2	59.4	45.4	Ramsey	9,255	44.9	26.0	19.1
Burleigh	43,896	18.8	15.7	15.7	Ransom	4,322	46.7	44.7	32.8
Cass	75,098	16.7	16.3	16.4	Renville	2,307	76.8	30.5	26.6
Cavalier	4,427	47.1	46.0	32.4	Richland	13,183	37.0	30.1	31.7
Dickey	2,724	49.0	46.9	36.4	Rolette	9,324	45.6	28.3	38.3
Divide	2,116	89.2	47.2	45.7	Sargent	3,386	56.3	47.9	43.3
Dunn	2,664	67.0	36.0	32.8	Sheridan	1,568	105.9	44.5	33.0
Eddy	2,061	79.4	37.8	27.3	Sioux	2,746	68.3	68.3	68.3
Emmons	3,526	54.9	39.2	31.2	Slope	662	228.7	47.2	36.5
Foster	2,908	62.0	33.9	28.6	Stark	16,667	29.5	21.1	21.2
Golden Valley	1,539	103.3	43.2	33.7	Steele	1,767	94.4	41.1	33.5
Grand Forks	51,599	18.3	16.8	18.3	Stutsman	16,236	30.7	20.0	18.4
Grant	2,591	69.3	46.7	37.8	Towner	2,648	66.6	34.4	30.4
Griggs	2,411	71.2	43.0	30.8	Traill	6,389	62.1	31.3	30.6
Hettinger	2,515	72.8	36.5	32.0	Walsh	10,103	45.8	35.1	33.7
Kidder	2,432	73.4	34.5	30.5	Ward	42,252	20.6	18.2	18.2
LaMoure	3,930	56.8	4.2	32.5	Wells	4,281	49.0	48.9	33.6
Logan	2,078	85.4	39.9	30.2	Williams	15,424	33.4	27.0	27.1
McHenry	4,765	49.8	35.8	34.0	Fort Berthold	3,938	47.4	47.4	47.4
McIntosh	2,935	65.4	52.5	35.4					
McKenzie	4,020	50.2	38.9	35.3	State	466,325	36.2	26.3	25.3
McLean	7,058	56.2	36.3	30.7	Minimum	662	16.7	15.7	15.7
Mercer	7,120	53.9	46.9	35.7	Maximum[b]	75,098	228.7	59.4	45.7

[a]Scenario A represents a baseline situation where each county operates their own landfill. Scenario B represents a regional approach using optimal landfill sizes and locations. Scenario C includes the use of transfer stations to ship waste to regional landfills.

[b]Fort Berthold and Standing Rock (Sioux County) jurisdictions were excluded from the minimum and maximum categories. Their costs remained unchanged in each scenario.

Transfer Station Scenario

Landfill sites that did not enter the solution in Scenario B were converted to transfer station sites. Additional links from transfer stations to regional landfill sites were included. Due to programming complexities and time constraints, not all possible locations for transfer stations were addressed. Results from Scenario C were intended to determine if transfer stations, given assumed costs and capacities, could generate additional cost reductions from transporting waste through those facilities versus shipping directly to landfills.

As discussed earlier, four options to Scenario C were tested. The transfer station operating cost was varied to change the break-even point between shipping direct or through a transfer station. When transportation costs with compaction trucks were $0.20 per ton-mile, semitrailer costs were $0.04 per ton-mile, and transfer station costs were $8 per ton, the break-even point was 50 miles. If a wasteshed was within 50 miles of a regional landfill, it was cheaper to ship directly to the landfill using compaction trucks. Wastesheds farther than 50 miles would ship waste to transfer stations using compaction trucks, then ship the waste from the transfer station to the regional landfill using semitrailers. The break-even point changed to 75 miles when the transfer station cost increased to $12 per ton with the same transportation costs.

Compared to Scenario B, the number and location of regional landfills remained the same. However, the landfill at Devils Lake was larger (175 TPD versus 75 TPD). Smaller landfills were needed at Grand Forks (175 TPD from 250 TPD) and Rolla (20 TPD from 75 TPD). Landfill sizes and locations remained constant in all four options.

Total costs fell 7 percent to $11.3 million, compared to Scenario B. Fixed costs decreased slightly, variable costs rose 26 percent (transfer station costs were included as variable costs), and transportation costs decreased 37 percent compared to Scenario B.

Conclusions

Solid waste disposal costs under a scenario where each county operates its own landfill ranged from $17 to $229 per ton, with a statewide average of $36 per ton. If each county were required (or elected) to develop its own landfill facility, almost half of the counties in North Dakota could incur MSW disposal costs in excess of $50 per ton. Local rural jurisdictions choosing to dispose of their waste in a community-based landfill could incur prohibitive costs. The use of regional landfills for waste disposal could

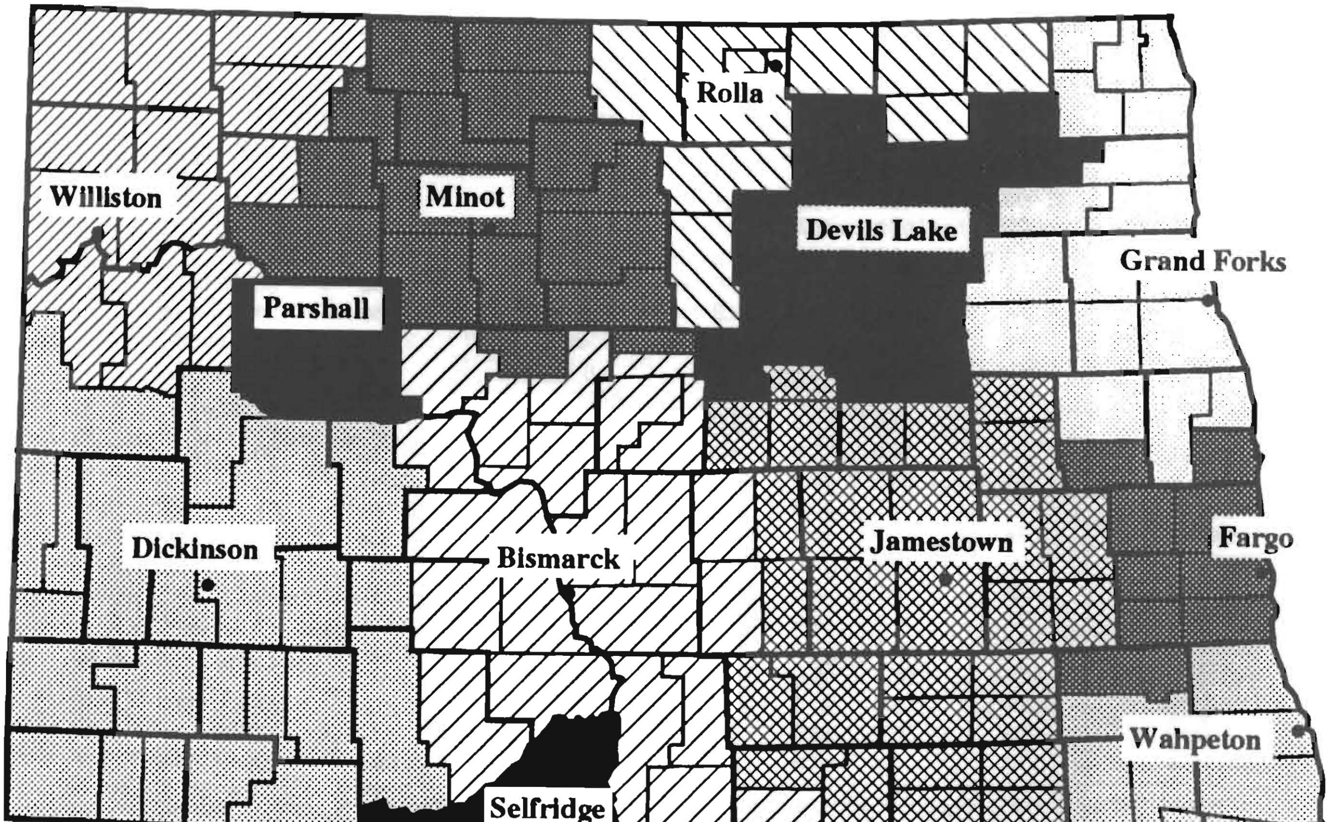

Figure 1. Waste draw areas and landfill locations using a regional approach to municipal solid waste disposal, North Dakota, 1992

lower the statewide ATC by as much as 28 percent, to $26 dollars per ton. Further cost savings of 7 percent were realized when transfer stations were used in conjunction with regional landfills.

Even with regionalization, sparsely populated rural areas will not build landfills as large as those built in urban areas. While solutions for rural situations differ from those for urban settings, regionalizing landfill sites still offers considerable savings to those participating. Buell et al. (1990) suggests the minimum efficient landfill size is 175 TPD. Our findings suggest that 75-TPD facilities are economically acceptable in sparsely populated rural areas.

Providing for politically and environmentally acceptable management of municipal solid waste at an acceptable cost is a challenge to local and state officials, planners, and policymakers. New requirements for landfill design and operation will require most existing facilities to be replaced or extensively redesigned. A major effect of these regulations is to place more emphasis upon economies of size in landfill development and operation. Small, community-based landfills may no longer be feasible.

This study illustrates some of the waste disposal costs facing North Dakota's smaller communities, particularly those removed from urban centers. The rural situation in North Dakota is not unique, and the implications may be applicable to other rural areas facing similar waste disposal problems. For these jurisdictions in particular, a considerable incentive exists for arriving at an acceptable regional plan for MSW management.

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