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2018 Summary of U.S. Agricultural Confined Space-Related Injuries and Fatalities

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Introduction

Since the 1970's, Purdue University's Agricultural Safety and Health Program has been documenting and investigating incidents involving grain storage and handling facilities at both commercial and on-farm locations. Over time, the effort was expanded to include incidents involving grain transport vehicles (trucks, wagons, railcars), injuries occurring inside of confined spaces due to exposure to powered mechanical components, such as augers, falls from or into confined spaces, and other types of agricultural confined spaces including forage storage silos, storage tanks, and manure storage and transport facilities.

All documented cases have been reviewed by a team of experts to ensure elimination of duplicates, assign case information to specific coding categories, and to identify potential contributing factors. Data were derived from a wide range of sources including online searches, death certificates (during early years), interviews with actual victims or family members and work product from civil litigation. Coded data were entered into the Purdue Agricultural Confined Space Incident Database (PACSID) allowing for summarization.[1]

As of the end of 2018, the PACSID contained information on 2,050 cases,[2] documented between 1962 and 2018,[3] that resulted in an injury, fatality, or required emergency extrication by first responders. Of these cases 1,214 (59%) were fatal. 1,462 (71%) involved grain storage and handling facilities, of which 1225 were reported as entrapment or engulfment in grain.

As noted in past summaries, the data presented do not account for all incidents involving agricultural confined spaces. There is no accumulative public record of these incidents due to the fact there are no comprehensive or mandatory incident/injury reporting systems for most of agriculture. In addition, there has been reluctance on the part of some victims and employers to report "near-misses" or non-fatal incidents, especially at farms, feedlots, and seed processing operations not covered by federal OSHA injury reporting requirements. Based upon earlier research, it is estimated that approximately 30% of cases go unreported.

[1] Summaries of past years can be found at www.agconfinedspaces.org.
[2] A case refers to one individual. Some incidents involve multiple victims or cases.
[3] There is one case in the database that occurred in 1956.

This report provides a summary of the cases documented in 2018 and provides a historical perspective, including trends. Specific attention is given to cases involving grain storage and handling facilities, which accounted for the majority of cases, as well as manure storage and handling operations. The report also includes a brief summary of fires and explosions at grain storage and handling facilities and observations on the training of emergency first responders utilizing live "victims".

The purpose of publishing these findings on an annual basis has been to contribute towards the reduction in the frequency and severity of these incidents by: 1) keeping the problem in the public's attention;, 2) assisting in developing more effective, evidence-based prevention and injury mitigation strategies; and 3) providing guidance to public policy makers in the development of more effective regulations targeting worker safety and health

2018 Summary of All Documented Agricultural-Confined Space-Related Cases

In 2018, there were 61 documented cases, an increase of 13% over the 54 cases reported in 2017. Of these cases, there were 30 documented grain entrapment cases,[4] 6 reported falls into or from grain storage structures, 7 asphyxiations due to deficient oxygen levels or toxic environments, and 11 equipment entanglements that occurred while working inside or around agricultural confined spaces, such as those involving in-floor and sweep augers, (Figure 1). Other incident types involved forage silos, manure pits, and pump pits. Grain entrapments accounted for 49% of the documented cases, a lower percentage than the historical average. For incident types with more than one case, falls and entrapments had the highest fatality rate reported at 100% and 50% respectively. In other words, 50% of the 30 victims entrapped in grain ended up being a fatality. The total number of fatal cases (27) was lower than the number of non-fatal cases (31). These figures are nearly identical to the 5 year running average of 31.40 non-fatal cases, and 27.40 fatalities per year. However, 2018 showed a decrease in both non-fatal and fatal cases when compared to the 10-year running averages of 36.90 and 30.20 cases per year respectively.

The total of 61 confined space cases places the number of this year's confined space-related cases slightly above the 5-year average (58.8 cases/year) (see Figure 2) and substantially below the 10-year average (67.10 cases/year). The modest increase in the number of cases documented should, however, be a concern considering the considerable attention given to the issue of confined spaces, especially in the grain industry. The 5-year running average for all agriculture-related confined space-related cases has continued to decrease from its peak in 2011 of 75.8 cases/year. 2018 reflected the lowest reported five-year average since 2008. The five-year average started to steadily increase from 36.8 cases per year in 2002 to the peak of 75.8 cases/year in 2011, before gradually declining to the current level. The dramatic increase in frequency experienced in the early 2000's was attributed to better documentation of incidents

[4] Two incidents involved two individuals or cases.

due to more aggressive nationwide surveillance efforts, coupled with enhanced access to case information via the internet.

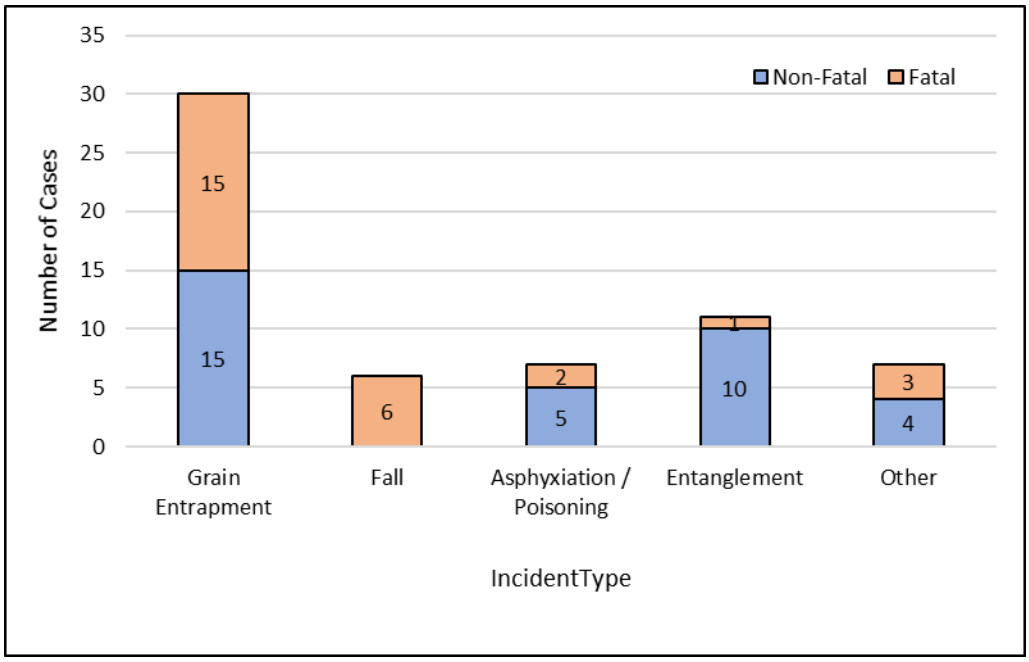

Figure 1: Distribution of all 2018 agricultural confined space-related cases by type of incident, N = 61.

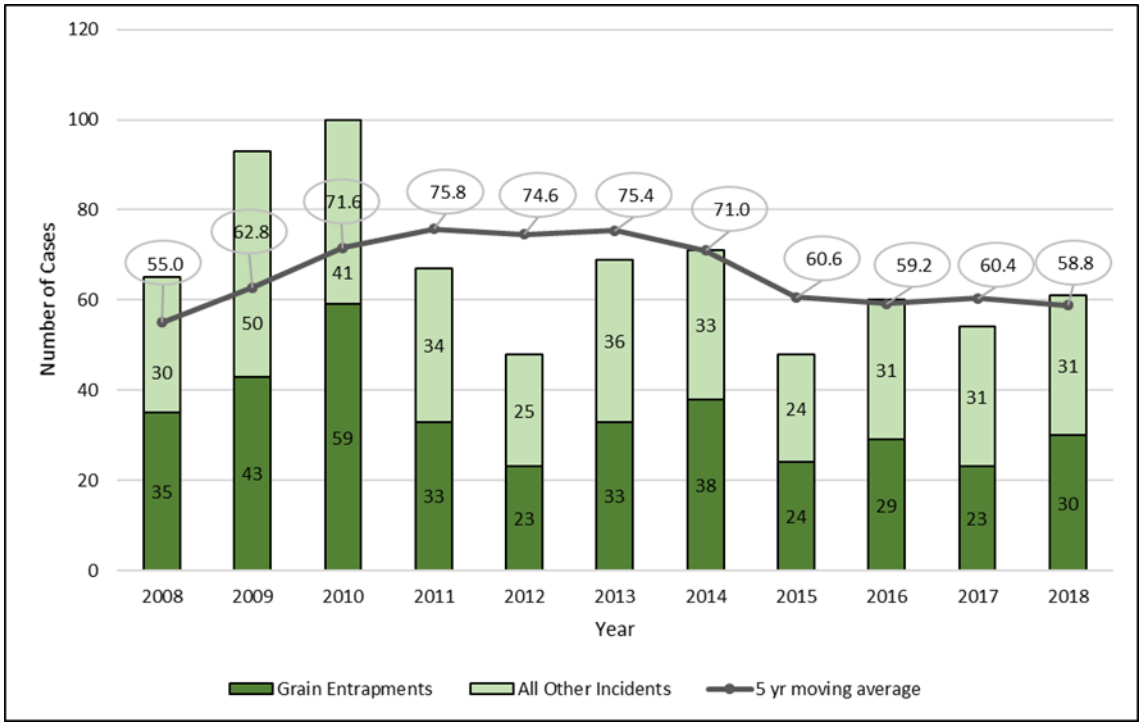

Figure 2: Number of all annual confined space cases recorded between 2008 and 2018.

In 2018, the states with the most documented confined space cases of all types, including fatal and non-fatal, were Iowa (8), Illinois (5), Nebraska (5), Ohio (5) and Wisconsin (5). There were four cases documented in Kansas and Wyoming. Overall, incidents were documented in 23 states in 2018, substantially more than the 17 states reporting incidents in 2017. Figure 3 illustrates the geographic distribution of all documented cases in the PACSID and those documented in 2018. The three states with the largest number of cases, historically, have been Iowa (245), Indiana (225) and Minnesota (193). As noted in previous summaries, it is estimated that this surveillance effort underreports cases by as much as 30% due to the lack of adequate reporting mechanisms. It is also believed that Indiana has had such a high number of documented cases because of more aggressive surveillance efforts over the past 40 years.

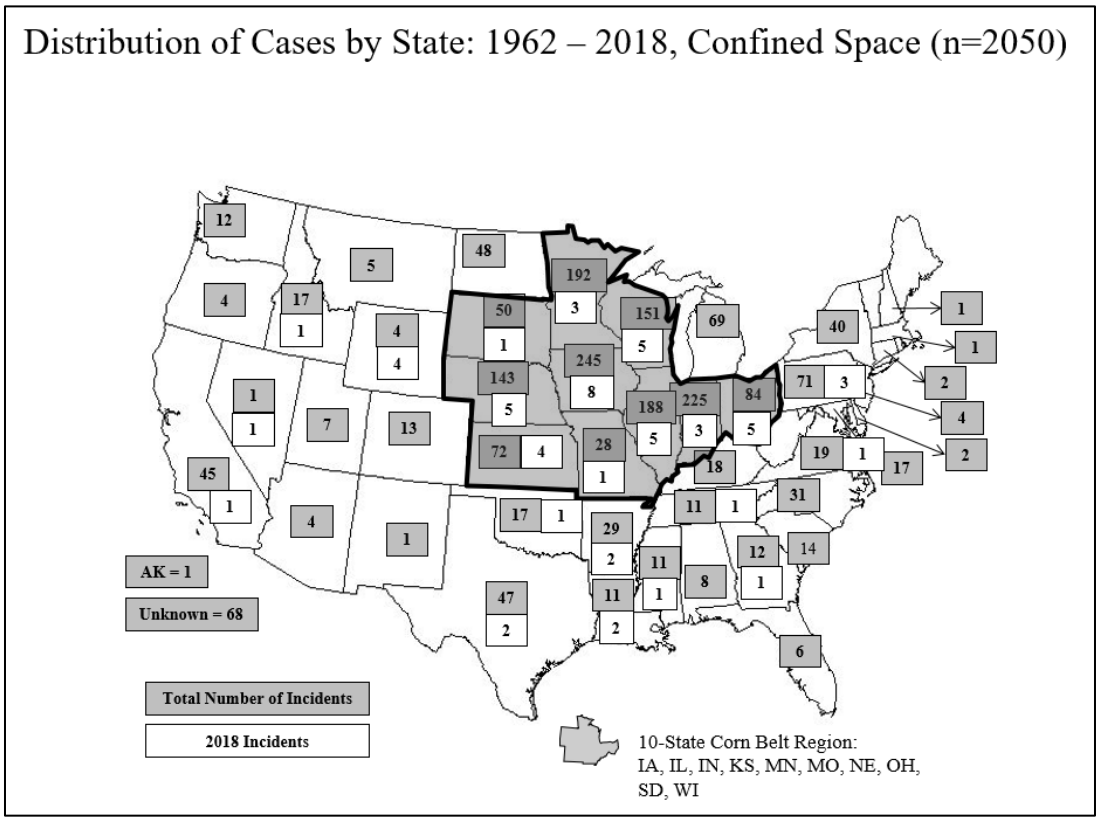

Figure 3: Geographic distribution of all confined space cases for 2018 and previous years (n=2050).

There was one case in 2018 in which the gender was female and the remaining cases all involved males. The female case involved a child under the age of 18 who suffocated in a grain wagon.

In total, there were ten cases (16.4%) involving a child or youth under the age of 21, as shown in Figure 4. The historical pattern that nearly one in five of all agricultural confined spaces have involved children and youth under the age of 21 should continue to be a concern. Overall, a specific age was known for 40 of the 61 victims in 2018, with the oldest victim being 80 and two children ages three and four years old. The average age was 42.2 and the median age 51.5 (Figure 4). Both the average and median ages were substantially below the current average

age of U.S. farmers of 58, which suggests that work in and around agricultural confined spaces is more likely to be performed by younger workers. Those over the age of 60 accounted for 6 (15%) of the 40 cases (where age was known). As noted, a large number of the cases documented (21) did not include the specific age of the victim.

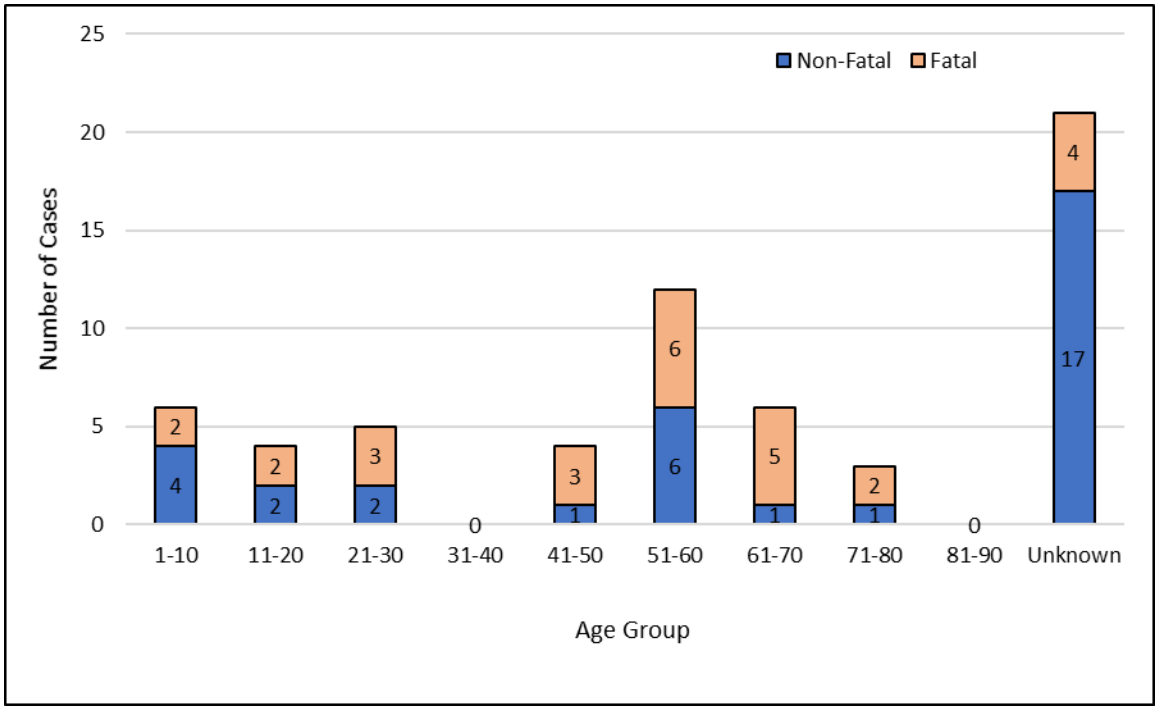

Figure 4: Age distribution of all 2018 agricultural confined space incident victims by number of cases recorded.

In 2018, there were 37 cases where the exemption status[5] of the facility with respect to OSHA regulations could be determined. Of those, 29 (78%) occurred on farms or other locations currently exempt from compliance with the OSHA Grain Handling Facilities Standards (29 CFR 1910.272) or Confined Space Standards (29 CFR1910.146), with the balance of known cases (22%) taking place at non-exempt commercial grain facilities, which is consistent with past trends. It is believed that the majority of the unknown cases, based on historical data, occurred at worksites that have OSHA exempt status.

As in the past, a comparison was made between agricultural confined space incidents and mining incidents because of similarities. In 2017, there were 28 fatal mining incidents and 23 fatal agricultural confined space incidents. In 2018, the number of reported fatal incidents in mining (27)[6] was equal to the number of fatal agricultural confined space incidents (27). Historically there have been more fatal mining incidents than those occurring in agricultural confined spaces.

[5] Under the current provisions of the two OSHA workplace safety and health standards most relevant to agricultural confined spaces, most agricultural worksites, including most farms, feedlots, and certain seed processing operations are exempt from compliance.

[6] According to the U.S. Department of Labor's Mine Safety and Health Administration (MSHA), 27 mining fatalities were recorded in 2018, which is the second lowest number ever documented.

Grain Entrapments

The 30 fatal and non-fatal grain entrapment cases documented in 2018 represented a 30% increase from 2017 when 23 were recorded. The total number of cases, fatal and non-fatal, documented in 2018 was slightly higher than the 5-year average (28.8 cases/year). Note, the 5-year running average continues to drop from its peak of 40.4 in 2011 (Figure 5). The number of fatal cases (15) is the third lowest recorded since 1985; only 2012 (8 cases) and 2017 (11 cases) reported a lower number of fatal grain entrapments. The number of non-fatal cases (15) was the fifth largest ever recorded after 2010 (27), 2011 (21), 2013 (21), and 2014 (20).

In 2018, the state with the most documented grain entrapments, fatal and non-fatal, was Iowa with five cases total. This was followed by Kansas (3), Wisconsin (3), and Arkansas, Illinois, Indiana, Louisiana, Minnesota, and Nebraska with two cases each. The remaining 7 states had one each. Overall, grain entrapments were documented in 16 states in 2018. The majority of grain entrapment cases occurred in the Midwest, or Cornbelt (83%), which was higher than last year during which 70% occurred in the Midwest. Historically, 74% of previously documented cases have occurred in the Midwest. Figure 6 provides a geographic distribution of all documented grain entrapment cases contained in the PACSID where the location was known. Indiana continues to have the highest number of documented grain entrapment cases. It is believed that this high number reflects more aggressive surveillance efforts in Indiana to document both fatal and non-fatal cases over the past 40 years rather than an actual larger number of cases than other states. It is believed that Iowa, Illinois, and Minnesota should have had a substantially higher number of cases based on both total grain production and grain storage capacity.

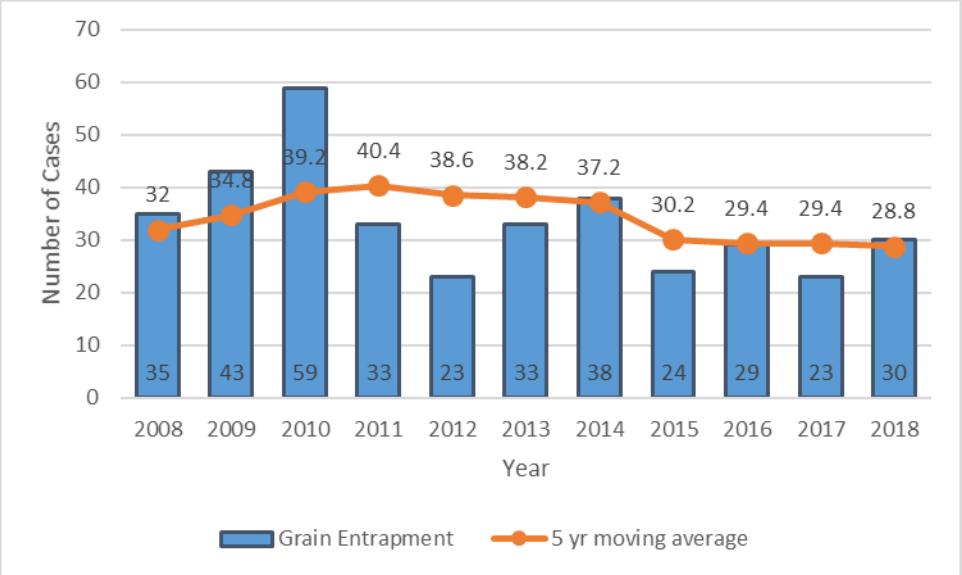

Figure 5: Number of annual grain entrapment cases recorded between 2008 and 2018

In addition to the 1225 cases involving entrapment or engulfment in grain, the PACSID also contains data on 237 other cases related to grain storage and handling, including falls into or from grain storage structures, asphyxiations, and entanglements in grain handling equipment such as in-floor and sweep augers.

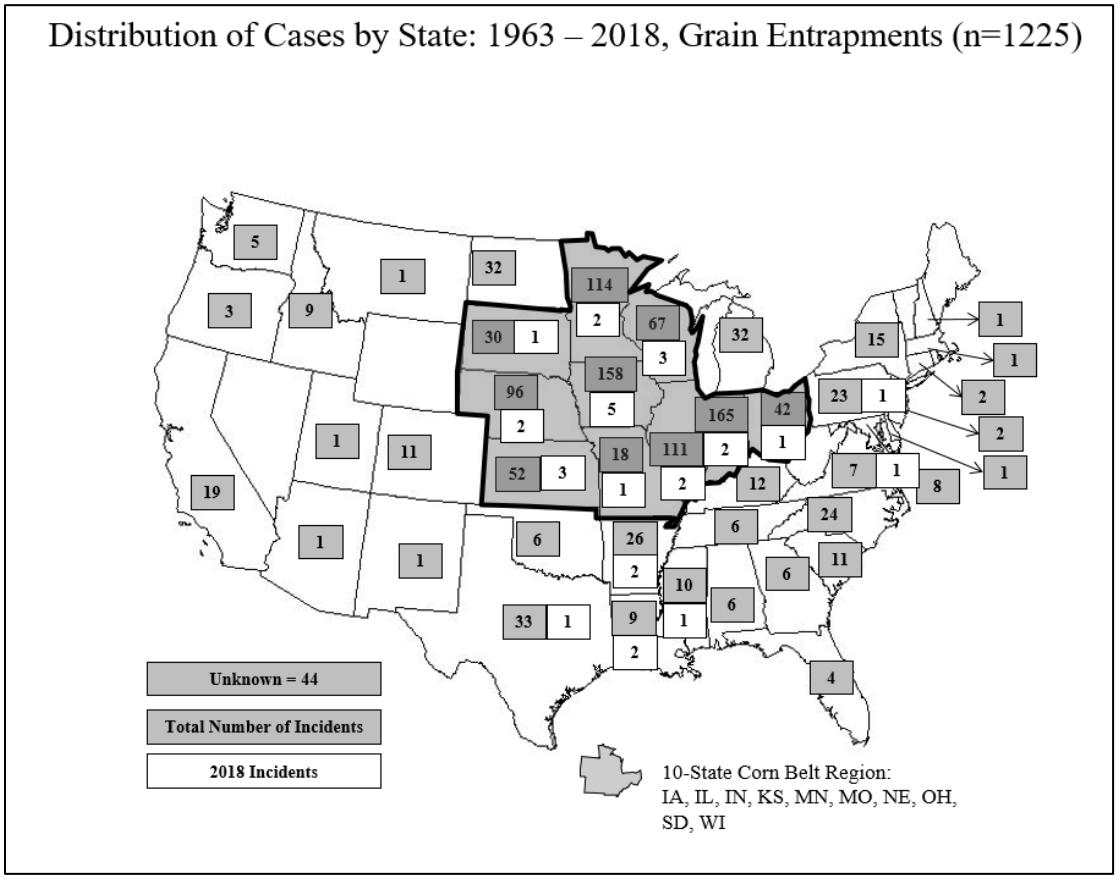

Figure 6: Geographic distribution of grain entrapment cases for 2018 and previous years (n=1225).

There was only one female victim with the remaining cases being male. There were five grain entrapment cases (16.7%) involving a youth under the age of 21, an age group that has accounted for as many as one in five cases in the past. The oldest victim was 80. The average age was 42 years old and the median age 51.5. Three cases of grain entrapments occurred in grain transport vehicles (GTV) and one resulted in fatality.

As in past years, it should be noted that this summary does not reflect all grain-related entrapments, fatal or non-fatal, that have occurred. Currently, over two-thirds of grain storage capacity in the U.S. is found on farms that are exempt from the current OSHA injury reporting requirement standards.

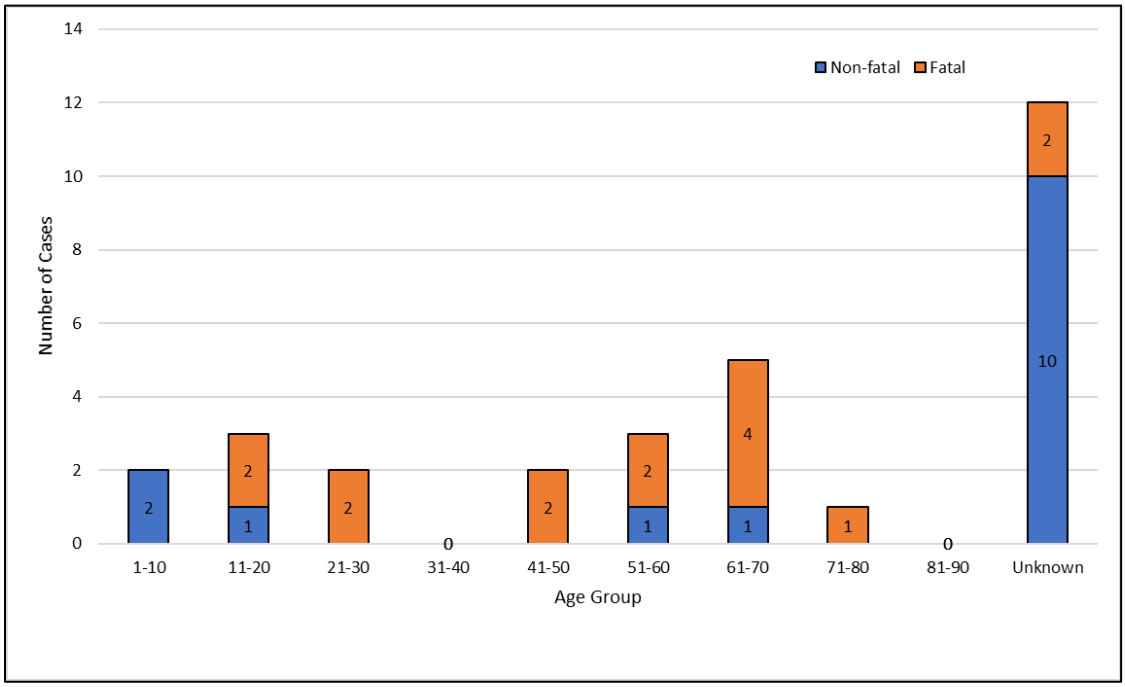

Figure 7: Age distribution of 2018 grain entrapment victims by number of cases recorded.

Using Children and Youth in Grain Safety/Rescue Training Activities

Through ongoing surveillance efforts, cases have been identified in which fatalities or injuries were documented as the result of involving children and youth as live "victims" in safety demonstrations, grain rescue training, or recreational/educational activities. This has included two male victims, age 6 and 13, who asphyxiated in free flowing grain used in a "sand box" during an educational visit to a farm. In addition, cases were reported and documented in which children and youth were being deeply entrapped in grain, up to their shoulders, to demonstrate the effects of entrapment and to conduct extrication training for emergency first responders. A review of on-line sources found literally hundreds of images showing children, including infants, being partially buried in grain. The potential hazards associated with these unsafe practices include:

- Choking and asphyxiation on grain
- Exposure to respiratory hazards and/or asthma triggers, including moldy grain
- Excessive pressure on the chest and breathing difficulties
- Claustrophobia/emotional trauma
- Injuries related to forceful emergency extrication

As the result of these findings, an editorial was published in the April 2018 (Vol. 24 No. 2) issue of the Journal of Agricultural Safety and Health calling for an end to the use of children and youth, and others, uninformed regarding the hazards of flowing grain, as "victims" in flowing grain demonstrations and extrication training. There is no evidence to justify the need for or the value of placing children and youth at risk of harm, even if volunteered by a parent or guardian to participate. On the contrary there is research to suggest that presenting a recognized

hazardous activity as recreational or fun may, in fact, result in a lower appreciation of the potential risks involved. It is recommended that only mannequins be used in flowing grain demonstrations, and that safety professionals present, whenever live "victims" are being used, step up and intervene on behalf of those being placed in harm's way. It should also be noted that the practice may violate the Institutional Review Board policies of most agencies on the use of human subjects, especially children.

Cases have also been documented in which trained emergency first responders have experienced injuries during mock training exercises while being entrapped or extricated from grain for demonstration purposes. Again, mannequins are recommended for training purposes.

Summary of Manure Storage, Handling, and Transport Equipment and Facility Incidents

As part of ongoing surveillance of fatalities and injuries involving agricultural confined spaces by Purdue University's Agricultural Safety and Health Program, nearly 350 cases involving manure storage, handling and transport equipment and facilities have been documented over the past 30 years. With the exception of a summary of 77 fatalities published by Beaver (2005), these cases have not been completely entered into the Purdue University Agricultural Confined Spaces Incident Database (PACSID) or summarized due to a lack of resources and the limitations in the design of the database because of its origin as a means to maintain case information involving grain storage, handling, and transport operations. The differences in terminology used in the current database and dissimilar causative and contributing factors were a significant barrier.

In order to develop a consistent approach to process and analyze the data, 28 U.S. incidents involving 39 victims documented as having occurred in 2017 were examined for type of incident, victim characteristics, primary contributing factors and nature of injuries. A pilot analysis was completed and results were summarized (Nour, 2018). This pilot exercise resulted in a classification rubric for coding and analysis of descriptive information regarding each case. The final methodology will be used to analyze all historically documented manure-related incidents, as well as future incidents.

Note that the incidents examined in the pilot analysis for 2017 do not match the summary of all confined space incidents discussed earlier in this document. This discrepancy is due to fact that only those incidents clearly involving confined spaces, such as manure pits, were included in the earlier discussion. Cases such as roadway collisions and injuries or fatalities resulting from manure handling equipment were not included in the confined space results, but were accounted for in the pilot analysis of manure-related incidents.

Of the cases occurring in 2017, 21(54%) cases were fatal. There were six incidents that involved multiple victims, two victims in one case and three victims were reported in another, and in two incidents there were four victims. As with confined spaces in general, the risk of multiple victims is higher than for other types of farm-related incidents.

The cases were primarily work-related but also included ten cases that were classified as non-work, including the death of a three-year-old male who drowned after falling into an open

manure pit. All of the victims in 2017 were male with an average age of 36 which is substantially younger than the average for all grain-related victims (53) and the average age of farm owners (58).

The distribution of agents involved in 2017 is shown in Figure 8. There were 21 fatal cases with known causes, including 8 cases involving manure handling equipment, the most frequently identified agent, and 5 cases involved manure transport equipment, such as tankers.

The type of toxic gas the victim(s) were exposed to was rarely confirmed, but in prior research it appears that oxygen deficiency and the presence of hydrogen sulfide are significant contributors to fatalities in these cases.

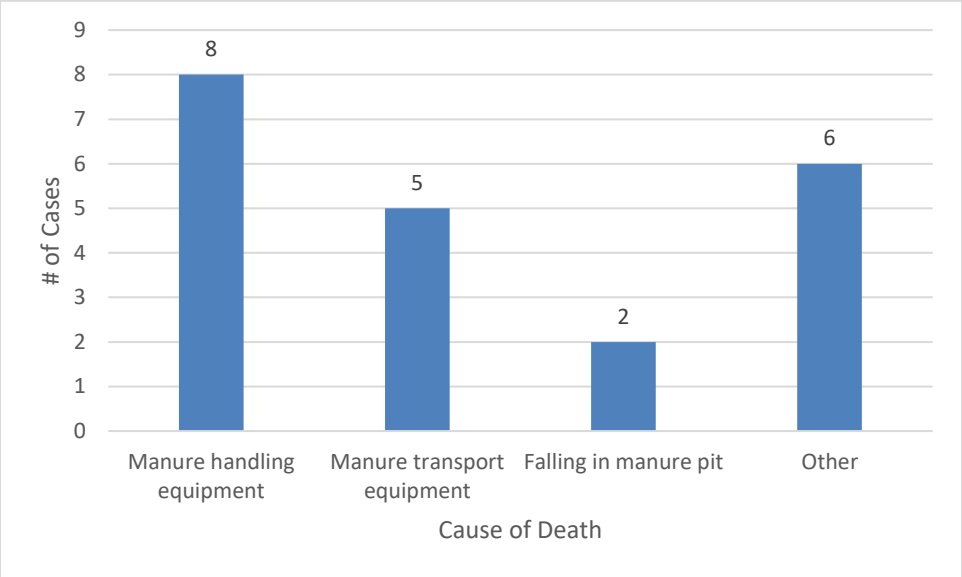

Figure 8: The distribution of agents involved in fatal manure-related cases (N=21).

As with the grain-related cases, the frequency of cases involving manure is relatively low, the proportion of fatalities, however, is high. The lack of comprehensive reporting requirements also suggests a significant under-reporting of these incidents.

2018 Grain Dust Explosions

Based on continuing research at Purdue University conducted by Professor K. Ambrose, there were 12 documented grain dust explosions in 2018 which was substantially above the 10-year average of 8.4 explosions per year. The explosions in 2018 resulted in one fatality and four injuries. Grain dust explosion incidents were reported at two ethanol plants, two feed mills, and eight grain elevators. Illinois and Iowa each reported two dust explosion incidents during 2018, while Minnesota, Indiana, Nebraska, Texas, Oklahoma, Wisconsin, Kansas, and Louisiana reported one each. In three of the incidents, the probable ignition source was reported as hot bearings and sparks. The cause of the remaining nine were unknown. In many cases, an explosion destroys the evidence that could confirm the ignition source. To prevent grain dust explosions, it is extremely important to keep the facility clean by following proper housekeeping

procedures clearly described by the relevant OSHA standards. In addition, all the employees must be trained on dust and ignition hazards, and to ensure that all equipment is in good working condition. With continued increase in the quantity of grains being handled across the U.S., especially at larger capacity on-farm storage sites, it is important for these facilities to maintain good preventive measures to mitigate any dust hazards and the risk of explosion.

Analysis on the Distribution of Incident Type and Facility by US and OSHA Regions

Agricultural confined space-related cases have occurred in every OSHA region but are mainly concentrated in two regions: region 5 and 7. Region 5 accounted for 44% of all agricultural confined space cases (909) with 59% of those cases being grain entrapments, and 13% being falls. Region 7 represented 24% (488) of all cases with grain entrapments, asphyxiation, and entanglements representing 66%, 10%, and 10% of those cases respectively. Region 1 represented the region with the smallest number of grain entrapments and region 4 represents the region with the largest percentage of total documented cases being grain entrapment cases (71%).

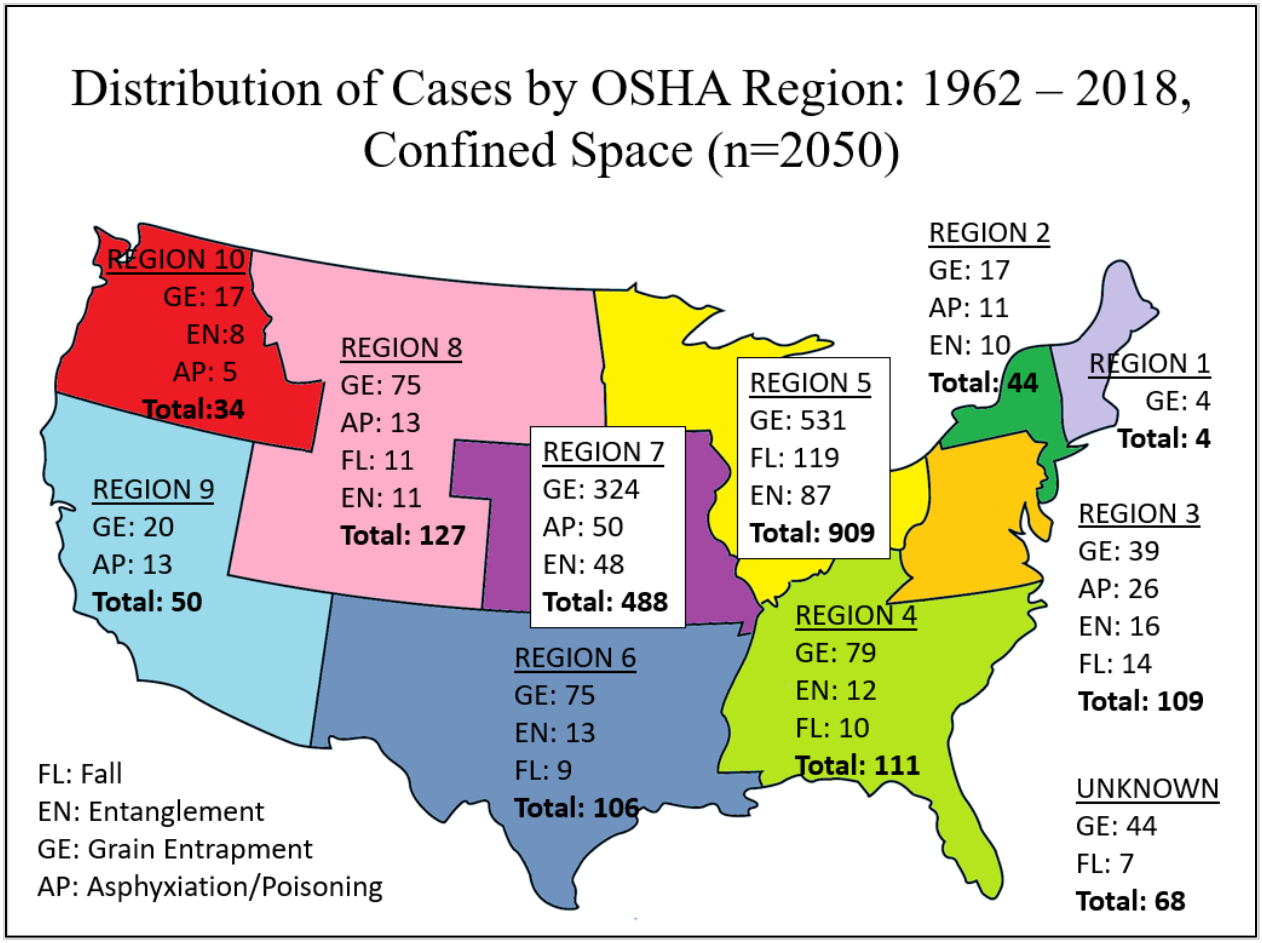

Figure 9: Agricultural confined case distribution by OSHA region from 1962-2018. The total number of cases and most frequent type of case is listed for each region (n=2050).

Observations

The following observations highlight several significant findings.

- No fewer than 61 fatal and non-fatal cases involving agricultural confined spaces were documented in 2018, representing a 13% increase over 2017.
- 49% of all cases documented involved grain-related entrapments as compared to other cases involving falls, entanglements, and asphyxiations.
- 44% of all documented agricultural confined space cases in 2018 were fatal compared to 59% historically.
- Iowa, Wisconsin, Illinois, Nebraska, and Ohio reported the most cases in 2018 with Iowa, Indiana, and Minnesota being the overall leaders historically.
- There were 30 grain entrapments in 2018 representing a 30% increase over 2017.
- Iowa, Wisconsin and Kansas reported the most grain-entrapment cases in 2018. Historically, Indiana, Iowa, and Minnesota and Illinois have reported the most cases.
- Five entrapments in 2018 involved children and youth under the age of 21.
- OSHA Region 5 and 7 have accounted for 69.8% of all documented agricultural confined space-related incidents.
- Over 340 cases involving manure storage and handling facilities and equipment have been documented of which approximately half have been fatal.

Project Website

With support from a Susan Harwood Training Grant from the U.S. Department of Labor, a unique website was developed (www.agconfinedspaces.org). The purpose of this site is to provide evidence-based resources for those conducting safety and health training in the area of agricultural confined spaces, especially in the area of grain storage and handling hazards. Training resources, frequently asked questions, past summaries of injuries and fatalities and an extensive bibliography can be found at the site. Since it was put online in 2013, it has hosted over 14,000 visitors.

One of the most frequently visited resource on the website is the curriculum developed for young and beginning workers in the grain industry (**Against the Grain**). The goal of this teaching resource is to provide agricultural and safety educators with an evidence-based 3-5 hour training program to present basic awareness safety and health training to youth, ages 16-21, who are employed at grain handling and storage facilities, including both exempt and non-exempt operations. The curriculum has been delivered to over 5,100 youth in secondary school agricultural education programs, Purdue students enrolled in agricultural studies, and informal, out-of-school settings. Pre- and post-testing have demonstrated a significant knowledge gain and instructor feedback has been very positive. The complete curriculum is available as a free download.

The second education resource at the site is designed for use in training emergency first responders to safely respond to incidents at grain storage and handling facilities. Over the past six years over 4200 emergency first responders have participated in training using this material. This curriculum is also available as a free download.

Published Works

As the result of the analysis of the data gathered over the past six years and related research, the following related articles have been published by the staff of Purdue's Agricultural Safety and Health Program. Full text for some of these articles are available at www.agconfinedspaces.org.

Roberts, M. J. Field, W. E., Maier, D. E., Stroshine, R. L. Determination of Effort Required to Insert a Rescue Tube into Various Grain Types. ***Journal of Agricultural Safety and Health***, 18:4, 2012.

Riedel, S. M., Field, W. E. Summation of the Frequency, Severity, and Primary Causative Factors Associated with Injuries and Fatalities Involving Confined Spaces in Agriculture. ***Journal of Agricultural Safety and Health***, *19*(2), 83-100, 2013.

Field, W. E., Heber, D. J., Riedel, S. M., Wettschurack, S. W., Roberts, M. J., Grafft, L. J. Worker Hazards Associated with the Use of Grain Vacuum Systems. ***Journal of Agricultural Safety and Health***, 20(3), 147-163, 2014.

Issa, S.F., Field, W.E., Hamm, K.E., Cheng, Y.H., Roberts, M.J., and Riedel, S.M. Summarization of Injury and Fatality Factors Involving Youth and Grain Entrapment or Engulfment in Agriculture. ***Journal of Agricultural Safety and Health***, 22(1), 13-32, 2016

Roberts, M. J. Field, W. E., Maier, D. E., Stroshine, R. L. Determination of Entrapment Victim Extrication Force with and without Use of a Grain Rescue Tube. ***Journal of Agricultural Safety and Health***, 21:2, 2015.

Issa, S.F., Cheng, Y.H., and Field, W.E. Summary of Agricultural Confined Space-related Cases: 1964-2013. ***Journal of Agricultural Safety and Health***, 22(1), 34-45, 2016.

Cheng, Y.H. and W.E. Field. Summary of Auger-related Entanglements Occurring Inside Agricultural Confined Spaces. ***Journal of Agricultural Safety and Health***, 22:2, 2016.

Issa, S.F., Field, W.E, Schwab, C.V., Issa, F.S., Nauman, E. Contributing Causes of Injury or Death in Grain Entrapment, Engulfment and Extrication. ***Journal of Agromedicine***, 22:2, 2017.

Issa, S.F. and Field, W.E. Determining the Pull-Forces Required to Extricate a Victim Entrapped at Various Angles in a Grain Mass. ***Safety***, 3(11), 2017.

Cheng, Y.H., Field, W.E., Tormoehlen, R.L., French, B. Utilizing Secondary Agricultural Education Programs to Deliver a Grain safety Training for Young and Beginner Workers. ***Journal of Agromedicine***, 22:4, 2017.

Field, W.E., Cheng, Y.H., Tormoehlen, R.L., Aherin, R., Schwab, C., Neenan, D., Roberts, M. Let's Stop Treating Our Youth Like Dummies. Editorial. ***Journal of Agricultural Safety and Health***, 24:2, 2018.

Issa, S.F., Nour, M.N., Field, W.E. Utilization and Effectiveness of Harnesses and Lifelines in Grain Entrapment Incident's; Preliminary Analysis. ***Journal of Agricultural Safety and Health***, 24:2, 2018.

Cheng, Y.H., Field, W.E., Issa, S.F., Kelly, K., Heber, M., Turner, R. Summary of U.S. Injuries and Fatalities Involving Entrapment and Suffocation in Grain Transport Vehicles. ***Journal of Agricultural Safety and Health***, 24:2, 2018.

Issa, S.F., Wassgren, C., Schwab, C.V., Stroshine, R., Field, W.E. Estimating Passive Stress Acting on a Grain Entrapment Victim's Chest. ***Journal of Agricultural Safety and Health***, 24:3, 2018.

Nour, N.M, Field, W.E., Ni, J.Q. and Cheng, C. Development of Methodology to Document and Code Farm-related Injuries and Fatalities Involving Manure Storage, Handling, and Transport-with Summary of 2017 Incidents. ***Journal of Agromedicine***, 10.1080/1059924 x 2018.

Issa, S.F., Nauman, E., Wassgren, C., Schwab, C.V., Ahsan, Z.S., Field, W.E. Measured Spine Tensile Force Limits for Extracting Grain Entrapped Victim. Submitted to Journal of Safety.

Audio-Visual Resources

The project has contributed to the development of several audio-visual resources that have contributed to enhancing a better understanding of the hazards associated with agricultural confined spaces. These include:

- "Don't Go with the Flow." Instructional package with video on grain rescue strategies, 1998. National Grain and Feed Association.
- "Grain Bin Safety - Protecting Yourself and Your Family," 2011. National Corn Growers and National Grain and Feed Association.
- "STOP, THINK, LIVE", 2016. Re-enactment of an actual grain rescue with prevention recommendations. Posey County, Indiana Farm Bureau.
- "Silo", 2019. Chronicles a day in the life of a grain farmer and his family. When a teenager becomes the victim of a grain entrapment, the local fire department must figure out how to rescue him before it is too late. silothefilm@gmail.com. To be released September, 2019.

For additional information on this report, contact Professor Bill Field at 765-494-1191 or field@purdue.edu. In addition, refer to these sources for more information on this topic:

- www.agconfinedspaces.org
- www.grainsafety.org
- www.grainentrapmentprevention.com
- http://apps.npr.org/buried-in-grain/