The objective of the IADC Deepwater Well Control Guidelines (DWWCG) is to provide guidance for maintaining primary well control, applying secondary well control methods and responding to an emergency if a blowout occurs. The Operational Risk Management and Well Integrity (ORM and WI) Chapter is intended to provide an overview for establishing and maintaining the wellbore barriers that prevent the loss of well control (LWC). Each chapter of the guideline is intended to help the rig team understand a new topic and how it relates to maintaining control of the well.

ORM concepts can provide context for how the remaining chapters relate to one another. In summary, the relationships can be visualized as shown in Figure 1.1.

Figure 1.1 mimics a Bow-Tie Diagram of the actions for maintaining well control. The Chapters on the left side of the event correlate with establishing preventive barriers, whereas sections on the right side of the event correlate with escalation barriers and responses to reduce the consequences. Barriers and Bow-Tie Diagrams are covered in more detail in the sections that follow.

### 1.2 OPERATIONAL RISK MANAGEMENT

Operational Risk Management (ORM) is used by the IADC to describe how operational and asset integrity is ensured through the management of major hazards. Major hazards are defined as those that pose a significant risk for:

- Multiple fatalities or permanent total disabilities
- Extensive damage to the installation
- Severe impact to the environment.

The IADC Deepwater Well Control Guidelines is intended to provide a recommended practice to its membership for maintaining control of the well for floating drilling operations. The Operational Risk Management and Well Integrity Chapter provides an overview of the terms, concepts and practices relating to managing the barriers required to maintain well control. As indicated in Figure 1.2, Well Integrity (WI) is a subset of ORM and is focused specifically on well construction and maintaining control of the well.

**Note:** In recent years there has been an increasing trend within the upstream industry to use the term “Process Safety” to refer to the risk management of drilling operations. However, process safety already has a well-established definition and application in the chemical industry and in downstream activities such as oil refining. It has a narrow focus on preventing fires, explosions and accidental chemical releases, with the main consideration and concern being public safety. Within the United States, the Occupational Safety and Health Association (OSHA) introduced regulation specific to process safety management which explicitly focuses on highly hazardous chemicals. Process safety focuses on a defensive approach for protection of a well-defined, consistent process which normally occurs within a narrow set of parameters. Operational Risk Management (ORM) is considered more appropriate for the larger set of potential hazards associated with upstream operations. For offshore drilling, ORM emphasizes a proactive and dynamic approach to the creation and continuous management of barriers that change depending on the operating condition. Consequently the IADC DWWC Guidelines will not refer to “Process Safety” in relation to drilling, completion or any other upstream well operations.
1.2.1 Operational risk management vs. personal safety

ORM focuses on preventing Major Accident Events (MAEs) such as large hydrocarbon releases, explosion, fire or flooding which could cause serious injury or fatality to multiple personnel, severe damage to the vessel or significant pollution. In contrast, personal safety focuses on preventing injuries such as slips, trips or falls which normally involve only one or several individuals performing manual tasks. Figure 1.3 is intended to illustrate this difference, and that Major Accident Events tend to have lower frequency but higher severity when compared to personal safety accidents.

Just as operational risk and personal safety have different risk profiles regarding severity and frequency, they also have different types of hazards which can cause an incident. For safety management of offshore operations it is important to focus on both personal safety and operational risk. There is a specific need to plan, monitor and discuss the MAE hazards and to assign responsibility to ensure they are controlled and monitored during all phases of operation. It is also important to ensure that the risk management knowledge that is developed during system design and operational planning is transferred to the rig team so they will have full knowledge of the hazards involved and the strategies for preventing MAEs. Expanding the pre-tour and pre-job meetings for MAE hazards could be one option for communicating to the rig team and explaining these hazards and how to prevent them.

1.2.2 Preventive barriers

Preventive barriers are considered to be hazard control systems and can be visualized as slices of “Swiss Cheese” that intervene to prevent a hazard from leading to an accident. As no single barrier is perfect, the holes in each slice indicate weakness in the barrier that may allow them to be defeated or bypassed. This is illustrated in Figure 1.4. The goal of effective ORM is to have multiple barriers arranged where they support each other, i.e., the holes never line-up, thereby ensuring the system as a whole is effective. It is also important that barriers are independent to the highest degree possible, so that failure of one barrier doesn’t lead to the failure of others.

To ensure that preventive barriers are not compromised, it is important for all personnel to understand the potential MAEs and know their role in managing the availability and effectiveness of the preventive barriers. When all rig personnel have this awareness and responsibility, operational and system integrity can be established and maintained. During pre-tour or pre-job meetings, it is important to discuss the status of the preventive barriers in place, whether they have been compromised or degraded over time, and who is responsible to monitor and cross check to ensure they remain effective.

Barriers can generally be categorized as follows:

- Equipment: Passive physical barriers, such as mud, cabling and cement, used to control the well formation pressure to prevent a blowout or environmental release of hydrocarbons from occurring. Additional, or secondary equipment barriers, such as the BOP systems, are
designed to intervene in case the other physical barriers fail. Equipment barriers are sometimes also referred to as technical barriers.

- **Process**: The plan or methodology consisting of a management system (SEMS, Safety Case, etc.), operating procedures, maintenance programs, alarms and process monitoring to ensure that operations are conducted with barriers in place and within operational limits.

- **People**: Competent personnel understanding preventive barriers, following procedures while understanding equipment limitations, with knowledge of who is responsible for monitoring and maintaining the barriers, and with the authority to take effective preventive action when required.

A significant characteristic of MAEs is that they usually result from complex combinations of equipment failures, human errors, and/or software failures. Human intervention is sometimes the last and most important line of defense to prevent MAEs such as loss of well control that leads to a blowout.

### 1.2.3 Equipment barriers

Physical barriers are classified as either primary or secondary, and during conventional drilling or completion operations this usually involves fluid hydrostatic as the primary barrier while cement, the BOP and other mechanical components form the secondary barrier. This will be covered in more detail in the Well Integrity section of this chapter.

There are several documents which provide requirements and guidance for the design, installation and testing of physical barriers, which include:

- API Spec 16A: Specification for Drill-through Equipment;
- API Spec 16D: Specification for Control Systems for Drilling Well Control; Equipment and Control Systems for Diverter Equipment;
- API Standard 53: Blowout Prevention Equipment Systems for Drilling Wells;
- API Recommended Practice 59: Recommended Practice for Well Control Operations;
- API Recommended Practice 96: Deepwater Well Design and Construction;
- NORSOK D-010: Well Integrity in Drilling and Well Operations.

Since the specific design requirements and principles of well barriers are well documented by the above references, they need not be covered in detail within the scope of this guideline. The focus instead will be the operational and quality assurance aspects of primary and secondary well barriers, and the rig-based practices needed to support monitoring and maintaining them.

### 1.2.4 People and process barriers

From an operational standpoint, the effectiveness of barriers is directly related to the rig team’s understanding, monitoring capabilities, and ability to take appropriate action to ensure the effectiveness of the barriers.

As daily operational plans are developed, it is important to consider:

- What limits are we working to?
- What barriers are in place before starting an activity?
- How and when were those barriers verified?
- How will barriers be continuously monitored and who is responsible?
- Will barriers be installed or removed as part of this activity?
- How can the planned activity alter or impact any barriers?

The rig-based team should discuss and coordinate these topics to ensure that it is functioning effectively to monitor the potential threats to preventive barriers during drilling, tripping, casing and cementing. Understanding and coordinating the main barriers, as well as assigning the responsible persons to monitor — along with their required actions — are key factors of the operation’s success. This coordination can be accomplished during the Supervisor’s planning meetings (through daily work instructions), pre-tour meetings, and pre-job meetings. During these coordination sessions, operational barriers and potential threats to their effectiveness should be reviewed and discussed to ensure all personnel involved in the operation are cognizant of current conditions and understand acceptable conditions. The status and effectiveness of the procedures, training and competency, drills, maintenance, etc., should all be confirmed. Finally, actions should be identified that ensure the barriers remain effective throughout the job.
In addition to preventive barriers, there are escalation barriers that focus on the control of the situation to limit the accident severity. The combination of preventive and escalation barriers can be visualized by what is known as a “Bow-Tie Diagram.” Bow-Tie analysis is a risk assessment method that captures the hazards and preventive barriers on the left side, the “Top Event,” which could lead to a MAE, in the middle, and escalation barriers and consequences on the right side. Typically, a separate Bow-Tie analysis is developed for each top event, detailing the relationships of the hazards, preventive barriers and escalation barriers. The objective of understanding this relationship is to ensure that multiple barriers are in place for each hazard and that barriers are independent of each other. A simplified example, illustrating the concept for a blowout stemming from loss of well control, is shown in Figure 1.5. The individual hazards can come from the wellbore, equipment failure, and/or operating procedures. Assignments of responsibility and the criticality of the barrier can be made in the Bow-Tie analysis to assist each employee in clearly understanding their role in ensuring the barriers are monitored and maintained.

1.2.6 Effective operational risk management programs for well control

Every offshore installation should already have in place a broad safety management program covering the risks associated with MAEs. Well control-related MAEs such as underground blowout and blowout may represent the dominant risk scenarios for the installation and therefore well control issues should be addressed in the overall safety management program through the following activities:

- Systematic identification of the preventive and escalation barriers that can be used to prevent or mitigate well control-related MAEs;
- Systematic design of equipment, processes, and procedures to support the maintenance and operation of the well control barriers;
- Procedures to test and verify the effectiveness of barriers;
- Designation of personnel responsible for continuous monitoring and maintenance of each barrier;
- Development of procedures describing appropriate actions to be taken if barriers fail or are degraded;
- Incident investigation, root cause analysis, lessons learned, and corrective actions for incidents involving degraded or failed well control barriers;
- Development of training and decision support tools to ensure that well control personnel are competent for normal operation and will respond appropriately during well control incidents to prevent the occurrence of MAEs.

The operational activities relating to managing the threat to the installation posed by the hazard of hydrocarbons in the well will be covered in more detail in the following Well Integrity section.

1.3 WELL INTEGRITY MANAGEMENT

Within the overall system of ORM, there are specialized disciplines such as Well Integrity and Water-tight Integrity. Well Integrity Management addresses the specific major hazard of hydrocarbons in formations penetrated by the well bore.
Such special attention is necessary due to the severe potential consequences of loss of well control causing a blowout.

### 1.3.1 Background and overview

Well Integrity Management originated in well production operations where teams relied on long-term physical barriers to maintain, monitor and optimize well productivity. Barrier reliability became particularly challenging as wells exceeded their original design lives. By 2005, production surveys confirmed the extent of well integrity issues, with one response being the formation of dedicated teams to focus on the integrity of mechanical barriers. Other findings included tracing the cause of some barrier failures back to the drilling and completion phases.

Independent of the survey findings, incidents during well construction in Norway, Australia and USA emphasized the need to improve risk management of hazards during drilling and suspension operations. The ultimate aim is to ensure integrity throughout the well life cycle, from Design through to final Abandonment as shown in Figure 1.6, irrespective of the well’s purpose, value or age.

Well construction is comprised of the Design, Drilling and Completion phases, each of which require a drilling contractor and well control barriers. Likewise, a rig team will be required for the Workover and Abandon phases. The handover process between each phase is crucial to ensuring that barrier effectiveness is maintained throughout the well life cycle.

The benefits of sound well construction include:

- Safe, successful Drilling and Completion activities;
- Reduced likelihood of suspending production and reduced need to re-enter for Workover;
- More efficient setting of permanent barriers during Abandonment (less remediation/repairs).

### 1.3.2 Well integrity during the well construction phase

Well integrity starts with the assumptions and basis of the well design and includes component design, materials selection and ratings, and equipment manufacturing QA/QC. However, these aspects will not be covered in this document because they do not involve the rig team or the Drilling Contractor. Further discussions on the design and planning aspects of barrier systems can be found in Chapter 2, “Well Planning and Rig Operations”. Industry documents, such as the API standards listed earlier, also cover design and planning aspects.

At the rig site, well integrity is managed as a combination of the following three factors to be discussed in this chapter:

- Staying within the “drilling window”: Section 1.4;
- Understanding barrier systems: Section 1.5, 1.6 and 1.7;
- Managing transitions: Section 1.8.

The latter two factors combined can be referred to as barrier management, and these include what we think of as traditional “well control.” The first factor is essential to Well Integrity, namely to understand what drilling (or operating) window is required in the program and what margin the current well condition indicates is available. These limits should be frequently reassessed during operations.

### 1.3.3 Introduction to well integrity

Experience shows that a system of multiple barriers, when correctly installed, maintained and tested, can achieve a high degree of system reliability. Experience also shows that continuous monitoring of physical barriers and having appropriate operational barriers available can maintain safe rig operations.

Well integrity management ensures adequate and appropriate barriers are in place throughout all well operations so that escalation of a well control event is prevented and a fit-for-purpose well is delivered at handover. Well integrity is the proper combination of long-term physical barriers and short-term well control barriers. For instance, once a casing string has been installed and cemented, it becomes part of the secondary containment system along with the BOP on top of the wellhead.

Cement barriers and mechanical barriers such as wellheads, casing and seal assemblies, are the main long-term well construction barriers forming the foundations of the well during the drilling phase. As the well progresses additional long-term barriers such as packers, tubing, hangers and xmas trees may be installed during the completion phase.

A drilling rig brings with it two standard short-term well control barriers: a kill weight fluid system and a Blow-out Preventer system. These temporary barriers allow the rig to safely work with the main long-term barriers in the well. This could mean installing well construction barriers during drilling and