Working Paper:

A Framework for Well Plugging

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October 3, 2022

Following the oil price collapse of 1986, the oil industry in the United States widely deferred and accumulated its decommissioning obligations. Now, as production declines and challenges grow, the lack of historical decommissioning activity has left participants both inside and outside of the industry without a common or comprehensive terminology to talk about the situation. This Working Paper proposes consistent terminology as a starting point to frame the discussion of oilfield decommissioning, especially of well plugging.

THE PROBLEM

The oil industry needs a frank discussion – then a change in practice – about how it handles aging wellbores and surface facilities. Defining the situation is the first step, but producers and regulators inside the industry have not yet agreed among themselves on even basic terminology to use in defining the situation. Meanwhile researchers, other professions, media, and the general public find themselves using terms that make sense to them, even if those terms don't translate directly to the industry players doing the work.

For instance, public discussion often uses the terms "abandoned" and "orphaned" interchangeably to mean that the operator has walked away and left the well and equipment to rot. The industry, by

contrast, often uses “abandoned” to mean responsibly “plugged,” the opposite of the common layman’s use, and it uses “orphaned” to mean a subset of unplugged wells with no responsible operator. Within the industry, some may use “plugging” to refer only to downhole operations while others may extend the term to decommissioning of surface equipment as well.

Once terms are defined to organize and quantify the situation, then discussion can proceed on decommissioning topics from technical and financial to regulatory and statutory.

PROPOSED TAXONOMIES:

To be most useful, a framework for plugging and other decommissioning activities will:

- describe the meaningful dimensions of the decommissioning process,
- cover the range of possibilities in each dimension,
- demarcate natural boundaries in distribution and character within each dimension, and
- allow for further information within each dimension using modifiers or subsets.

We propose terminology related to six characteristics in three aspects of decommissioning upstream oil and gas assets, plus additional modifiers or subsets:

1. Scope of work to be done during decommissioning and associated costs.
2. Wellbores and surface locations to suggest the likely timing and magnitude of decommissioning.
   - Status
   - Vintage
   - Type of surface infrastructure
   - Setting of surface location
3. Responsible parties to do the work.
   - Type of entity
   - Status of entity

We also propose terminology to characterize groups of wells as a combination of responsible party status and infrastructure status.

Some parts of the framework are obvious and uncontroversial, some attempt to disambiguate common terms, and still others introduce new nomenclature. Note that proposed terms are shown in bold. Most terms are obvious or conventional (if sometimes vaguely defined), but novel terms are further emphasized using quotation marks.

The framework is offered as a starting point for creation of a consensus terminology, and it is licensed for use as Creative Commons. The scope of terms, choice of words, and their exact definitions may be expanded or refined in that process. Please reach out to suggest improvements or to participate in an industry-wide consortium to formalize terms.

About Decommissioning Obligations

While "plugging" may be the most salient part of decommissioning, it is only a subset of the required obligations for upstream oil and gas infrastructure. Plugging refers directly to downhole operations, *i.e.* those within or related to the wellbore from the surface to total depth. Decommissioning or retirement includes also surface activities and is thus the more complete and useful term. The accounting profession labels decommissioning tasks "Asset Retirement Obligations" (AROs), and petroleum engineering has defined but not often used the term "Abandonment, Decommissioning, and Restoration" (ADR).

The objective of decommissioning is to remediate then protect the subsurface, the surface (including groundwater), and the atmosphere from unintended movement of fluids, both liquids and gas. To do this, we conduct three categories of tasks:

- Downhole or "Plugging",
- Surface Removal and Remediation, and
- Surface Restoration.[1]

Each begins with an expected scope of work offset by expected salvage value, each predictably expands to additional "unexpected" but material work, and future work may be required as problems develop. Three categories of costs over three scopes, including one subdivision of surface costs, makes 10 sub-totals of decommissioning costs listed and characterized in the following tables.

[1] Remediation is a separate and more uncertain task than removal, but they are combined in a single category since both are commonly required. Restoration, by contrast, is not required in many jurisdictions and contracts.

Downhole or "Plugging" Costs	
Planned &	Cost of known and planned activities necessary to plug wells according to statute, regulations, and/or contracts assuming no remediation is necessary.
Salvage	Value of equipment recovered from below the surface and sold to offset Planned costs (such as tubing, casing, rods, and downhole pump).
Contingency	Costs related to unplanned difficulties in planned scope (such as unknown conditions or mechanical failures) or to the possibility of expanded scope of operations (such as the need to remediate or restore integrity to the wellbore prior to planned operations).
Legacy	On-going liability for repair and remediation of issues not discovered or not created until after primary retirement operations.

Surface Removal and Remediation Costs	
Removal &	Cost of removing equipment from the surface according to statute, regulations and/or contract.
Salvage	Value of equipment removed from the surface of the property and sold to offset the cost of Removal (such as pumping units, compressors, and storage tanks).
Remediation	Cost of remediating known environmental damage to the surface or groundwater according to statute, regulation, and/or contract (such as soil contamination).
Contingency Remediation[2]	Costs related to unplanned difficulties within planned remediation scope or to possibility of existing but currently unknown scope for remediation.
Legacy Remediation	On-going liability for remediation of issues not discovered or not created until after primary retirement operations.

[2] Note that Removal operations should have little or no Contingency or Legacy costs.

Surface Restoration Costs	
Restoration or Reclamation	Cost to restore locations to previous conditions in accordance with statutory, regulatory, and/or contractual requirements (such as restoring original surface grade, spreading soil, and replanting vegetation).
Contingency	Costs related to unplanned difficulties within planned restoration scope or to possibility of existing but currently unknown scope for restoration.
Legacy Restoration	On-going liability, if any, to correct any failures of restoration activities.

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About Wells

Vintage of drilled wells

Vintages are designed to correspond to the data available and, relatedly, to the likely decommissioning methods used.

Vintage	Definition	Implications
"API" or "Regulatory API"	Well number assigned by regulatory authority, greater than 20000 (in most states). Wells known and monitored by authorities.	Drilled since mid-1960s. Better information available. If plugged, probably done according to modern standards.
"Historical API"	Well number assigned by a commercial company or other entity to regulatory assignments, less than 20000 (in most states).	Drilled before mid-1960s. Less information available. If plugged, maybe not done according to modern standards
"Pre-API"	No API number assigned to the well. Regulatory records may or may not document the well.	Very old well. Little information available. If plugged, methods and standards uncertain and unlikely modern.
"Phantom"	May or may not exist.	Not clear whether the well was drilled or not.

Status of wells

The status of the well characterizes is proximity to decommissioning, and the following characterizes a progression of states. Subsequent tables offer modifiers or sub-categories for some of the status categories for further characterization. Note that "abandoned" is not used in this framework since it already bears channelized and inconsistent definitions.

Status		Definition	Implications
Permitted		Received a regulatory permit (and usually a unique well number) but has not been spud.	No plugging liability yet created.
Unplugged	Drilled	At least part of the wellbore has been drilled, but the next status has not been reached. Can add "Cased" if casing has been installed.	Need for plugging has been created. Usually a temporary status.
	Active	Non-zero production or injection reported during the last two months of available data.	Operating at the present time
	Idle	No production or injection for more than two months but less than 13 months (max of 12 months).	Waiting period to choose and perform the next step.
	Inactive	No active operations and no definite plans for operations. (When known, operator intent defines the category.) No production or injection for 13 months or more.	Held for longer term option value or waiting to plug.
Decommissioned, or Retired	Capped	Retired by welding a plate on the open end of the surface casing, but without modern downhole barriers. ("Uncapped" means no wellhead and no metal seal on mouth of well.)	Some form of retirement was applied but downhole plugs may be non-existent, improvised, or pre-modern. Applies to most pre-API wells,
	Plugged	Downhole operations conducted to prevent movement of fluids. Using cement, bentonite or other modern materials regardless of maturity of design. Excludes wells stuffed with other materials or only capped.	Stable condition, no known problem. May include wells with fewer or different downhole barriers than required by modern standards.
"Breached"		Previously decommissioned (without regard to method) but fluids are currently moving or pressurized between locations intended to be isolated (such as from one sub-surface zone to another, to the top of the wellbore, or to the atmosphere).	Need for repair and possible remediation.
"Re-plugged"		Well has again been remediated and secured (without regard to the standards met).	Previously breached, believed to be secured presently.
"Re-breached"		Re-plugging has failed.	Need for repair and possible remediation.

Modifiers for Unplugged wells

Pertains to	Definition
Integrity	**Compliant:** well meets regulatory criteria for long term storage and retains integrity. No label implies Compliant. **Non-compliant:** well does not meet regulatory criteria for long term storage, and/or suspected or known breach of wellbore integrity (such as hole in casing, collapsed casing, or cement failure).
Age	**"Geriatric":** well drilled more than 50 years before the present time or before it was decommissioned.

Modifiers for Active wells

Since wells sell both oil and gas and in widely varying proportions, it is useful to combine the disparate products to a single measurement of rate as an indicator of economic significance. Traditionally, the two are combined on the basis of energy content at a ratio of 6 Mcf to one equivalent barrel of oil (BOE). This measurement, however, makes gas production appear more valuable than it is. To put production on more relevant equivalence, we suggest the use of "barrels of value" (BOV)[3] instead of "barrels of oil equivalent" (BOE) at a ratio of 18 Mcf to one barrel of value. The same rate cut-offs can be applied to either measure of equivalence.

Pertains to	Subsets or Modifiers
Rate of production *averaged over previous 12 calendar months of continuous or Intermittent production*	**Stripper or Marginal:** less than 15 BOV or BOE per day. (Note that some jurisdictions use 10 BOE per day.) **"Micro":** less than 2 BOV or BOE per day.
Continuity of production	**Intermittent:** well has reported no activity for nine or more months of the 24 months preceding (and including) the last reported activity. (Applies only to Active wells, designation superseded by Idle and Inactive.) **Reactivated:** well previously idled for greater than 12 months but returned to production, injection, same or different geologic formation, for a minimum of three months.

[3] *Forget about BOE, Let's talk about "BOV"* by Dwayne Purvis, P.E., September 8, 2021. www.dpurvisPE.com

Modifiers for Inactive and similar wells

Pertains to	Modifiers
Inactive condition	**Temporarily abandoned or "mothballed":** well has been prepared or conditioned for longer term storage by, *e.g.*, filling the well with inhibitive fluids, removing equipment from the hole, and/or placing a removable plug closely above the perforations. **"Neglected":** no production/sales for more than five years, even if other operations have been conducted or production has been attempted. **"Deserted":** no production/sales for more than 10 years.
Active condition	**"Hospice":** wells which remain Active but which are operated at a financial loss or would operate at a loss if burdened with costs necessary for sustainable production. **"Mirage producers":** wells which are reported to be active but, in fact, are not.

Modifiers for Breached wells

Pertains to	Subsets
Location of movement within borehole	**Internal:** within the outermost casing at the given depth **External:** in the casing-borehole annulus around the largest casing at the given depth. **Broached:** between internal and external spaces or between nested casing. **Open hole:** within a segment of the borehole without any casing.
Location of movement along borehole	Within or between. . . **Surface:** at ground level or within a few feet. **Freshwater zone:** from ground level to the base of freshwater aquifers. **Subsurface:** below the base of freshwater aquifers.
Severity of fluid movement	**Leak:** Unintentional release of liquids which can be stopped with equipment already installed. In the case of a decommissioned well, volumes released or fluid pressure at the surface are below reportable or problematic limits. **Blow-out:** Unintentional release which cannot be controlled with installed equipment. In the case of a decommissioned well, all unrepaired breaches will continue indefinitely and uncontrollably, so all downhole breaches of a retired wells qualify as a "blow-out."

About Surface Locations

Individual wells may be plugged one at a time, but surface decommissioning tasks for larger, shared facilities occur only after many or all wells have ended their economic life. Related as they are, some of the same terms can be used to describe associated surface equipment— such as **Active, Idle, Inactive** – based on the total volumes processed through the equipment. Most relevant dimensions to characterize costs are type and setting of the locations.

Types of surface locations

Location	Definition
Well sites	Location of wellhead(s), commonly includes surface equipment dedicated to the immediate well(s).
Flow lines	Pipes for the movement of fluids within the field and upstream of custody transfer points.
Satellite facilities	Facilities shared by more than one but not all wells in the field.
Central facilities	Facilities shared by all or most of the wells in field.

Setting of surface locations

Location	Definition	Implications
Federal offshore	Located in federal waters.	Higher decommissioning costs, tighter regulations, some money held for bonding, and clearer terms for liability after sale.
State waters	Located in state waters.	Higher decommissioning costs, tighter regulations.
Federal onshore	Land leased from or regulated by any of several federal agencies.	Likely includes cost of restoration.
"Protected"	Land subject to state or federal protections such as designated wetlands and wildlife preserves.	Likely includes cost of restoration.
Urban	Areas defined as such by U.S. Census Bureau.	Likely private ownership, likely requires more restoration than Rural.
Rural	Areas defined as such by U.S. Census Bureau.	Most common situation and least surface restoration required.

Modifiers of surface locations

Pertains to	Definition
Knowledge of potential remediation issues	**Inspected:** Phase 1 environmental inspection report has been concluded within the last 3 years. **"Inspection outdated":** Phase 1 inspection has been performed but conditions are known to have changed or the report is no longer current. **Not inspected:** Phase 1 inspection not performed or more than 10 years old.
Location	**"Proximal":** existing or planned non-oilfield infrastructure is close enough that retirement scope could be affected. **Inaccessible:** road to the location and/or the location itself is no longer readily accessible to large equipment required to conduct work on the well or facilities.

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About Responsible Parties

The current **Operator** of the well bears direct accountability for decommissioning, and usually the Operator also owns proportionally most or all of the infrastructure being decommissioned. Still, secondary liability may pass to previous Operators or owners and to non-operating owners according to the status of the entities.

Types of entities

Entity	Definition
Operator	Company currently designated as the operator of the well by regulatory filing or contract.
Original Operator	Company responsible for the well when drilling ended. May be different than the company that obtained the permit and (though rarely) different from the company responsible when the well was spud.
Predecessor Operator, or Predecessor in operations	Any Operator of the well prior to the present time.
Successor Operator, or Successor in operations	Any Operator after a certain Operator or point in time.
"Terminal Operator"	Operator at the time of the decommissioning and responsible for the same. (Note that the last active operations and the design of the plugging procedure may pre-date the Terminal Operator.)
Contract Operator	Operator without equity ownership in the well.
Plugging Company, or Decommissioning Contractor	The contractor or other company that physically executes the decommissioning operations.
Co-owner or Non-operating owner	An equity owner of working interests in the well who does not conduct physical operations on the well. "Predecessor" and "Successor" may also be applied to Co-owners.

Status of responsible parties

Operator	Definition
Active	Private business under normal conditions, either legally existent or *de facto* existent by on-going activity. (Note that the label includes no criteria or implication about scale of activity or the ability of the operator to fund obligations.)
"Reorganizing"	Operator exists but is currently reorganizing under bankruptcy protection.
Delinquent	Operator of record is known, but the condition of the operator is not known. Regulator is temporarily trying to identify and engage the operator.
Defunct	Operator is no longer in existence or a viable business entity, thus responsibility falls to another party.
NOC	Operator is a national oil company or other government-owned entity and not subject to the same financial limitations as a private company.
Unknown	The last operator is currently unknown due to insufficient information. This designation should be used only temporarily.

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Combinations

Perhaps most usefully, the status of infrastructure can be combined with the status of the operator to create categories useful for large-scale discussions of decommissioning.

<table>
<tr><th>Operator
Well</th><th>Active</th><th>Reorganizing</th><th>Delinquent</th><th>Defunct</th><th>Unknown</th></tr>
<tr><td>Permitted</td><td colspan="5">Never drilled</td></tr>
<tr><td>Drilled</td><td rowspan="3">In Use</td><td rowspan="3">“Foster”
Unplugged and
operator may not be viable</td><td rowspan="3"></td><td rowspan="3">Orphan
Unplugged and
no private custodian</td><td rowspan="3"></td></tr>
<tr><td>Active</td></tr>
<tr><td>Idle</td></tr>
<tr><td>Inactive</td><td>“Warehoused”</td></tr>
<tr><td>Decommissioned</td><td colspan="3">“Corporate legacy”
Previously retired
and the last custodian or its successors
remains in existence</td><td colspan="2">“Public legacy”
Previously retired
and the last custodian and
its successors no longer
exist or can’t be found</td></tr>
<tr><td>Breached</td><td colspan="5">“Zombie”
Breached or Re-breached</td></tr>
<tr><td>Re-plugged</td><td colspan="5" rowspan="2">(same as above)</td></tr>
<tr><td>Re-breached</td></tr>
</table>

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FURTHER WORK

Though it represents substantial thought and incorporates feedback from a number of reviewers, the framework needs more input and more consensus from a broader range of participants. The Professional Petroleum Data Management Association (PPDM) intends to take on the task and welcomes volunteers. Please reach out to projects@ppdm.org.

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With special thanks to reviewers who may not wish to be identified by name.