QUANTIFICATION PROTOCOL FOR ACID GAS INJECTION:

ABRIDGED

Submitted to:

Alberta Environment

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Disclaimer

The following document presents an abridged version of the Acid Gas Injection protocol prepared for Alberta Environment which has completed an initial round of technical review. This document has been prepared as a means of supporting a broader stakeholder consultation process. As such, this document should not be used as a quantification protocol.

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1.0 Project and Methodology Scope and Description

This quantification protocol is written for the acid gas processing system operator or an acid gas project developer. Some familiarity with, or general understanding of, the operation of an acid gas processing facility is assumed.

The opportunity for generating carbon offsets with this protocol arises from the direct and indirect reductions of greenhouse gas (GHG) emissions resulting from the geological sequestration of acid gas streams containing greenhouse gasses as part of raw natural gas processing.

Processing a raw gas stream for the purpose of producing a saleable natural gas product results in an acid gas waste stream by-product. The acid gas stream can contain significant amounts of both hydrogen sulphide (H_2S), Carbon Dioxide (CO_2) and other contaminants.

In the baseline condition for projects applying this protocol the acid gas stream would be processed in;

- a Liquid Redox Process, or
- in a multi-stage Claus unit,

where, in either case, the CO_2 would be released to the atmosphere during flaring of tail gas. In the project condition capture and permanent containment of the entire acid gas stream reduces the quantity of CO_2 released to the atmosphere.

Further, the process of compression, transportation, and sequestration of acid gas reduces the quantity of GHG released to the atmosphere as it is less energy intensive than the baseline processes (Liquid Redox Process or multi-stage Claus process) required for safe disposal of the acid gas stream. **Figure 1.1** offers a project element life cycle chart for a typical project. In some cases where the multi-stage Claus process is in operation (in the actual vs. theoretical baseline) the operator may make the decision to maintain the process to produce elemental sulfur and steam from the Claus unit. This flexibility is has been incorporated in the protocol.

Where the waste acid gas stream is injected into an active reservoir (where raw gas is actively being withdrawn) there is the opportunity for the CO_2 to be "recycled" – that is the same CO_2 molecule could be withdrawn with the raw gas – separated and re-injected over and over – resulting in an over estimation of the baseline condition and thus the resulting offset. With the objective of conservativeness where CO_2 is captured and injected into an active reservoir, the CO_2 will be considered recycled and no credit claimed.

Finally, the Acid Gas Injection projects implemented in conformance with this protocol will not result in permanent elimination of the CO_2 emissions. The resulting offsets should however be considered inherently permanent as a result of the project monitoring and robustness of the injection reservoir mandated by the regulator in the permitting phase.

This protocol serves as a generic 'recipe' for project developers to follow in order to meet the measurement, monitoring and GHG quantification requirements for reductions from acid gas sequestration activities under controlled conditions.

The baseline condition represents the emissions of GHG from flaring the tail gas of a Liquid Redox Process, or multi-stage Claus unit at an acid gas processing facility. The baseline condition is calculated from a theoretically appropriately sized Liquid Redox Process, or multi-stage Claus. **FIGURE 1.2** offers an element life cycle chart for a typical baseline configuration.

FIGURE 1.1: Project Element Life Cycle Chart

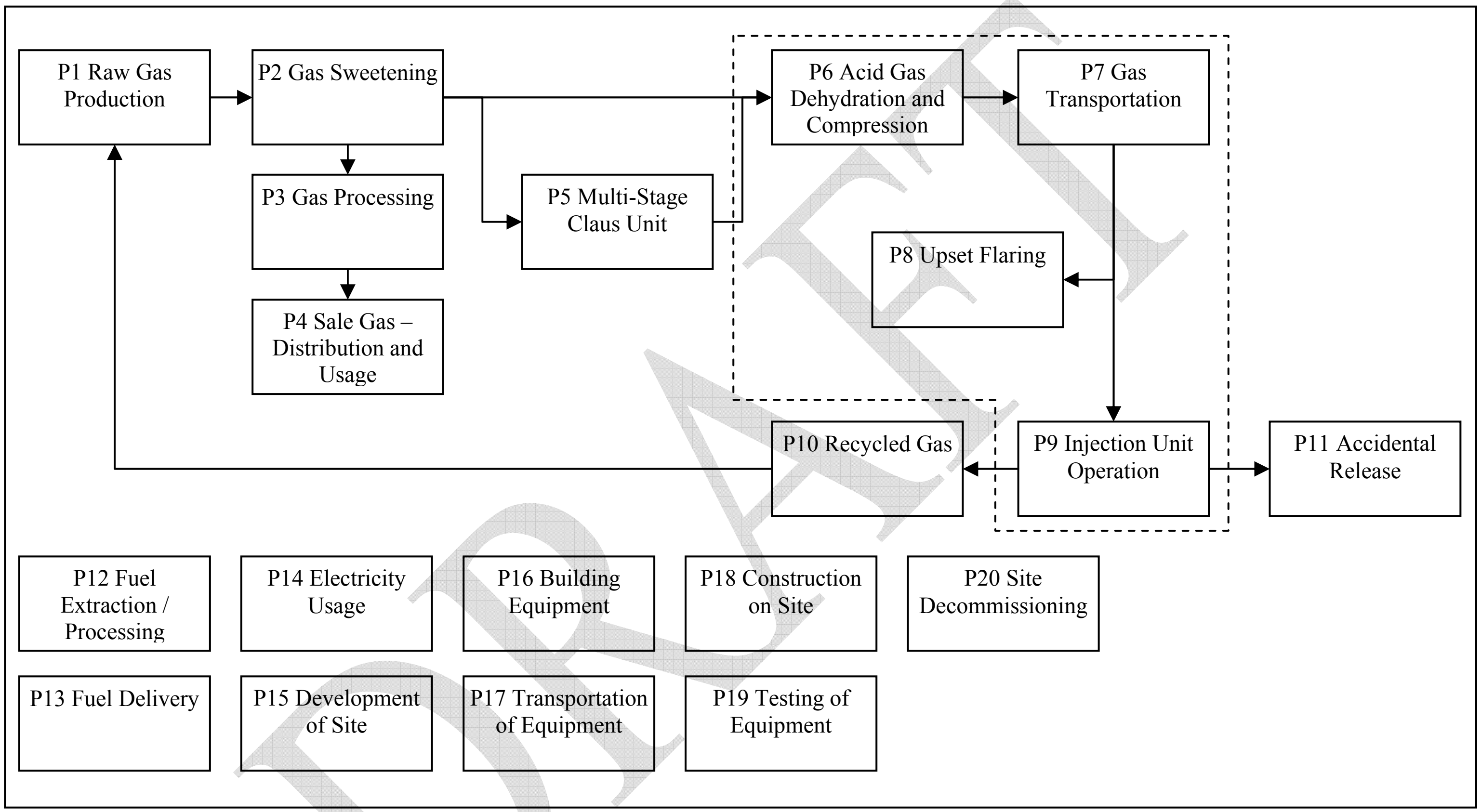
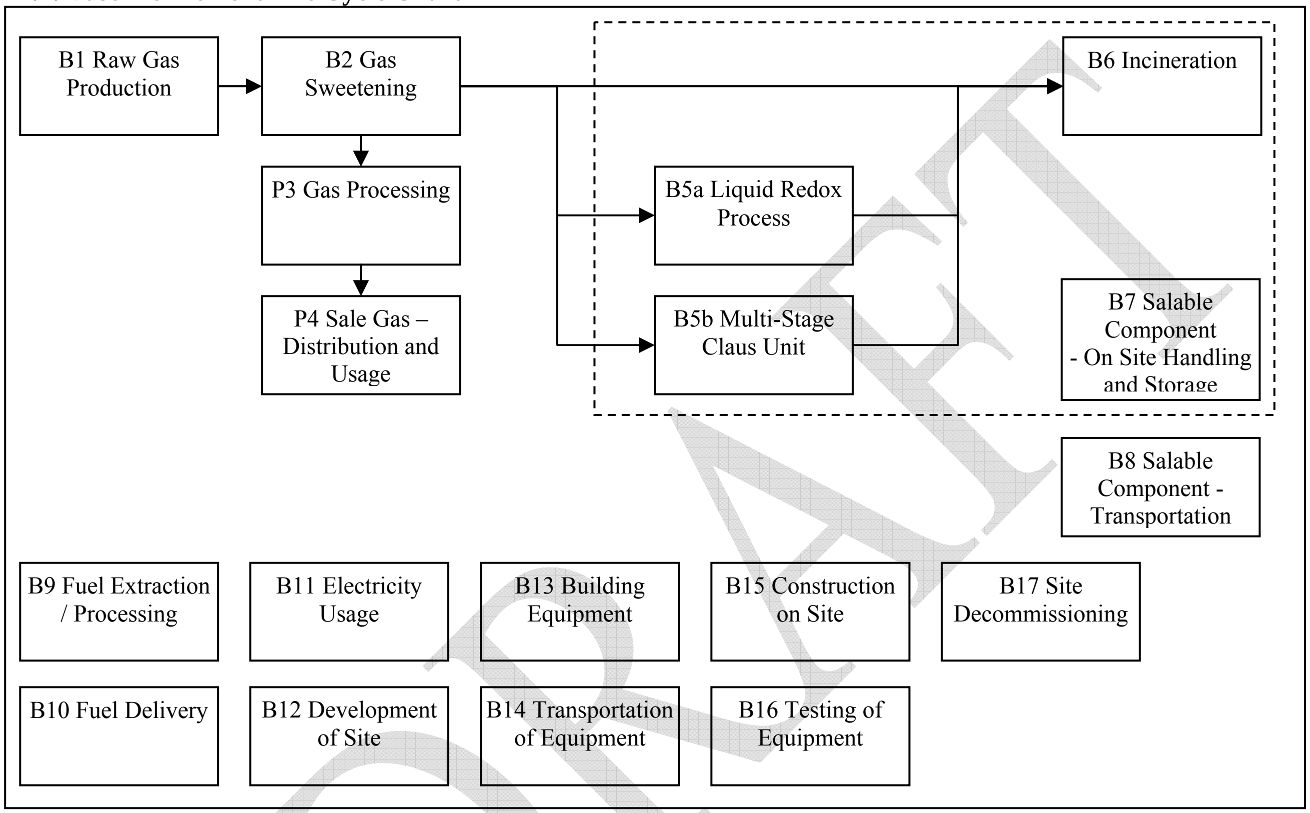


FIGURE 1.2: Baseline Element Life Cycle Chart



To demonstrate that a project meets the requirements under this protocol, the project developer must provide evidence that:

1. The sequestration project results in removal of emissions that would otherwise have been released to the atmosphere as indicated by an affirmation from the project developer and project schematics;

2. Where the entities/operations are separate and distinct, the emissions reduced are captured under the protocol and will be reported as being emitted at the source facility such that the emission reductions are not double counted;

3. The Acid Gas injection scheme has obtained approval from the Alberta Energy and Utilities Board (EUB) and meets the requirements outlined under Directive 051: Injection and Disposal Wells – Well Classifications, Completions, Logging and Testing Requirements.

4. Metering of injected gas volumes takes place as close to the injection point as is reasonable to address the potential for fugitive emissions as demonstrated by a project schematics;

5. The quantification of reductions achieved by the project is based on actual measurement and monitoring (except where indicated in this protocol) as indicated by the proper application of this protocol; and

6. The project must meet the requirements for offset eligibility as specified in the applicable regulation and guidance documents for the Alberta Offset System.

Flexibility in applying the quantification protocol is provided to project developers in the following ways:

1. Project developers may use alternative monitoring methodologies and/or equipment rather than the methodologies and/or equipment described in this protocol. The proponent must justify that the chosen methodology and/or equipment provides equivalent or more conservative data than the specified equipment;

2. Site specific emission factors may be substituted for the generic emission factors indicated in this protocol document. The methodology for generation of these emission factors must be sufficiently robust as to ensure reasonable accuracy;

3. Where a significant volume of the raw gas is produced from the same reservoir as the acid gas injection well, an alternate methodology for calculating the volume of recycled gas may be used. The proponent must justify that the chosen methodology provides verifiable data.

4. Projects may be developed where existing Claus units will remain in place. The baseline condition in this case should be redefined to exclude emissions resulting from the operation of the existing Claus unit.

If applicable, the proponent must indicate and justify why flexibility provisions have been used.

2.0 Quantification of Reductions, Removals and Reversals of Relevant SS's

Quantification of the reductions, removals and reversals of relevant SS's for each of the greenhouse gases will be completed using the methodologies outline in **TABLE 2.1**, below. These calculation methodologies serve to complete the following three equations for calculating the emission reductions from the comparison of the baseline and project conditions.

$$\text{Emissions Reduction} = \text{Emissions}_{\text{Baseline}} - \text{Emissions}_{\text{Project}}$$

$$\text{Emissions}_{\text{Baseline}} = \text{Emissions}_{\text{Fuel Extraction and Processing}} + \text{Emissions}_{\text{Liquid Redox Process}} + \text{Emissions}_{\text{Multi-Stage Claus Unit}} + \text{Emissions}_{\text{Incineration}}$$

$$\text{Emissions}_{\text{Project}} = \text{Emissions}_{\text{Fuel Extraction and Processing}} + \text{Emissions}_{\text{Gas Compression}} + \text{Emissions}_{\text{Upset Flaring}} + \text{Emissions}_{\text{Injection Unit Operation}} + \text{Emissions}_{\text{Recycled Gas}}$$

TABLE 2.1: Quantification Procedures

1.0 Project/Baseline SS	**2. Parameter / Variable**	**3. Unit**
	Project SS's	
P12 Fuel Extraction and Processing	Emissions $_{Fuel\ Extraction\ and\ Processing}$ = Σ (Vol. Fuel $_I$ * EF Fuel $_{i\ CO2}$) ; Σ (Vol. Fuel $_I$ * EF Fuel $_{i\ CH4}$) ; Σ (Vol. Fuel $_I$ * EF Fuel $_{i\ N2O}$) ;	
	Emissions $_{Fuel\ Extraction\ and\ Processing}$	kg of CO_2; CH_4 ; N_2O
	Volume of Each Type of Fuel Combusted for P5 to P8 / Vol. Fuel $_i$	L / m^3 / other
	CO_2 Emissions Factor for Fuel Including Production and Processing / EF Fuel $_{i\ CO2}$	kg CO_2 per L / m^3 / other
	CH_4 Emissions Factor for Fuel Including Production and Processing / EF Fuel $_{i\ CH4}$	kg CH_4 per L / m^3 / other
	N_2O Emissions Factor for Fuel Including Production and Processing / EF Fuel $_{i\ N2O}$	kg N_2O per L / m^3 / other
P6 Acid Gas Dehydration and Compression	Emissions $_{Gas\ Dehydration\ and\ Compression}$ = Σ (Vol. Fuel $_i$ * EF Fuel $_{i\ CO2}$) ; Σ (Vol. Fuel $_i$ * EF Fuel $_{i\ CH4}$) ; Σ (Vol. Fuel $_i$ * EF Fuel $_{i\ N2O}$)	
	Emissions $_{Gas\ Dehydration\ and\ Compression}$	kg of CO_2; CH_4 ; N_2O
	Volume of Each Type of Fuel Used / Vol. Fuel$_i$	L / m^3 / other
	CO_2 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CO2}$	kg CO_2 per L / m^3 / other
	CH_4 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CH4}$	kg CH_4 per L / m^3 / other
	N_2O Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ N2O}$	kg N_2O per L / m^3 / other
P8 Upset Flaring	Emissions $_{Flaring}$ = (Vol. AG Flared * % CO_2 * ρ_{CO2}); Σ (Vol. Fuel $_i$ * EF Fuel $_{i\ CO2}$) ; Σ (Vol. Fuel $_i$ * EF Fuel $_{i\ CH4}$) ; Σ (Vol. Fuel $_i$ * EF Fuel $_{i\ N2O}$)	
	Emissions $_{Flaring}$	Kg of CO_2 ; CH_4 ; N_2O
	Volume of Acid Gas Flared / Vol. AG Flared	m^3
	Carbon Dioxide Composition in AG / % CO_2	%
	Density of CO_2 / ρ_{CO2}	kg / m^3
	Volume of Each Type of Fuel used to Supplement Flare / Vol Fuel $_i$	L / m^3 / other
	CO_2 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CO2}$	kg CO_2 per L / m^3 / other
	CH_4 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CH4}$	kg CH_4 per L / m^3 / other
	N_2O Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ N2O}$	kg N_2O per L / m^3 / other
P9 Injection Unit Operation	Emissions $_{Injection\ Unit\ Operatoin}$ = Σ (Vol. Fuel $_i$ * EF Fuel $_{i\ CO2}$) ; Σ (Vol. Fuel $_i$ * EF Fuel $_{i\ CH4}$) ; Σ (Vol. Fuel $_i$ * EF Fuel $_{i\ N2O}$)	
	Emissions $_{Injection\ Unit\ Opertiona}$	kg of CO_2; CH_4 ; N_2O
	Volume of Each Type of Fuel Used / Vol. Fuel$_i$	L / m^3 / other
	CO_2 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CO2}$	kg CO_2 per L / m^3 / other
	CH_4 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CH4}$	kg CH_4 per L / m^3 / other

	N_2O Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ N2O}$	kg N_2O per L / m^3 / other
P10 Recycled Gas	Emissions $_{Recycled\ Gas}$ = Σ (Vol. $_{Recycled\ Gas}$ * % CO_2 * ρ_{CO2})	
	Emissions $_{Recycled\ Gas}$	kg CO_2
	Volume of Gas Produced at Wells Within the Same Reservoir / Vol. $_{Adjacent\ Gas}$	m^3
	CO_2 Composition in Adjacent Gas / % CO_2	%
	Density of CO_2 / ρ_{CO2}	kg/m^3
Baseline SS's		
B9 Fuel Extraction and Processing	Emissions $_{Fuel\ Extraction\ and\ Processing}$ = Σ (Vol. Fuel $_I$ * EF Fuel $_{i\ CO2}$) ; Σ (Vol. Fuel $_I$ * EF Fuel $_{i\ CH4}$) ; Σ (Vol. Fuel $_I$ * EF Fuel $_{i\ N2O}$) ;	
	Emissions $_{Fuel\ Extraction\ and\ Processing}$	kg of CO_2; CH_4 ; N_2O
	Volume of Each Type of Fuel Combusted for B5 / Vol. Fuel $_i$	L / m^3 / other
	CO_2 Emissions Factor for Fuel Including Production and Processing / EF Fuel $_{i\ CO2}$	kg CO_2 per L / m^3 / other
	CH_4 Emissions Factor for Fuel Including Production and Processing / EF Fuel $_{i\ CH4}$	kg CH_4 per L / m^3 / other
	N_2O Emissions Factor for Fuel Including Production and Processing / EF Fuel $_{i\ N2O}$	kg N_2O per L / m^3 / other
B5a Liquid Redox Process	Emissions $_{Liquid\ Redox\ Process}$ = Σ (Vol. Fuel $_i$ * EF Fuel $_{i\ CO2}$) ; Σ (Vol. Fuel $_i$ * EF Fuel $_{i\ CH4}$) ; Σ (Vol. Fuel $_i$ * EF Fuel $_{i\ N2O}$)	
	Emissions $_{Liquid\ Redox\ Process}$	kg of CO_2; CH_4 ; N_2O
	Volume of Each Type of Fuel Used / Vol. $Fuel_i$	L / m^3 / other
	CO_2 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CO2}$	kg CO_2 per L / m^3 / other
	CH_4 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CH4}$	kg CH_4 per L / m^3 / other
	N_2O Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ N2O}$	kg N_2O per L / m^3 / other
B5b Multi-Stage Claus Unit	Emissions $_{Multi\text{-}Stage\ Claus\ Unit}$ = Σ (Vol. Fuel $_i$ - ((E $_{Claus}$ * η $_{Heat}$) / (η $_{Energy}$ * ω $_{Fuel\ i}$))) * EF Fuel $_{i\ CO2}$) ; Σ(Vol. Fuel $_i$ - ((E $_{Claus}$ * η $_{Heat}$) / (η $_{Energy}$ * ω $_{Fuel\ i}$))) * EF Fuel $_{i\ CH4}$) ; Σ (Vol. Fuel $_i$ - ((E $_{Claus}$ * η $_{Heat}$) / (η $_{Energy}$ * ω $_{Fuel\ i}$))) * EF Fuel $_{i\ N2O}$)	
	Emissions $_{Multi\text{-}Stage\ Claus\ Unit}$	kg of CO_2; CH_4 ; N_2O
	Volume of Each Type of Fuel Used / Vol. $Fuel_i$	L / m^3 / other
	Process Energy Recovered / E $_{Claus}$	GJ
	Heat Transfer Efficiency / η $_{Heat}$	-
	Fuel Energy Efficiency / η $_{Energy}$	-
	Realized Energy Density from Each Type of Fuel / ω $_{Fuel\ i}$	GJ / m^3
	CO_2 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CO2}$	kg CO_2 per L / m^3 / other

	CH_4 Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ CH4}$	kg CH_4 per L / m^3 / other
	N_2O Emissions Factor for Each Type of Fuel / EF Fuel $_{i\ N2O}$	kg N_2O per L / m^3 / other
B6 Incineration	Emissions $_{Incineration}$ = (Vol. Gas Flared * % CO_2 * ρ_{CO2}) ; (((Vol. Gas Flared) * ($HV_{combined}$ – HV_{tail})/(HV_{fuel} – $HV_{combined}$)) * EF Fuel $_{i\ CO2}$) ; (((Vol. Gas Flared) * ($HV_{combined}$ – HV_{tail})/(HV_{fuel} – $HV_{combined}$))* EF Fuel $_{i\ CH4}$) ; (((Vol. Gas Flared) * ($HV_{combined}$ – HV_{tail})/(HV_{fuel} – $HV_{combined}$)) * EF Fuel $_{i\ N2O}$) ;	
	Emissions $_{Flaring}$	kg CO_2 ; CH_4 ; N_2O
	Volume of Gas Flared / Vol. Gas Flared	m^3
	CO_2 Composition in Gas / % CO_2	%
	Density of CO_2 / ρ_{CO2}	kg / m^3
	Heat Value of Tail Gas / HV $_{tail}$	MJ / m^3
	Heat Value of Fuel Gas used to Supplement Flare / HV $_{fuel}$	MJ / m^3
	Heat Value of Combined Tail Gas and Fuel Gas / HV $_{combined}$	MJ / m^3
	CO_2 Emissions Factor for Each Type of Fuel $_{i\ CO2}$	kg CO_2 per L / m^3 / other
	CH_4 Emissions Factor for Each Type of Fuel $_{i\ CH4}$	kg CH_4 per L / m^3 / other
	N_2O Emissions Factor for Each Type of Fuel $_{i\ N2O}$	kg N_2O per L / m^3 / other

APPENDIX A: Glossary of New Terms

Acid Gas: A gas that can form acidic solutions when mixed with water. The most common acid gases are hydrogen sulfide [H_2S] and carbon dioxide [CO_2] gases. Both gases cause corrosion; hydrogen sulfide is extremely poisonous. Hydrogen sulfide and carbon dioxide gases are obtained after a sweetening process applied to a sour gas.

Acid Gas Injection: Injection of acid Gas into deep geological formations including, but not necessarily limited to, depleted oil and gas reservoirs and deep saline aquifers.

Aquifer: A water-bearing portion of a petroleum reservoir with a water drive.

Reservoir: A subsurface body of rock having sufficient porosity and permeability to store and transmit fluids. Sedimentary rocks are the most common reservoir rocks because they have more porosity than most igneous and metamorphic rocks and form under temperature conditions at which hydrocarbons can be preserved. A reservoir is a critical component of a complete petroleum system.