DEPARTMENTS OF BIOLOGICAL
AND AGRICULTURAL ENGINEERING
AND GRAIN SCIENCE AND INDUSTRY

Emergency Storage of Grain:

Outdoor Piling

Outdoor piling of grain is a temporary or emergency grain storage practice used by grain elevator operators during bumper-crop years. The degree of success that elevator operators experience results from a combination of variables. Some of these variables can be controlled by the elevator manager, such as site preparation, pile dimensions, use of aeration, moisture and cleanliness of grain placed on the ground, and the amount of grain placed on the ground. Variables that are outside of the control of the elevator manager include weather (precipitation and temperature), and in many cases, the length of time grain is left on the ground. In addition, neighboring residences and businesses should be considered to avoid dust, rodent, vermin, and traffic complaints or problems.

Site Preparation

The first step in site preparation entails site selection. Selecting a naturally occurring high point on the elevator's property or at a site near to the grain elevator offers a more economical option than bringing in material to fill low areas. Preparation of the ground pad involves stabilizing the existing base by adding strength and decreasing permeability. Contractors with experience building roads are likely best equipped to perform this task.

Pad preparation includes creating a crown at the center point of the pile and providing a gradual slope away from the center. Good drainage is provided with slopes of 1 to 2 percent. Reduced water permeability of the pad can be best accomplished by mixing lime, fly ash, or cement in the soil prior to compaction. Check fly ash prior to use to ensure the absence of heavy metals. The amount of compression necessary for a good pad should approach 95 percent of the standard proctor density. This value can be measured on site by the engineering firm using a density gage.

The area surrounding the pad should be well drained to remove water running off the pile and pad. Most pads vary in surface area between 1 to 2 acres. One inch of precipitation on a 1 acre surface results in 27,152 gallons of water.

During site selection, consider how big an area to prepare. To determine this, elevator operators must assess how much grain they expect to place on the ground, the size and capacity of the conveying equipment, and the type of grain placed on the pad. Trucks need $^{1}/_{4}$ to $^{1}/_{2}$ acre or a diameter of 130 feet to turn around in a circle without having to back long distances.

Circular piles typically are accompanied with stationary conveying equipment for placement and reclaim. Consequently, the discharge spout may be as high as 60 feet above the ground surface. Surface area and volume for different heights of circular piles for wheat, grain sorghum, and corn are provided in Table 1.

Frequently, grain is piled outdoors by portable augers powered by tractors, resulting in elongated triangular shaped piles. The amount of ground surface area required for piles that are 15, 20, and 25 feet high for wheat, corn, and grain sorghum are presented in Table 2. Piles higher than 25 feet may result in burial of the auger and damage to the under carriage during movement. Overhead conveyors are recommended for deeper piles. Appendix 1 and 2 provide capacities for corn and grain sorghum stored in elongated piles based on the width and length dimensions of the pile base.

Grain Placement

Ideally, only place cool (50 to 60 degrees Fahrenheit), dry (14 percent moisture), clean grain on outdoor piles. This enables the storage manager to maximize pile height and diameter thereby reducing the amount of surface area exposed to weather damage.

Practically, quality tolerances are pushed with respect to temperature and moisture content when creating outdoor piles. Early harvest corn that requires drying may be placed on the ground at temperatures approaching 90 degrees Fahrenheit. In situations such as this, grain elevator managers should consider making piles smaller to allow heat loss. Installation of an aeration system is critical if the grain is placed on the ground at temperatures above 60 degrees Fahrenheit.

Figure 1 provides an example of temperature loss in a pile 82 feet wide with one that was 66 feet wide, respectively. Temperature loss in the center of the smaller piles was greater than the larger pile. Self-heating had begun in the larger pile and continued until kernel damage reached 70 percent, while kernel damage in the smaller pile remained relatively constant around 8 percent.

Table 1. *Angle of repose, pile radius, and bushels for corn, wheat, and sorghum piled from 50 and 60 foot heights for cone shaped outdoor grain piles.*

Height (feet)	Grain	Angle of Repose	Pile Radius	Bushels
50	Corn	22°	124 ft	644,004
	Wheat	25°	107 ft	479,526
	Sorghum	27°	98 ft	402,251
60	Corn	22°	148 ft	1,100,000
	Wheat	25°	129 ft	832,581
	Sorghum	27°	118 ft	696,272

Note: *pack factor not included in bushel calculation*

Table 2. *Pile width (ft) and bushels for one foot length of elongated triangular shaped outdoor grain piles of corn, wheat, and sorghum piled at 15, 20, and 25 feet heights.*

Height	15 ft		20 ft		25 ft	
Grain	**Width**	**Bu/ft**	**Width**	**Bu/ft**	**Width**	**Bu/ft**
Corn	74	445	99	792	124	1237
Wheat	64	386	85.8	686	107	1072
Sorghum	58.9	353	78.5	628	98	981

Note: *pack factor not included in bushel calculation*

Build the pile uniformly to achieve maximum slope. This can be accomplished by keeping the drop distance from the spout to the pile at a minimum. The maximum angle of repose and pile height occurs when grain rolls down the side of the pile. It is important to avoid creating hills, valleys, folds, and crevices that will collect water. Sprouting and mold growth occur first in these areas. Keep people and animals off the grain pile, since divots in the pile collect water and intensify spoilage. Placing a temporary fence around the pile helps mitigate this problem.

Grain cleanliness also determines the success of outdoor piles. Segregation occurs during free fall situations. Light material can be caught in convective currents or moved by winds during grain placement. Its concentration at any point in the pile can result in the grain experiencing self-heating and quality deterioration. Placing clean grain in outdoor piles helps slow quality deterioration.

Aeration

Typically, ventilation ducts are positioned parallel to the long axis of rectangular piles (Figure 2). This type of design facilitates grain reclaim and directs cooling to the problem area of the pile (its core). Ducts placed at the front and back ends of each pile should extend approximately 70 feet. For large piles (length of the long axis is greater than 200 feet) ventilation of the pile core may be accomplished by running ducts in from the side and intersecting at the center of an 80 foot duct running parallel to the long axis, thus forming a T shape.

Use low velocity fans that provide approximately 0.1 cubic foot of air per minute per bushels to the pile core. Run fans as soon as cooling becomes available. General guidelines for the time required to move a cooling front through a corrugated steel bin are provided in K-State Research and Extension bulletin MF-2090, *Questions & Answers About Aeration Controllers*. Use of an inexpensive aeration controller that turns fans on and off based on outside temperature will facilitate rapid cooling.

Reclaim

Quality deterioration in outdoor grain piles can occur rapidly. The reclaim process may necessitate further grain conditioning via aeration, drying, or blending. During grain reclaim, spoiled grain becomes commingled with sound grain, contaminating the entire amount with damaged kernels and commercially

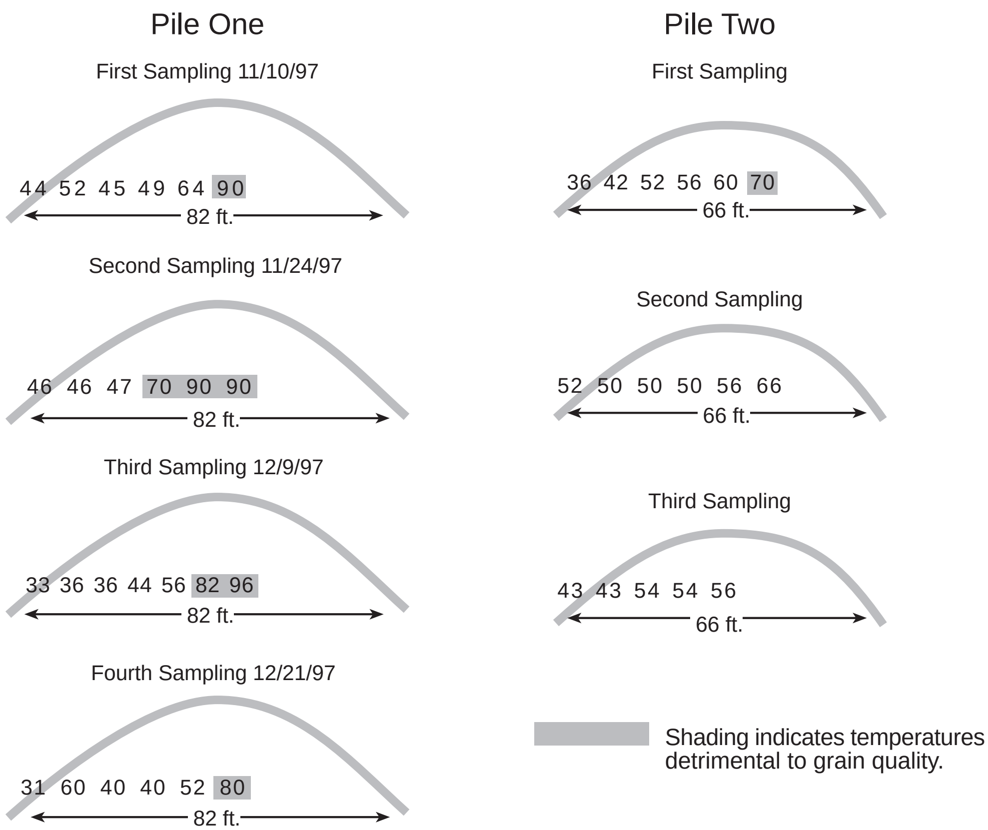
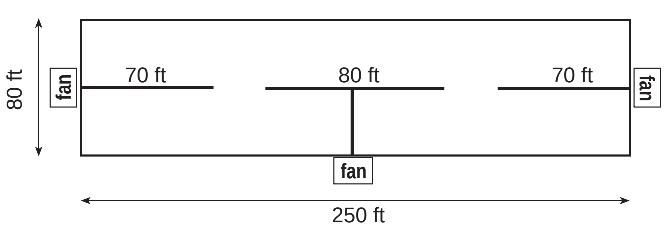


Figure 1. *Temperature (degrees Fahrenheit) profiles of two ground piles of corn sampled at 2-week intervals.*

objectionable odors. While no easy answers exist in solving this problem, leaving spoiled grain along the base and edge of the pile on the ground as the rest of the pile is removed may help grain handlers avoid having to blend all the grain stored in outdoor piles. Likewise, piles with the long axis pointing east-west may experience greater quality deterioration along the southern face of the pile. Segregating grain from the northern half of the pile (with less damage) from the southern half of the pile (more damage) helps limit the amount of grain that requires additional conditioning via cleaning, drying, and blending.

Figure 2. *Ventilation design for an elongated rectangular pile of grain.*



Picking grain up from outdoor piles as soon as space becomes available should be considered and practiced where possible. The costs and benefits of this practice, versus waiting until space becomes available for the entire ground pile prior to reclaim, should be weighed against penalties associated with quality deterioration. This becomes difficult because discounts associated with odor are based on a yes/no decision. Thus, failing to reduce odor through conditioning and blending to below the discount level can greatly increase the cost of outdoor piling of grain.

Economic Evaluation of Outdoor Piles, Temporary Storage, and Steel Bins

A partial budget analysis was performed to assess the additional costs of piling grain outside with and without aeration. For comparison purposes, fixed and variable costs associated with temporary storage and the construction of a corrugated steel storage bin are included in the analysis. A spreadsheet program in Microsoft Excel is available for grain elevator managers and farmers to calculate his or her anticipated expenses. This spreadsheet is available upon request at the following e-mail address: alm@wheat.ksu.edu.

For comparison purposes, scenarios 1, 2, and 3 are based on 1 million bushels of grain. The calculations are designed to reflect fixed costs associated with site preparation, ventilation equipment, and construction (as appropriate for each scenario). Variable costs associated with additional drying for ground piles, associated shrink, and conditioning costs are included for scenarios one and two. Expenses for personnel, fumigation, and grain quality evaluation for the four scenarios are not included in this analysis since additional costs in these three categories vary widely between grain elevators.

Scenario One

Figure 3 represents the steps and costs involved in storing grain in an outdoor pile without aeration. Activities for scenario one include preparing the pad, drying grain to one percent below the recommended safe storage moisture content for conventional storage, placing grain in the pile, reclaiming grain with a front end loader, and conditioning grain.

The cost of the pad preparation is amortized over 5 years at 8 percent interest. Maintenance costs of $1,000 per year are included, resulting in an average of $0.01 per bushel. Many individuals may not choose to make a long-term investment in preparing a pad for grain piling. Quotes for the cost of preparing a temporary site for 1 year (just grading costs) were similar to the cost of a permanent pad amortized over 5 years.

Conditioning grain after reclaim from outdoor piles with no ventilation included the following activities: one pass through the drier ($0.01 per bushel), approximately 300 hours of aeration (estimated at $0.005 per bushel), turning the grain twice ($0.001 per bushel), and one percent shrink associated with handling, drying, and blending.

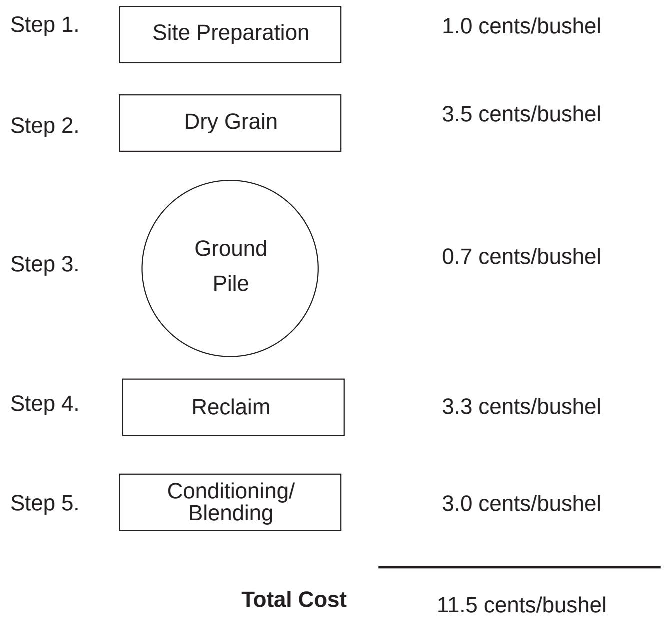


Figure 3. *Partial budget analysis summary for additional costs associated with outdoor piling of grain.*

Scenario Two

Figure 4 includes the steps involved in storing grain in an outdoor pile with aeration. This scenario assumes that grain is dried to the recommended safe storage moisture content, thus, a one percent shrink and added cost of drying is not included.

The additional expense associated with installing and operating a ventilation system was added. The bid provided used 18 inch diameter 16 gauge perforated corrugated full round ducts with shop welded perforated end plates, connector band, and tie down. Also included in the calculation are 3 horsepower axial fans with guard and 3450 rpm TEAO motor, for a total cost of $31,340.

The reconditioning and blending costs were assumed to be half of those incurred by outdoor piles.

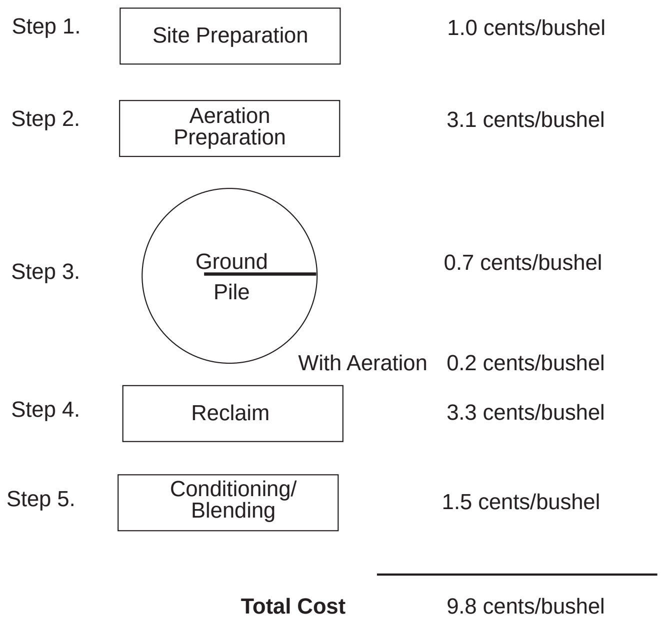


Figure 4. *Partial budget analysis summary for additional costs associated with outdoor piling and aerating grain.*

Scenario Three

Figure 5 represents use of temporary storage with aeration. The cost for temporary storage is amortized over 5 years at 8 percent interest. No additional drying or shrink associated with handling are included. Aeration costs are approximately 25 times greater than Scenario 2 based on the assumption that fans run continually to hold the tarp down on the top of the pile.

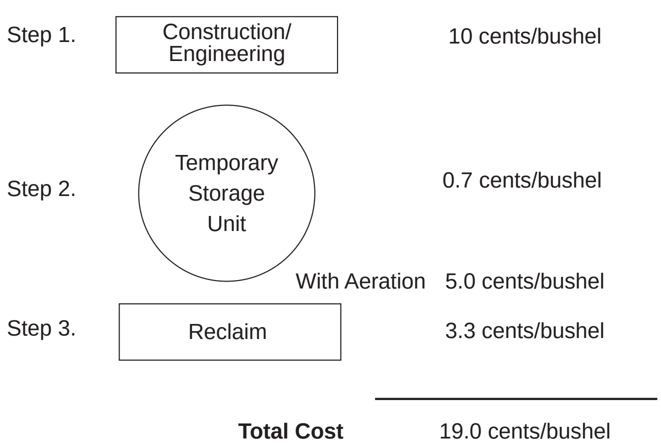


Figure 5. *Partial budget analysis summary for fixed and variable costs associated with temporary storage.*

Scenario Four

Figure 6 represents a corrugated steel bin storage system. This scenario does not include ventilation, additional drying, shrink, or conditioning costs. Total expense for the corrugated steel bin is amortized over 15 years at 8 percent interest.

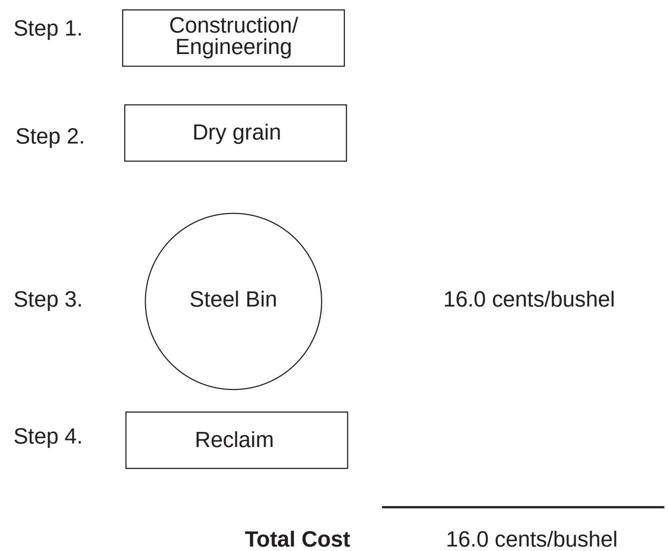


Figure 6. *Partial budget analysis summary for fixed and variable costs associated with a 750,000 bushel corrugated steel storage.*

Summary

Activities necessary to mitigate grain loss in outdoor grain piles fall into three categories, which include site preparation, grain placement, and grain reclaim. Site preparation steps include proper site selection, pad preparation, drainage, and planning for the correct area necessary, based on estimated bushels targeted for outdoor grain piles. Grain placement, quality requirements, and aeration will determine the success of storing grain in outdoor piles. Reclaiming grain provides an additional management step whereby grain may be segregated based on quality deterioration.

The economic analysis for different storage options will vary by elevator, the length of storage, pile size, and quality deterioration resulting from outdoor piles. The feasibility of each option depends upon the management expertise and personnel availability, as well as the ability to condition and blend grain. Individuals are encouraged to perform their own calculations based on individual quotes, marketing strategy, and past ground storage experience.

Appendix

Table 1. Estimation of Bushels of Corn in a Grain Pile.

Angle of Repose 22°

Width of Base (ft)	Pile Height (ft)	Circular Pile (bu)	Length of Pile Base (ft)										
			40	60	80	100	120	150	180	210	240	270	300
20	4	338	970	1,616	2,263	2,909	3,555	4,525	5,495	6,464	7,434	8,404	9,373
30	6	1,142	1,818	3,273	4,727	6,182	7,636	9,818	12,000	14,181	16,363	18,545	20,727
40	8	2,708	2,586	5,172	7,757	10,343	12,929	16,807	20,686	24,565	28,443	32,322	36,201
50	10	5,289	3,030	7,070	11,111	15,151	19,191	25,252	31,312	37,372	43,433	49,493	55,554
60	12	9,139	2,909	8,727	14,545	20,363	26,181	34,908	43,635	52,362	61,089	69,816	78,543
70	14	14,512	1,980	9,899	17,818	25,736	33,655	45,534	57,412	69,290	81,169	93,047	104,926
80	16	21,662		10,343	20,686	31,029	41,372	56,887	72,401	87,916	103,431	118,945	134,460
90	18	30,844		9,818	22,908	35,999	49,089	68,725	88,361	107,996	127,632	147,268	166,903
100	20	42,310		8,081	24,242	40,403	56,564	80,805	105,047	129,288	153,530	177,772	202,013
110	22	56,314		4,889	24,444	43,998	63,553	92,886	122,218	151,550	180,883	210,215	239,547
120	24	73,111			23,272	46,544	69,816	104,724	139,631	174,539	209,447	244,355	279,263
130	26	92,954			20,484	47,796	75,108	116,077	157,045	198,013	238,982	279,950	320,918
140	28	116,097			15,838	47,513	79,189	126,703	174,216	221,730	269,243	316,757	364,270
150	30	142,795			9,091	45,453	81,815	136,359	190,902	245,446	299,989	354,533	409,077

Assume there is no grain piled against the sidewalls or endwalls and zero compaction.

Table 2*. Estimation of Bushels of Grain Sorghum in a Grain Pile.*

Angle of Repose 27°

Width of Base (ft)	Pile Height (ft)	Circular Pile (bu)	Length of Pile Base (ft)										
			40	60	80	100	120	150	180	210	240	270	300
20	5	427	1,223	2,038	2,853	3,669	4,484	5,707	6,930	8,152	9,375	10,598	11,821
30	8	1,441	2,293	4,127	5,961	7,796	9,630	12,381	15,133	17,884	20,636	23,387	26,139
40	10	3,415	3,261	6,522	9,783	13,044	16,305	21,196	26,088	30,979	35,871	40,762	45,653
50	13	6,670	3,821	8,917	14,012	19,107	24,202	31,845	39,488	47,131	54,774	62,417	70,060
60	15	11,525	3,669	11,006	18,343	25,680	33,017	44,023	55,029	66,034	77,040	88,046	99,052
70	18	18,302	2,497	12,483	22,470	32,457	42,443	57,424	72,404	87,384	102,364	117,344	132,324
80	20	27,319		13,044	26,088	39,132	52,175	71,741	91,307	110,873	130,439	150,004	169,570
90	23	38,898		12,381	28,890	45,399	61,907	86,670	111,433	136,196	160,959	185,722	210,485
100	25	53,357		10,191	30,572	50,953	71,334	101,905	132,477	163,048	193,620	224,191	254,763
110	28	71,019		6,165	30,826	55,487	80,148	117,140	154,131	191,123	228,115	265,106	302,098
120	31	92,202			29,349	58,697	88,046	132,069	176,092	220,115	264,138	308,161	352,184
130	33	117,226			25,833	60,277	94,721	146,387	198,053	249,718	301,384	353,050	404,716
140	36	146,413			19,973	59,920	99,867	159,787	219,707	279,628	339,548	399,468	459,388
150	38	180,081			11,464	57,322	103,179	171,965	240,751	309,537	378,323	447,109	515,895

Assume there is no grain piled against the sidewalls or endwalls and zero compaction.

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