Undertaking Risk Assessments for the Operation of Agricultural Tractors (Without a Roll Over Protective System)
#### Undertaking Risk Assessments for the Operation of Agricultural Tractors (Without a Roll Over Protective System):

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Undertaking Risk Assessments for the Operation of Agricultural Tractors (Without a Roll Over Protective System):

Definitions:

(Taken from the Occupational Health and Safety Regulations)

“agricultural tractor” means a vehicle, with more than 20 engine horsepower, running on wheels, designed to furnish the power to pull, carry, propel or drive an implement that is designed or used for agriculture, but does not include a self-propelled implement;

“low-profile tractor” means an agricultural tractor with the following characteristics:

(a) the front wheel spacing is equal to the rear wheel spacing, as measured from the centre line of each right wheel to the centre line of the corresponding left wheel;

(b) the clearance from the bottom of the tractor chassis to the ground does not exceed 46 cm (18 in);

(c) the highest point of the hood does not exceed 1.5 m (60 in);

(d) the tractor is designed so that the operator straddles the transmission when seated.

“qualified person” means knowledgeable of the work, the hazards involved and the means to control the hazards, by reason of education, training, experience or a combination thereof.

“risk assessment” Means a process whereby hazards are identified then analyzed to determine the level of risk they pose, followed by determining ways to eliminate or control the hazard.
Undertaking Risk Assessments for the Operation of Agricultural Tractors (Without a Roll Over Protective System):

BC Occupational Health and Safety Regulation Pertaining to Tractors without ROPS 28:41:

Requirements:

(Taken from the Occupational Health and Safety Regulations)

"risk assessment" for tractors means an assessment of the risk that an agricultural tractor will roll over while it is being operated, based on the relevant circumstances of the proposed operation including the following:

(a) the stability of the agricultural tractor, taking into account such factors as the configuration of the agricultural tractor and any attachments mounted on or pulled by the agricultural tractor during operation;

(b) the ground conditions where the agricultural tractor will be operated, including the presence of ditches, drop-offs and ground irregularities such as holes, soft spots or mounds;

(c) the grades on which the agricultural tractor will be operated;

(d) the nature of the activities to be performed with the agricultural tractor;

(e) the applicable safe work procedures established by the employer;

(f) the training and experience of the operator;

(g) the presence or absence of direct supervision of the operator by a qualified person.
Undertaking Risk Assessments for the Operation of Agricultural Tractors (Without a Roll Over Protective System):


[2] Section 16.22 does not apply to an agricultural tractor if it is being driven or used as part of agricultural operations on farm land.

[3] Subject to subsection (4), a worker must not drive or use an agricultural tractor as part of agricultural operations on farm land unless the agricultural tractor has a ROPS.

[4] A worker may drive or use an agricultural tractor without a ROPS as part of agricultural operations on farm land if a qualified person has carried out a risk assessment and has determined that, in the circumstances, the agricultural tractor can be operated safely and with a low risk of a rollover, and any of the following apply:

(a) the agricultural tractor was manufactured on or before January 1, 1985;

(b) the agricultural tractor

(i) is a low profile tractor that is used in agricultural operations on farm land in places that have low overhead clearance, such as orchards, hop yards, farm buildings or greenhouses, where overhead clearance is not adequate to allow an agricultural tractor with a ROPS to operate, and

(ii) is being driven or used as part of those agricultural operations;

(c) the agricultural tractor is fitted with implements that are incompatible with a ROPS.

[5] The employer must permanently affix, on an agricultural tractor without a ROPS that is driven or used as part of agricultural operations on farm land, a notice that is legible and visible to a person in the operator’s position, stating that the agricultural tractor

(a) does not have a rollover protective structure, and

(b) may be driven and used only in areas and for activities authorized by the employer.
Undertaking Risk Assessments for the Operation of Agricultural Tractors (Without a Roll Over Protective System):

Explanatory Notes: for the Occupational Health and Safety Regulations 28.41:

(Taken from the Occupational Health and Safety Regulations)

It is proposed to amend section 28.41 of the Occupational Health and Safety Regulation ("OHSR") to limit the activities and places where an agricultural tractor without a rollover protective structure ("ROPS") may be driven and used.

Under section 28.41(2) of the OHSR, agricultural tractors manufactured after January 1, 1985 must have a rollover protective structure except for low profile tractors used in agricultural situations where there is low overhead clearance, or if the tractor is fitted with implements incompatible with a ROPS. This exception specifically references orchards as a situation where this exception could be applicable. As a result, some orchard operators believe that ROPS is never required on their low profile tractors, which is not the case. This misunderstanding extends to other types of agricultural operations but is particularly prevalent in the interior of BC. The ROPS exemption for low profile tractors only applies if the tractor is being used primarily in the stated applications.

Between May and October 2009, there were three incidents resulting in fatalities involving tractor rollovers. The tractors involved did not have ROPS.

Published guidance documents from WorkSafeBC limit the use of a tractor without a ROPS to ground surfaces with a slope of not more than 20%, and to roads at least twice as wide as the tractor if there is a ditch or drop off at an edge of the road. The 20% slope criteria is a “one size fits all” slope criteria and does not take into account the variation in stability between agricultural tractors of different design. For example, a low profile tractor would be more stable than a “conventional” tractor in terms of its tendency to tip over because it has a lower centre of gravity and a wider wheel track. Also, the stability of a particular tractor will vary based on attachments mounted on or being used with the tractor. In addition to the equipment-related factors, the ground conditions where the tractor will travel or be used will affect the stability of the tractor. There are too many variables affecting tractor stability to allow the OHSR to stipulate a single slope limit criteria to be applied to all tractors without a ROPS. And there is concern if a slope limit is specified for an agricultural tractor it will be assumed by some people that any use of a tractor on ground up to that slope limit would be safe from a rollover. That is not the case because, as stated above, there are a number of factors besides ground slope that can affect the risk of a tractor rollover.
Undertaking Risk Assessments for the Operation of Agricultural Tractors (Without a Roll Over Protective System):

The proposed amendment will require the employer to limit the use of a tractor without a ROPS to areas and activities where the employer has done a risk assessment and determined the conditions are such that the tractor can be operated safely and there is a low risk of a rollover. The employer would need to ensure all workers authorized to operate the tractor are aware of the areas and activities where the tractor may be used. The risk assessment would require consideration of at least the factors set out in proposed new section 28.41(1).

Proposed section 28.41(2) will exempt an agricultural tractor being driven or used as part of an agricultural operation from section 16.22. The effect of this clause is to require an agricultural tractor being used other than as a part of an agricultural operation to be subject to the provisions of section 16.22.

Proposed section 28.41(3) will require all agricultural tractors driven or used as part of an agricultural operation to have a ROPS, except as permitted by proposed section 28.41(4).

Proposed section 28.41(4) will allow certain tractors to be driven and used without ROPS but only in circumstances where a risk assessment has determined such tractors can be driven or used safely and with a low risk of rollover. The tractors eligible for the exemption from ROPS are the ones currently exempt, namely tractors built on or before January 1, 1985, low profile tractors being used where there are overhead clearance issues that preclude having a ROPS, and tractors fitted with implements that are incompatible with ROPS.

A risk assessment will determine the travel routes and places that a tractor without a ROPS can be driven and used. The risk assessment will also determine what attachments can be carried by or used with the tractor. The employer must ensure every worker authorized to drive or use a tractor without a ROPS is provided with sufficient training and supervision to understand the limitations on where and how the tractor can be driven and used.

Proposed section 28.41(5) will require an agricultural tractor without a ROPS to have a sign or notice displayed so it is visible to a person in the operator’s position stating the tractor does not have a ROPS and may only be used in areas and for activities authorized by the employer.

Some tractors have a ROPS that can be folded down when the tractor is to be used in an area with low clearance. When such a tractor is being used with the ROPS in the folded down position, it is to be considered as not having a ROPS and the provisions of the proposed amendment would apply.
Undertaking Risk Assessments for the Operation of Agricultural Tractors (Without a Roll Over Protective System):

**Risk Assessment Process:**

Identify the hazards – *Recognize*

Evaluate the level of risk – *Evaluate*

Control the hazard and eliminate or reduce the risk – *Control or Manage*

**RECOGNIZE**

What is/are the hazards? A hazard can be identified by observation, inspection, testing, communication and consultation with staff or by reviewing injury statistics, incident investigations, and recording the hazards identified.

**EVALUATE**

During the evaluation process we need to assess the risk the hazard presents. Each hazard should be studied to determine its level of risk, when doing so, there is several factors that play an important role that will need to be prioritized, and will require action. For each risk:

- Determine the **likelihood** of an incident occurring
  - Very Likely  Could happen frequently
  - Likely  Could happen occasionally
  - Unlikely  Could happen but rarely
  - Very unlikely  Could happen, but probably never will

Consider for example:

- The frequency, how many times is the operation of the tractor associated with the hazard
- The number of people exposed and the duration of exposure
- The skill/experience of person(s) operating the tractor, the presence or absence of qualified supervision
- The position of the hazard relative to operator and other hazards
Undertaking Risk Assessments for the Operation of Agricultural Tractors
(Without a Roll Over Protective System):

- Special characteristics of operator that may affect the likelihood of an incident, such as age, vision, hearing
- Ground conditions including the grades on which the agricultural tractor will be operated, the presence of ditches, drop-offs, and ground irregularities such as holes, soft spots or mounds.
- The condition and size of equipment, such as age, horsepower, centre of gravity, presence of ROPS, front end loader, additional hitched implements or mounted equipment.
- Determine the consequences of an incident occurring
  - Extreme: Death, permanent disablement
  - Major: Serious bodily injury
  - Moderate: Casualty treatment
  - Minor: First aid, no lost time work

Consider, for example:

- The potential for chain reaction (where a hazard can evolve and compound into a more dangerous situation)
- Operator position relative to the hazard
- Weight of Operator
- Size of the equipment, forces and energy level
- Potential for a continuous roll over
- Emergency response
RATING RISK:

In order to determine the significance of a hazard, it is first necessary to rate the hazard based on “how likely could it happen”, and “how severely could it hurt someone”.

This can quite simply be accomplished using the “RISK ASSESSMENT RATING MATRIX” on page ten.

Using the matrix table, a hazard is rated based on likelihood and consequences. As explained on pages seven and eight there is varying degree of likelihood, as well as, degree of consequence. Both of these are used in the matrix to assess the level of risk. They are ranked by column and row from the highest risk level to the lowest risk level.

The person using the matrix must do a thorough analysis to ensure they understand all aspects of the hazard including all tasks and work associated with the hazard. Depending on the degree of likelihood and consequence of an injury the person must make judgment calls, and select where the hazard fits in the matrix. That should produce a number anywhere from one to seven, one being the highest degree of risk, and seven the lowest. Use the examples on pages seven and eight for assistance.

When a degree of risk from one to seven has been selected, refer to the box at the bottom of the matrix to determine whether the hazard has a HIGH, MODERATE or LOW level of risk. Depending on which level of risk is appropriate it will also advise when to take action.

The matrix rating system will also assist to prioritize action if there is more than one hazard being considered.

Once the applicable level of risk (HIGH, MODERATE or LOW) has been established the level of risk will be entered in the “risk” column when completing the “TRACTOR OPERATION - RISK ASSESSMENT WORKSHEET”
## Risk Assessment Rating Matrix

<table>
<thead>
<tr>
<th>Likelihood: How likely could it happen</th>
<th>Consequences: How severely could it hurt someone</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Very Likely</strong></td>
<td>Extreme (Death, permanent disablement)</td>
</tr>
<tr>
<td>Could happen frequently</td>
<td>1</td>
</tr>
<tr>
<td><strong>Likely</strong></td>
<td></td>
</tr>
<tr>
<td>Could happen occasionally</td>
<td>2</td>
</tr>
<tr>
<td><strong>Unlikely</strong></td>
<td></td>
</tr>
<tr>
<td>Could happen but rare</td>
<td>3</td>
</tr>
<tr>
<td><strong>Very Unlikely</strong></td>
<td></td>
</tr>
<tr>
<td>Could happen, but likely never will</td>
<td>4</td>
</tr>
</tbody>
</table>

Use the ratings for each risk to develop a prioritized list of workplace risks requiring action.

The scores (1 – 7) indicate how important it is to do something about each risk.

1, 2, 3 **HIGH**, do something about these immediately

4, 5 **MODERATE**, do something about these risks as soon as possible

6, 7 **LOW**, these risks may not need immediate attention
Undertaking Risk Assessments for the Operation of Agricultural Tractors (Without a Roll Over Protective System):

**Control**

**Hierarchy of Control**

The Hierarchy of Control will assist in determining the most appropriate course of action to control the risk identified. The Hierarchy of Control ranks risk control strategies from the most effective to the least effective. Not all strategies will be practicable and a combination of strategies may be needed to achieve the best protection, for example hearing protection and a tractor cab.

**Engineered Control**

Where a hazard cannot be simply eliminated from the workplace, it is often still possible to reduce the risk by designing safeguards to be built into the equipment. This involves controlling the hazard right at the source, by adding safety features to machinery, or by redesigning a system or task.

A familiar example is the application of a Roll Over Protective System (ROPS) - this is an example of an engineered solution to a long-standing hazard.

Control measures that are “built in by design” are very reliable, and their success does not depend on individual judgment, training, or decision-making.

**Administrative Control**

Where engineered controls are not possible (for instance, when using older, less-safe equipment, that best suits the task), the next best alternative is an administrative or procedural control. These involve the use of policies or procedures to reduce the exposure to the hazard. Administrative controls include reduction of exposure time, and worker training and education. An employer may decide to adopt a company policy that requires everyone to follow a certain procedure, as a way of reducing the risk of injury.

However, administrative controls may not be a very effective means of controlling hazards. Administrative controls depend on too many factors that cannot be predicted. People may not understand the seriousness of a hazard or they may underestimate a risk. They may not remember all the steps of a procedure. They may feel pressure to “cut corners.”
Undertaking Risk Assessments for the Operation of Agricultural Tractors (Without a Roll Over Protective System):

You must be especially vigilant with administrative controls to ensure that operators’ exposure to the hazard is effectively controlled.

**Personal Protective Equipment**

The decision to use personal protective clothing or gear is a last resort, when it’s not possible to control a hazard or reduce a risk in any other way. Actually, it’s an admission that the hazard still remains, and that the risk cannot be reduced at its source.

To be effective, operators who use personal protective equipment (PPE) must understand the hazards, and must accept the importance of using protective equipment consistently and correctly.

As well, special efforts must be made to ensure that personal protective equipment is chosen, used, and maintained correctly.

**Choosing the Right Control for Each Hazard and Risk**

In many cases, hazard controls are already built in by design (tractor cabs, for example provide ROPS), so there’s not much more for the employer to do.

However, in some situations, employers are expected to choose a hazard control that’s appropriate to the situation. Wherever this is the case, the Occupational Health and Safety Regulation requires you to follow the order of the hierarchy of controls, and adopt the most effective method possible in the circumstances.

The employer is responsible for choosing an appropriate method of control for these hazards.

A hazard control is considered appropriate if it:

- Is tailored to the hazard and level of risk in a given situation
- Meets the intent of the law
- Is workable for the workplace, given its size and resources.

**Monitor and Review the Effectiveness of Measures**

Determine whether chosen control measures are implemented as planned.

- Are chosen control measures in place?
- Are these measures being used?
Undertaking Risk Assessments for the Operation of Agricultural Tractors (Without a Roll Over Protective System):

- Are they being used correctly?

Determine whether chosen control measures are working.

- Have changes made to control exposure, resulted in what was expected?
- Has exposure to the assessed risks been eliminated or adequately reduced?

Determine whether there are any new problems.

- Have the implemented control measures resulted in the introduction of any new problems or in the worsening of any existing problems?
Undertaking Risk Assessments for the Operation of Agricultural Tractors (Without a Roll Over Protective System):

Conducting a Tractor Operation Risk Assessment

For a tractor operation risk assessments there is no need to overcomplicate the process. In many workplaces the hazards are well known and the necessary controls are easy to apply.

In the case of a small operation, the manager / supervisor may be confident and understand what’s involved and can do the risk assessment, as long as they meet the intent of “qualified”, or they may request FARSHA’s assistance.

Assessments must be done by a qualified individual (see definitions) who has a good working knowledge of the equipment and workplace. This is usually the owner, or a senior supervisor. In all cases, operators who are associated with the hazards should be involved in the process. Operators will have useful information about how the work is done, which will make the risk assessment more thorough and effective.

A tractor operation risk assessment should be undertaken on all tasks that have the potential to cause injury or illness. The task must be analyzed from start to finish and documented on the Tractor Operation Risk Assessment Worksheet. All of the hazards associated with a task should be individually identified in the hazards column. Using the Risk Assessment Rating Matrix and the information provided to employ it, a level of risk (low, moderate or high) is entered in the risk column adjacent each hazard. Finally, using the information on appropriate method of control, based on the risk level, must be decided for each hazard, using the “Hierarchy of Control”. As discussed, the control will require either immediate attention, as soon as possible attention, or may not need immediate attention. This information must be included in the control column.

After conducting several risk assessments, and the principals of conducting them are well understood, all that the assessor should require is the “Risk Assessment Rating Matrix” and “Tractor Operation Risk Assessment Worksheets”

The following list provides examples of when tractor operation risk assessments must be done and should be done:

**Must be done:**

- Operating on slopes / grades without ROPS
- Operating on roadways without ROPS less than twice as wide as the tractor if there is a ditch or drop-off at the edge of the road
Undertaking Risk Assessments for the Operation of Agricultural Tractors (Without a Roll Over Protective System):

Should be done:

- Pulling heavy or stuck equipment without ROPS
- Operating a front end loader without ROPS
- Moving hay bales without ROPS
- Operating with PTO powered equipment without ROPS
# Undertaking Risk Assessments for the Operation of Agricultural Tractors

*Without a Roll Over Protective System:*

## TRACTOR OPERATION RISK ASSESSMENT WORKSHEET

<table>
<thead>
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<th>TASK</th>
<th>HAZARD</th>
<th>LEVEL OF RISK</th>
<th>CONTROL METHOD</th>
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### Other Requirements:

1. The employer must ensure every worker authorized to drive or use a tractor without a ROPS is provided with sufficient training and supervision to understand the limitations on where and how the tractor can be driven and used.

2. The tractor must have affixed to it, where it can be readily seen, a sign or decal stating that “the tractor does not have a ROPS” and “May be driven and used in areas and for activities authorized by the employer.”
Undertaking Risk Assessments for the Operation of Agricultural Tractors (Without a Roll Over Protective System):

Appendix A

Discussion on the Safe Operation of Tractors

(Excerpt from the FARSHA Guardian Bulletin "Your Tractor")

Your chances of getting killed while driving your tractor are higher than any other task you do around the farm or ranch. Tractor rollovers have been the leading cause of farm operator deaths for the past two decades. In fact one out of every five deaths on the farm / ranch occurs when a tractor rolls over on top of the operator. These incidents could occur at any time and any place. Tractor upsets normally occur so fast that, before the operator realizes what is happening and can take preventative action, it’s too late. The tragic thing about tractor rollovers is that many could be prevented. Safe driving techniques, and special equipment can reduce these risks.

**CENTER OF GRAVITY**

The central concept in tractor stability/instability is Center of Gravity (CG). A tractor’s CG is the point where all parts balance one another. For example, when a two-wheel drive tractor is sitting with all wheels on level ground, the CG is typically about 10 inches (25.4 cm) above and two feet (0.6 m) in front of the rear axle, and in the center of the tractor body. This results in approximately 30 percent of the tractor weight on the front axle, and 70 percent on the rear axle. For four wheel drive and center-articulated tractors, the CG is located slightly more forward. Added weights also effect the CG.

For a tractor to stay upright, its CG must stay within the tractors stability baseline. Stability baselines are imaginary lines drawn between points where tractor tires contact the ground. The line connecting the rear tire contact points is the rear stability baseline, while the lines connecting the rear and front tires on the same side are the side stability baselines. Front stability baselines exist but have limited use in stability/instability considerations, and are not normally include in such discussions. See Figure 1 for a complete illustration of a tractor’s CG and stability baselines.

![Figure 1: The stability baselines of a tricycle and a wide front-end tractor respectively](image-url)
Undertaking Risk Assessments for the Operation of Agricultural Tractors (Without a Roll Over Protective System):

While a tractor’s CG does not move, its relationship with stability baselines may change. This most often occurs as the tractor moves from a level position onto a slope. A changing CG-stability baseline relationship means the tractor is moving toward an unstable position. If the CG-stability baseline relationship changes significantly (e.g. tractor CG vector moves beyond the stability baseline), the tractor rolls over. Tractor CG action is no different from the CG action on any other mobil vehicle. What differs is that tractors have a higher CG when compared to most other vehicles, such as automobiles and trucks. The higher CG on modern tractors is an inherent design characteristic and relates to their operation over crops, residue, and rough terrain. Changing tractor design so that their CG is significantly lowered would largely defeat the purpose for having farm tractors.

When a tractor is on an incline, the distance between the tractors CG and stability baseline is reduced. If equipment, such as a front-end loader, a round bale lifting fork, or a chemical side saddle tank is mounted on the tractor, the additional weight shifts the CG toward that piece of equipment. As mounted equipment is raised, the CG is raised. As Figure 2 illustrates, a higher CG decreases tractor stability. In many normal working situations, ground terrain and mounted equipment combine to reduce the distance between the equipments CG and stability baselines.
Other factors important to tractor stability/instability include centrifugal force (CF), rear-axle torque (RAT), and drawbar leverage (DBL). Each of these factors works through the CG. Saying this another way, each of these factors may cause the tractor’s CG to go beyond the tractor’s stability baseline and overturn.

**CENTRIFUGAL FORCE**

Centrifugal force is the outward force nature exerts on objects moving in a circular fashion. Within the context of tractor stability/instability, CF is that force trying to roll the tractor over whenever the tractor is turning. Centrifugal force increases both as the turning angle of the tractor becomes sharper (decreases), and as the speed of the tractor increases during a turn. The CF increase is directly proportional to the turning angle of the tractor. For every degree the tractor is turned tighter, there is an equal amount of increased CF.

The relationship between CF and tractor speed, however, is not directly proportional. Centrifugal force varies in proportion to the square of the tractor’s speed. For example, doubling tractor speed from 3 mph to 6 mph increases the strength of centrifugal force four times \( 2^2 = 2 \times 2 = 4 \). Tripling tractor speed from 3 mph to 9 mph increases CF nine times \( 3^2 = 3 \times 3 = 9 \).

![Figure 3. The “point of no return” during a rear turnover may be reached in 3/4 of a second. (Source: Agricultural Safety, Deere and Company, Inc.)](image)

Centrifugal force is often a factor in tractor side overturns. When the distance between the tractor’s CG and side stability baseline is already reduced from being on a hillside, only a little CF force may be needed to push the tractor over. Centrifugal force is what usually pushes a tractor over when the tractor is driven too fast during a turn, or during road travel. During road travel rough roads may result in the tractor's front tires bouncing and landing in a turned position. Over correcting steering if the tractor starts to veer off the road is another example where CF is a factor in side overturns. The location of CG and amount of CF are points of stability/instability information tractor operators do not have at their disposal.
REAR-AXLE TORQUE

Rear-axle torque involves energy transfer between the tractor engine and the rear axle of two-wheel drive tractors. Engaging the clutch of such tractors results in a twisting force, called torque, to the rear axle. This torque is then transferred to the tractor tires. Under normal circumstances the rear axle (and tires) should rotate and the tractor will move ahead. In lay terms, the rear axle is said to be rotating about the tractor chassis. If the rear axle should be unable to rotate, the tractor chassis rotates about the axle. This reverse rotation results in the front-end of the tractor lifting off the ground until the tractor’s CG passes the rear stability baseline. At this point the tractor will continue rearward from its own weight until it crashes into the ground or other obstacle. The most common examples of this happening are when the rear tractor tires are frozen to the ground, are stuck in a mud hole, or are blocked from rotating by the operator.

A tractor may overturn from rear axle torque before an operator realizes that the overturn is imminent. Remember that the CG of a tractor is found closer to the rear axle than the front axle. Because of this, a tractor may only have to rear to about 75 degrees from a level surface before its CG passes the rear stability baseline and continues on over. This position is commonly called the point of no return (see Figure 3). Research has shown that a tractor may reach this position in 3/4 of a second, and that it may take an operator longer than this to successfully stop the rearward motion. There are many tractor-operating situations where there is even less than 3/4 of a second to recognize and successfully react to an impending rear overturn. For example, when a tractor is in a deep hole, or is traveling up a steep incline, the distance between the tractors CG and rear stability baseline is narrowed. If excessive rear axle torque is applied, the tractor will reach the point of no return more quickly. Figure 4 illustrates this situation.

![Diagram of the "point of no return" during a rear overturn.](image1)

![Diagram showing the center of gravity moves toward the tractor’s rear stability baseline when the tractor is headed up a hill, or if the rear wheels are below normal ground surface, such as when stuck in soft ground.](image2)

Figure 3. The “point of no return” during a rear overturn may be reached in 3/4 of a second. (Source: Agricultural Safety, Deere and Company, Inc.)

Figure 4. The center of gravity moves toward the tractor’s rear stability baseline when the tractor is headed up a hill, or if the rear wheels are below normal ground surface, such as when stuck in soft ground.
Undertaking Risk Assessments for the Operation of Agricultural Tractors (Without a Roll Over Protective System):

Four-wheel drive tractors are less susceptible to the rear axle torque hazard than two-wheel drive tractors because torque is applied to both the front and rear axles and tires. Also, more weight is carried on the front axle, moving the CG forward. These features lessen the tendency of the front of four-wheeled drive tractors to lift off the ground. But, once the front end does lift, there is little practical difference between two- and four-wheeled drive tractors.

**DRAWBAR LEVERAGE**

Drawbar leverage is another principle of stability/instability related to rear overturns. When a two-wheel drive tractor is pulling a load, its rear tires push against the ground. Simultaneously, the load attached to the tractor is pulling back and down against the forward movement of the tractor. The load is said to be pulling down because the load is resting on the earth’s surface. This backward and downward pull results in the rear tires becoming a pivot point, with the load acting as force trying to tip the tractor rearward. An angle of pull is created between the ground’s surface and the point of attachment on the tractor. Figure 5 illustrates these points. The heavier the load, and the higher the angle of pull, the more leverage the load has to tip the tractor rearward.

![Diagram of drawbar leverage](image)

Figure 5. The “angle of pull” is rearward and downward. The point at which the rear tires contact the ground becomes the pivot point.

A tractor, including its drawbar, is designed to safely counteract the rearward tipping action of pulled loads. When loads are attached to a tractor at any point other than its designed location, the design of the tractor for pulling loads is defeated. A tractor pulling a tree stump can be used as an example to show the effects of safe and unsafe hitching. Assumptions for this example include a tree stump that does not budge, a log chain that does not break, and a tractor with properly ballasted (weighted) tires and an engine that does not stall.

Suppose the tractor is hitched safely, that is, the log chain wrapped around the tree stump is attached to the tractor drawbar. The tractor is engaged and begins to pull on the stump. When the tree stump does not pull loose, the tractor will react in one of two ways. The most expected reaction will be a slipping (spinning) of the rear tires. This will continue until the operator stops the tractor. The second reaction may also involve a slipping
of the rear tires, but the slipping may be neither smooth nor consistent. That is, they may slip with a jerking motion, and one tire may slip more than the other. Either one of these conditions may lead to a lifting of the front end of the tractor.

When the front end of the tractor lifts, the rear drawbar of the tractor will lower. This is a function of tractor geometry. The higher the front end raises, the lower the rear drawbar is driven. As the drawbar lowers, the angle of pull and the leverage the load has to tip a tractor rearward is also lowered. By design, a load will always lose its ability to tip a tractor rearward before the tractor's CG reaches the rear stability baseline. As the load loses its ability to continue to tip the tractor rearward, the front end falls back to the ground. If the tractor operator doesn't stop the pulling action, the entire process will repeat itself, resulting in a bouncing of the tractor's front end.

On the other hand, hitching unsafely, for example to a point higher than the drawbar, increases the angle of pull and leverage of a load. As the tractor tips rearward, these might not reduce to a harmless level before the tractor's CG reaches the rear stability baseline. When a load is hitched to a rear axle, the angle of pull and leverage do not reduce as the front end raises because the location of the hitch point (rear axle) stays constant throughout the rearward tip. A higher hitch point also increases the pressure of the rear tires against the ground. This may prevent the rear tires from slipping. When the rear tires stop slipping, rear axle torque will begin lifting the front end. Accident reports suggest that most cases of improper hitching are associated with pulling and dragging non-mobile objects such as tree stumps, logs, fence posts, boulders, non-wheeled equipment such as large livestock feeders and tanks, and farm equipment mired in mud. The tractor operator is often tempted to hitch above the drawbar to lift the load while pulling it. Figures 6 and 7 illustrate safe and unsafe hitching.
Tractors trying to pull a load up an incline take less leverage to flip rearward because the tractors CG is closer to the rear stability baseline. It is also possible to flip a tractor rearward when the load is properly hitched to the drawbar. This may happen when several factors occur. If the tractor is headed up an incline at too fast a speed and the load, such as a large log, suddenly digs into the ground, the rearward pull may be so quick and strong that the momentum generated by the rearward lift may result in a rear overturn.

**ROLL-OVER PROTECTIVE STRUCTURE AND SEAT BELT**

The roll-over protective structure (ROPS) and seat belt, when worn, are the two most important safety devices to protect operators from death during tractor overturns. It is important to remember that the ROPS does not prevent tractor overturns. Rather, it prevents the operator from being crushed during an overturn. To work as designed, the operator must stay within the protective frame of the ROPS. This means the operator must wear the seat belt. Not wearing the seat belt may defeat the primary purpose of the ROPS.

A ROPS often limits the degree of rollover, which may reduce the probability of injury to the operator. A ROPS with enclosed cab further reduces the likelihood of serious injury because the operator is protected by the sides and windows of the cab. This assumes that cab doors and windows are not removed.