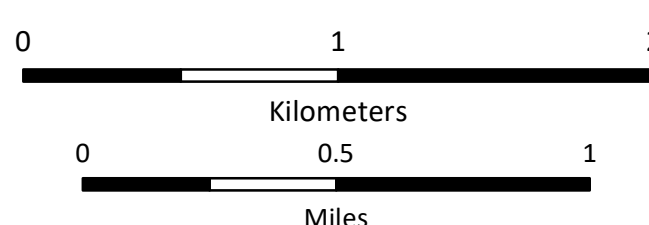


QUATERNARY SYSTEM

OAHF FORMATION

- Qod** Yellow-brown, quartz dominated, well sorted, medium to very-fine grained, windblown sand accumulated in high-relief dunes with maximum relief up to 72 feet.
- Qow** Gray-brown, quartz dominated, well sorted, medium to very-fine grained, windblown sand as undulating tabular sheet sands with occasional low-relief dunes. Relief commonly from zero to ten feet.
- Qgu** Quaternary Geology Undifferentiated

Scale 1:24,000



Lambert Conformal Conic Projection
North American 1983 Datum
Standard Parallels 48°15'0"N, 48°22'30"N
NGVD 1988



Other Features

- Water
- River
- US Route
- BLM Surface and Mineral Lands
- Highways
- Railroad
- Local Road
- Section Line
- State Trust Land



WINDBLOWN SAND RESOURCES IN THE DENBIGH QUADRANGLE

Fred J. Anderson

2020

INTRODUCTION

Windblown sand resources in the Denbigh Quadrangle are characterized in this geomorphologically based geologic resource investigation. Recent sampling and testing of windblown sand deposits in this area (Anderson, 2020) has demonstrated that sand found in dune deposits exhibit properties that are suitable for use as proppant in the hydraulic fracturing of oil wells in the Williston Basin of North Dakota based on current industry requirements.

DUNE DEPOSIT MAPPING

The dune deposits depicted on this map were identified from Light Detection and Ranging (LIDAR) elevation data overlain with National Agricultural Imagery Program (NAIP) images from 2016. Individual deposits were delineated by mapping the topographic boundary between areas of generally flat topography and the high-relief dunes that occur in larger coalesced dune fields. Fourteen high-dune fields were mapped in addition to the larger, low-relief sheet sands found across the remainder of the quadrangle. These undulating sheet sands also contain scattered low-relief <10 ft (3m) dunes.

RESOURCE ESTIMATION METHODOLOGY

The topographic data for each of the deposits (Figure 1) was volumetrically modeled independently (Table 1) from the overall LIDAR data set. Resource volumes were calculated in selected three-yard intervals, beginning from the topographic bottom of the deposit. Based on this resource modeling the high-dune areas are estimated to contain nearly 129 million tons of windblown sand. The majority of which occur within the one to seven-yard elevation intervals. These areas contain the greatest volume of sand per acre and thus are likely to be the most suitable areas for sand production.

Deposit 1 is estimated to contain well over 36 million tons. Deposit 2 is estimated to contain over 25 million tons. Deposit 3 is estimated to contain nearly 22 million tons. This map with detailed resource breakdowns by modeled elevations enables more accurate determinations of potential resource volumes at larger scales. Deposit 15 is calculated as a thickness of sand over the remaining map area between the high-relief dune fields which starts at a relief-adjusted base that is one meter below the modeled base plane. As such, this modeled volume and subsequent resource estimate may contain areas where windblown sand deposit thickness exceed one meter (3.28 ft).

PROPPANT SAND CHARACTERISTICS

Testing for proppant potential has revealed that the windblown sands found throughout this area are well sorted, medium to very-fine-grained, quartz-dominated sand with crush-resistance values ranging up to 7,000 psi (7K) in washed samples sized in the 50/140 sand size class. Acid solubilities are generally <8% as these windblown sands are found to be generally devoid of carbonates. Particle shape factors are relatively uniform at 0.5 to 0.8 for grain roundness and sphericity (Anderson, 2020).

DUNE GEOMORPHOLOGY AND GROUNDWATER CONDITIONS

Maximum relief within dune deposits tends to decrease along with the overall size of the deposit which range over 60 ft (18.3 m) from > 10 ft (3 m) to just over 70 ft (21.3 m). More than half of the deposit areas have maximum relief ≥ 50 feet (≥ 15.2 m). Groundwater is shallow throughout this area commonly occurring at depths ranging from 3-11 ft (0.9-3.4 m) below land surface outside of the high-relief dune fields.

REFERENCES

Anderson, F. J., 2020, Evaluation of Windblown Sand Deposits in North-Central North Dakota for Potential Use as Proppant: North Dakota Geological Survey, Report of Investigation No. 124, 109 p.

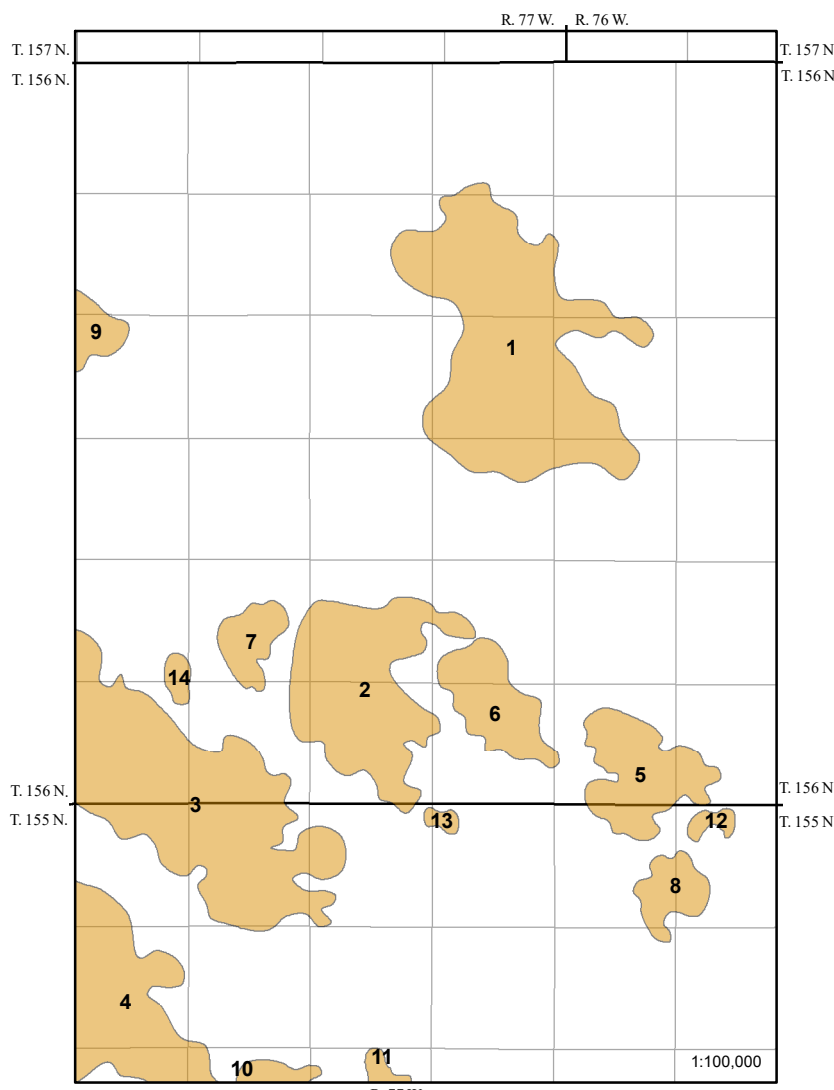


Figure 1. Windblown sand deposit areas numbered sequentially, in order of decreasing size, within the Denbigh Quadrangle.

Table 1. LIDAR-based volume and tonnage estimates for windblown sand deposits in the Denbigh Quadrangle. Volume and tonnage estimates are shown for the entire deposit along with the thickness interval (e.g. 1 – 4 yd).

Deposit Area	Area		Volume		Resources tons	Deposit Volume (yd³)				Deposit Mass (tons)							
	m²	acres	m³	yd³		<=1	1 – 4	4 – 7	7 – 10	>10	<=1	1 – 4	4 – 7	7 – 10	>10		
1	7,091,329	1,752	25,223,497	30,688,995	36,867,972	11,229,297	9,024,501	4,494,084	2,894,310	3,046,803	13,490,224	10,841,510	5,398,930	3,477,056	3,660,252		
2	3,811,479	942	17,465,624	21,277,636	25,561,714	7,041,516	6,301,401	3,913,245	2,262,845	1,758,629	8,459,268	7,570,136	4,701,145	2,718,450	2,112,715		
3	6,505,812	1,608	14,449,227	17,994,731	21,617,820	11,618,941	4,677,850	1,167,848	410,783	119,309	13,958,319	5,619,697	1,402,984	493,490	143,330		
4	2,906,765	718	9,388,122	11,437,865	13,740,784	5,067,804	4,165,324	1,649,105	457,377	98,255	6,088,165	5,003,977	1,981,139	549,466	118,037		
5	1,841,382	455	6,460,092	7,780,205	9,346,685	1,947,322	3,002,433	1,894,388	686,081	249,981	2,339,399	3,606,949	2,275,807	824,218	300,312		
6	1,399,972	346	5,625,644	6,966,965	8,369,707	3,022,573	2,523,200	835,093	463,850	122,249	3,631,143	3,031,226	1,003,233	557,242	146,863		
7	671,283	166	2,487,366	3,047,111	3,660,624	924,439	1,109,283	651,986	234,349	127,054	1,110,568	1,332,628	783,258	281,534	152,636		
8	699,815	173	2,245,155	2,764,021	3,320,533	882,598	1,377,341	426,311	62,084	15,087	1,060,302	1,654,657	512,145	75,304	18,125		
9	445,762	110	1,405,316	1,748,698	2,100,704	898,328	836,124	14,246	0	0	1,079,198	1,004,871	17,115	0	0		
10	252,826	62	1,261,807	1,590,981	1,911,314	231,342	355,843	411,202	512,316	80,278	277,921	427,490	493,995	615,467	96,441		
11	145,205	36	720,119	901,534	1,083,050	25,500	160,043	222,119	265,106	228,766	30,624	192,267	266,840	318,483	274,826		
12	160,516	40	403,503	548,227	658,608	304,174	191,310	52,642	101	0	365,417	229,829	63,241	121	0		
13	108,412	27	246,908	304,318	365,590	171,369	103,341	27,454	2,154	0	205,873	124,148	32,981	2,588	0		
14	184,809	46	213,047	271,958	326,715	223,497	48,461	0	0	0	268,497	58,218	0	0	0		
Total Potential Resources (high dunes)					128,931,900	43,588,700	33,876,455	15,759,723	8,251,956	5,846,411	52,364,928	40,697,203	18,932,813	9,913,419	7,023,537		
Total Potential Resources (low dunes)					124,030,856	15,404	78,935,436	103,247,551	124,030,856								

