WHAT STARTS HERE CHANGES THE WORLD
THE UNIVERSITY OF TEXAS AT AUSTIN

Towards an Ontology Driven Enhanced Oil Recovery Decision Support System

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The University of Texas

W3C Workshop on Semantic Web in Oil & Gas Industry, Houston, December 9,10, 2008

Outline

- Background
- Our Focus
- Our Approach
- Pilots
- Some Tentative Visions
- Next Steps
- Acknowledgements

Background

- UT Expertise in Enhanced Oil Recovery
- Knowledge in
  - Professors and Students
  - Dissertations and Papers
  - Laboratory Procedures
  - Laboratory Data
- Need for Integrated Approach
- Industry needs help in Decision-Making

Our Focus

Decision Making Processes in Enhanced Oil Recovery (EOR)

For a given reservoir:

1. Which EOR Methods are most promising?
2. What is the potential for each of the promising EOR Methods?
3. What is the best design for each EOR Method to be applied?

   e.g. Best Alkaline, Surfactant, Polymer (ASP) Formulation?

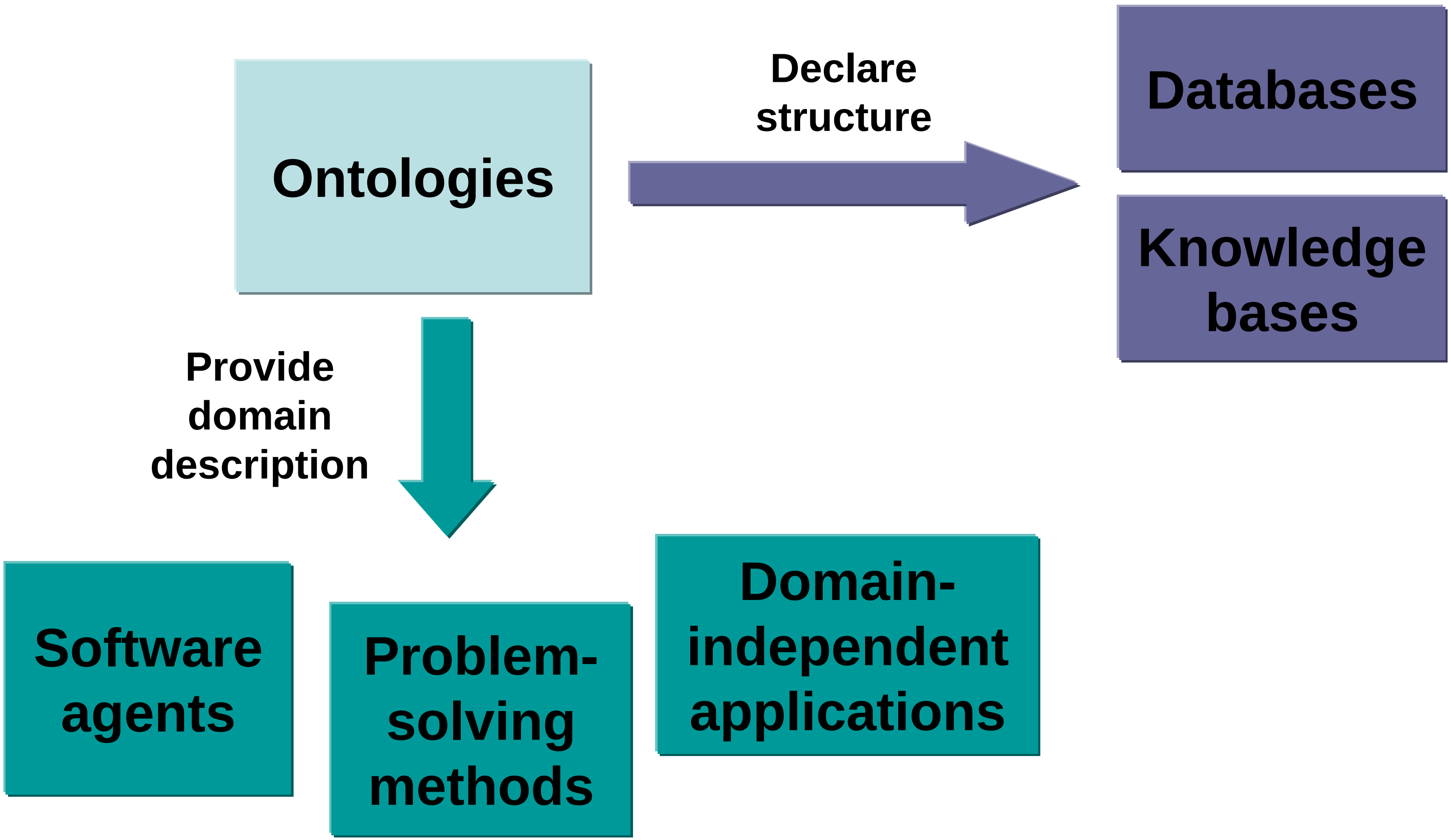
Workflows to be Considered

- Screening
- Laboratory
- Geology
- Simulation
- Field Trial
- Production

Our Approach

- Capture Knowledge
- Focus on EOR and its Workflows
- Build Ontology Pilots
- Create Knowledge Base and Query System

An Ontology Is Often Just the Beginning

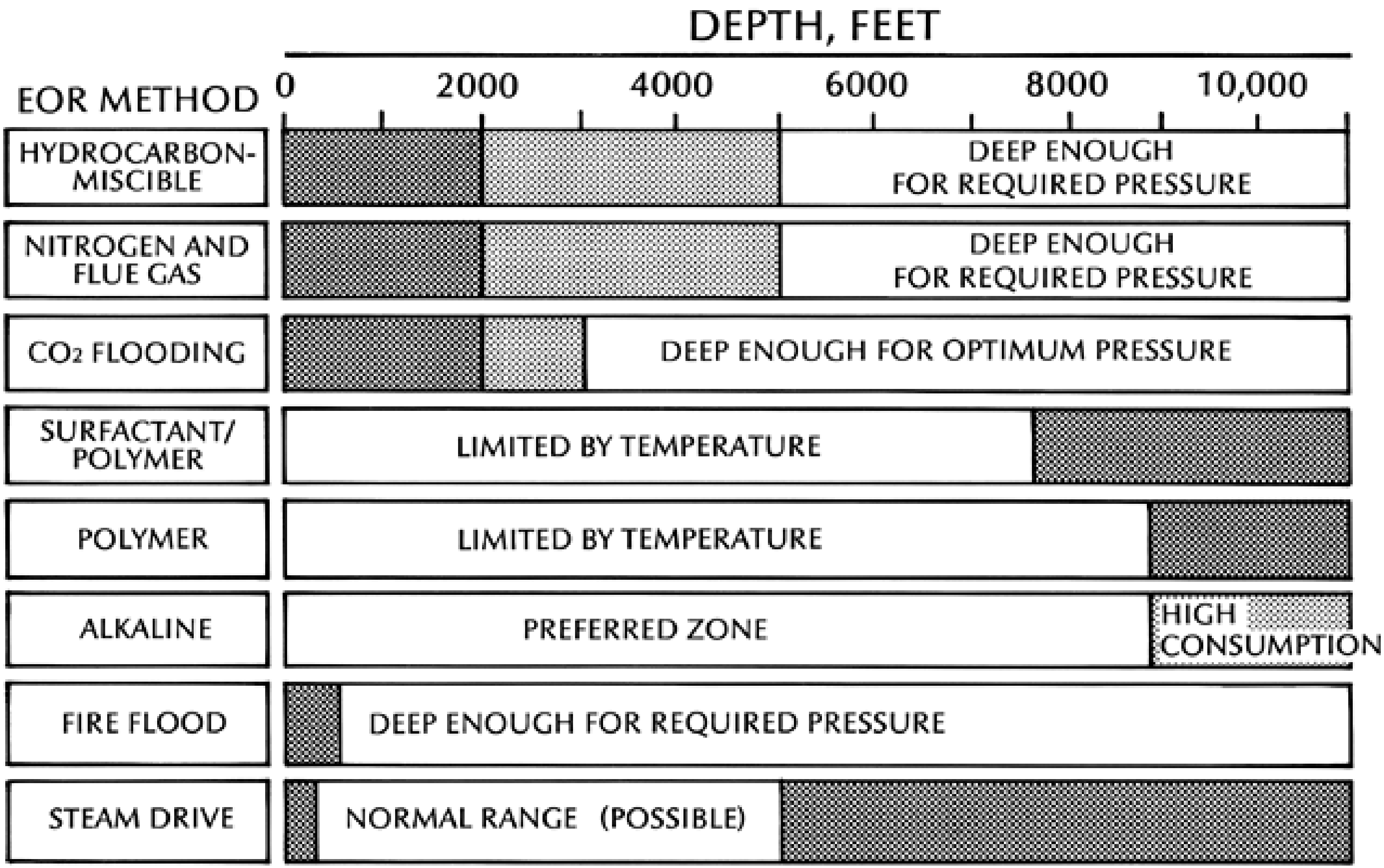


Pilots

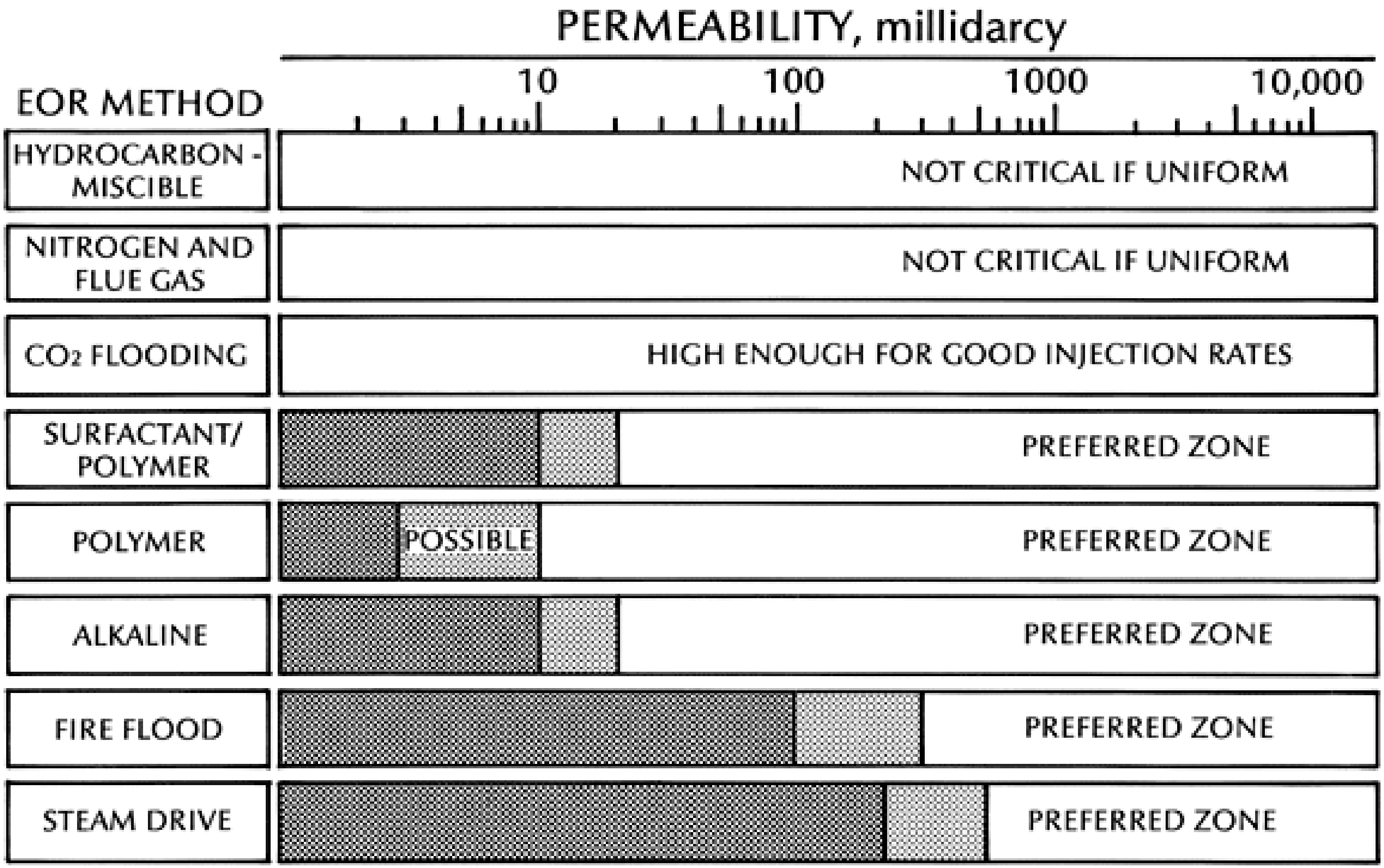
- EOR Screening Ontology Pilot
- Surfactant Selection Workflow
  - Expanded to EOR General Ontology with Chemicals
- EOR Simplified Recovery Calculation Ontology Pilot
- Scale-Up Uncertainty in Reservoir Characterization Pilot
- Risk Management Ontology Pilot

EOR Screening Ontology Pilot

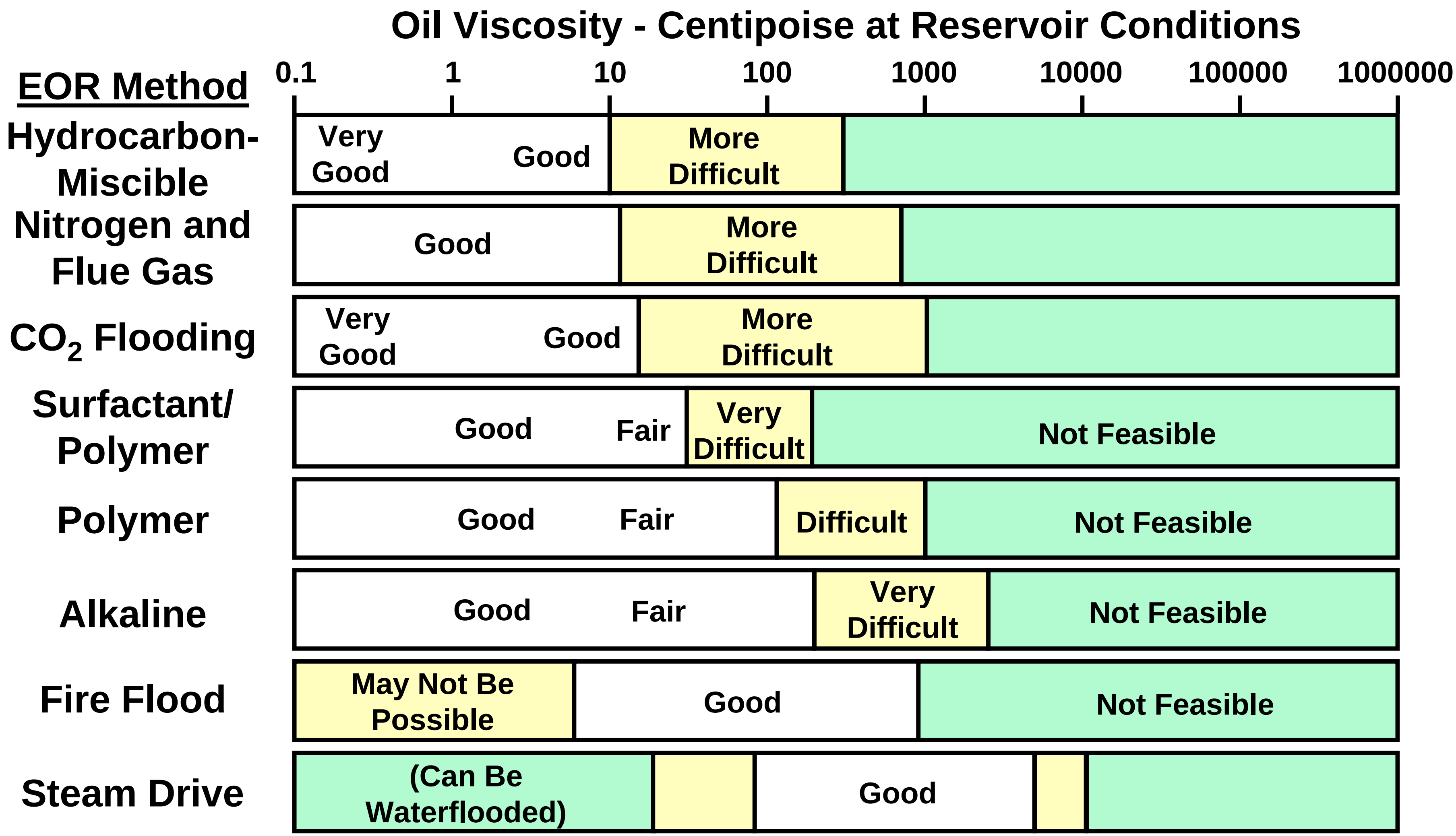
Depth Limitations...



Permeability Guides...

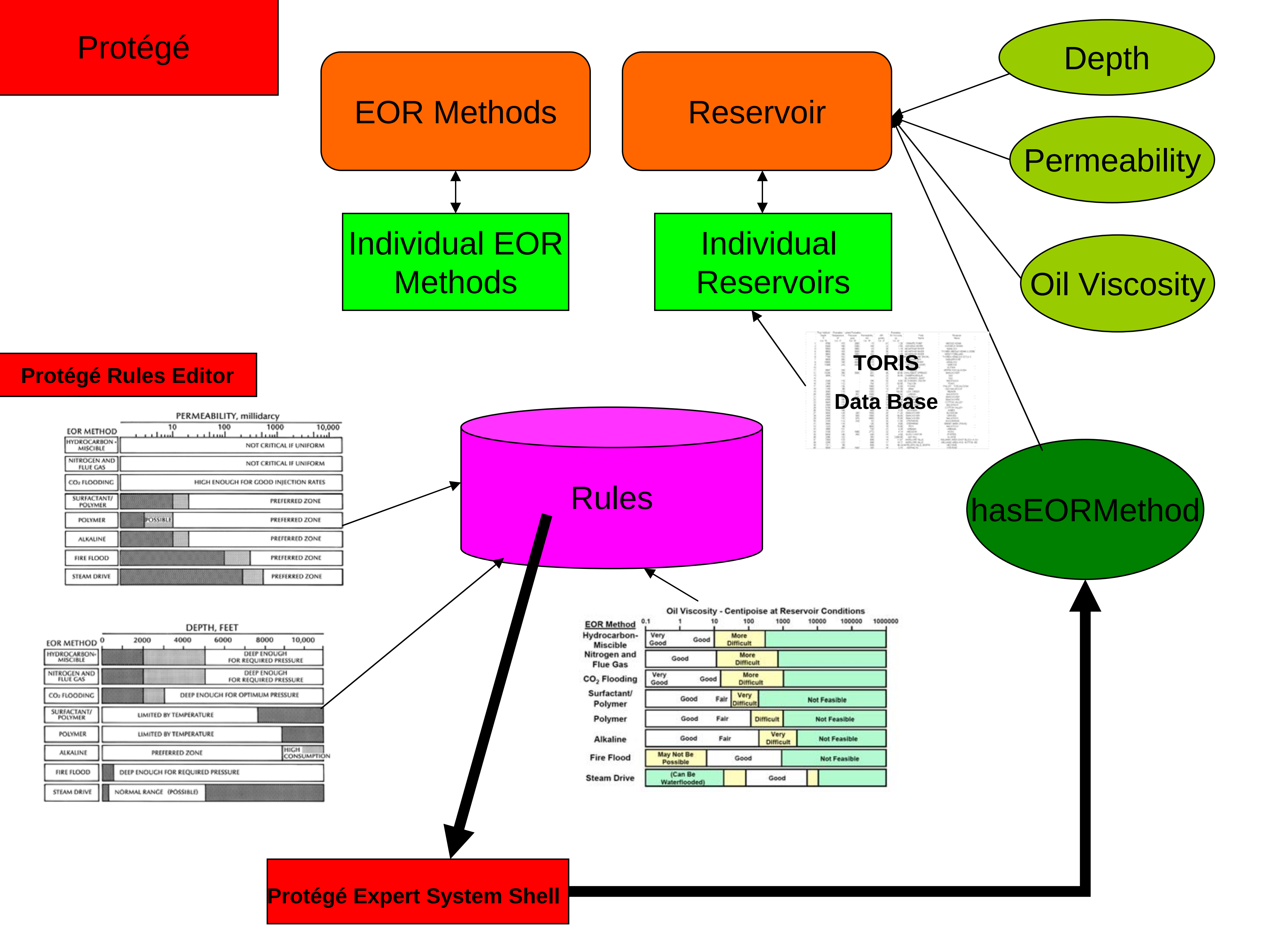


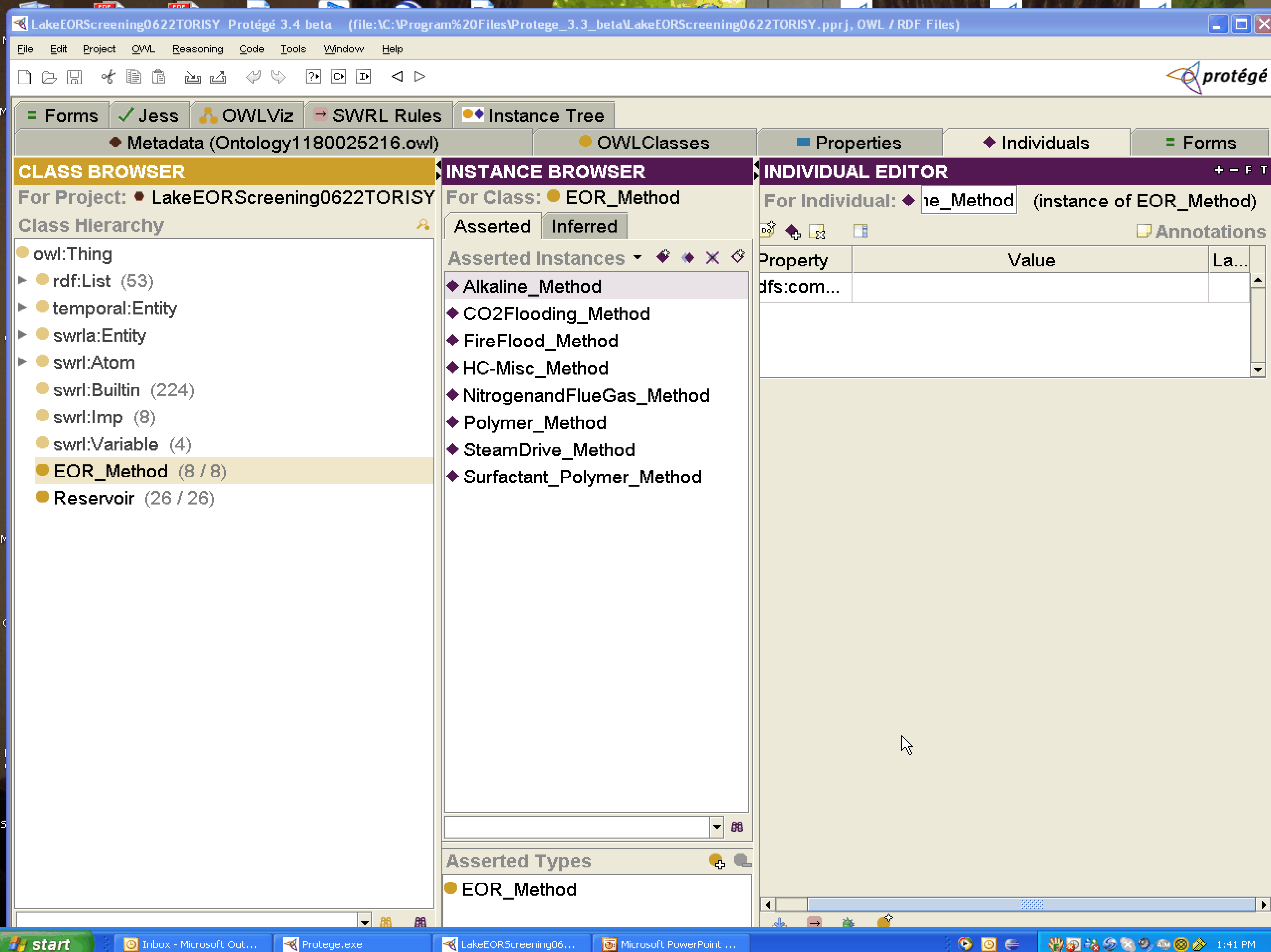
Preferred Oil Viscosity Ranges...



Partial TORIS Data Base

	True Vertical Depth ft Col. 16	Formation Temperature oF Col. 17	urrent Formation Pressure psia Col. 18	Permeability md Col. 19	API gravity Col. 21	Formation Oil Viscosity cp Col. 22	Field Name	Reservoir Name
1	8780	153	2000	10	41	1.20	GRANITE POINT	MIDDLE KENAI
2	6300	160	3360	100	22	2.50	KUPARUK RIVER	KUPARUK RIVER
3	9350	180	3900	53	35	1.19	MCARTHUR RIVER	HEMLOCK
4	8850	163	3000	65	36	1.10	MCARTHUR RIVER	TYONEK MIDDLE KENAI G ZONE
5	9650	185	2900	102	33	1.49	MCARTHUR RIVER	WEST FORELAND
6	7100	153	4100	3	35	0.72	MIDDLE GROUND SHOAL	TVONEK-HEMLOCK E,F,& G
7	9000	200	3950	450	27	0.90	PRUDHOE BAY	SADLEROCHIT
8	10800	180	4500	170	39	1.90	SWANSON RIVER	HEMLOCK
9	11085	210	3000	13	43	0.46	CITRONELLE (UNIT)	VARIOUS
10							GILBERTOWN	EUTAW
11	5807	159		600	29	2.56	POLLARD	UPPER TUSCALOOSA
12	10240	256	2600	201	46	44.40	CHALYBEAT SPRINGS	SMACKOVER
13	2690	115		506	22	35.00	CHAMPAGNOLLE	OLD
14					32		EL DORADO, EAST	OLD
15	2100	110		195	32	6.50	EL DORADO, SOUTH	NACATOCH
16	2106	112		754	21	60.00	FALCON	TOKIO
17	3400	135		1000	31	5.00	FOUKE	PALUXY - TUSCALOOSA
18	1150	88		1500	14	377.39	IRMA	OLD NACATOCH
19	2545	118	800	1200	17	160.00	LICK CREEK	MEAKIN
20	2060	110	901	1500	34	7.60	LISBON	NACATOCH
21	7500	207	3245	1085	38	3.19	MAGNOLIA	SMACKOVER
22	6300	180	2850	45	36	0.85	MIDWAY	SMACKOVER
23	5669	170		393	31	3.00	NEW LONDON	COTTON VALLEY
24	2300	115	350	1800	19	12.00	SANDY BEND	NACATOCH
25	5700	170		750	42	1.30	SCHULER	COTTON VALLEY
26	7530	198		400	34	6.20	SCHULER	JONES
27	2600	125	200	1500	20	71.20	SMACKOVER	BLOSSOM
28	2400	120	500	1000	20	56.00	SMACKOVER	GRAVES
29	2000	110	875	5000	20	75.00	SMACKOVER	NACATOCH
30	2100	114	918	92	30	12.00	STEPHENS	BUCKRANGE
31	2650	115		125	30	8.00	STEPHENS	SMART AREA (TOKIO)
32	1220	89		3500	18	70.00	TROY	NACATOCH
33	3580	121		729	23	4.28	URBANA	URBANA
34	3100	131	1686	2772	32	4.14	WESSON	HOGG
35	5050	146	450	430	24	4.50	ALISO CANYON	PORTER
36	2286	122		350	14	3,000.00	ANT HILL	OLCESE
37	2300	123		698	19	11.67	ANTELOPE HILLS	WILLIAMS AREA EAST BLOCK A GU
38	2298	123		698	17	18.17	ANTELOPE HILLS	WILLIAMS AREA W.B. BUTTON BE
39	1311	98		698	16	98.24	ANTELOPE HILLS, NORTH	MIOCENE
40	5600	200	1500	350	34	0.70	ASPHALTO	STEVENS


Protégé
EOR Methods
Reservoir
Depth
Permeability
Oil Viscosity
Individual EOR Methods
Individual Reservoirs
TORIS
Data Base
Protégé Rules Editor
Rules
hasEORMethod
PERMEABILITY, millidarcy
EOR METHOD
10
100
1000
10,000
HYDROCARBON-MISCIBLE
NOT CRITICAL IF UNIFORM
NITROGEN AND FLUE GAS
NOT CRITICAL IF UNIFORM
CO2 FLOODING
HIGH ENOUGH FOR GOOD INJECTION RATES
SURFACTANT/POLYMER
PREFERRED ZONE
POLYMER
POSSIBLE
PREFERRED ZONE
ALKALINE
PREFERRED ZONE
FIRE FLOOD
PREFERRED ZONE
STEAM DRIVE
PREFERRED ZONE
DEPTH, FEET
EOR METHOD
0
2000
4000
6000
8000
10,000
HYDROCARBON-MISCIBLE
DEEP ENOUGH FOR REQUIRED PRESSURE
NITROGEN AND FLUE GAS
DEEP ENOUGH FOR REQUIRED PRESSURE
CO2 FLOODING
DEEP ENOUGH FOR OPTIMUM PRESSURE
SURFACTANT/POLYMER
LIMITED BY TEMPERATURE
POLYMER
LIMITED BY TEMPERATURE
ALKALINE
PREFERRED ZONE
HIGH CONSUMPTION
FIRE FLOOD
DEEP ENOUGH FOR REQUIRED PRESSURE
STEAM DRIVE
NORMAL RANGE (POSSIBLE)
Oil Viscosity - Centipoise at Reservoir Conditions
EOR Method
0.1
1
10
100
1000
10000
100000
1000000
Hydrocarbon-Miscible
Very Good
Good
More Difficult
Nitrogen and Flue Gas
Good
More Difficult
CO2 Flooding
Very Good
Good
More Difficult
Surfactant/Polymer
Good
Fair
Very Difficult
Not Feasible
Polymer
Good
Fair
Difficult
Not Feasible
Alkaline
Good
Fair
Very Difficult
Not Feasible
Fire Flood
May Not Be Possible
Good
Not Feasible
Steam Drive
(Can Be Waterflooded)
Good
Protégé Expert System Shell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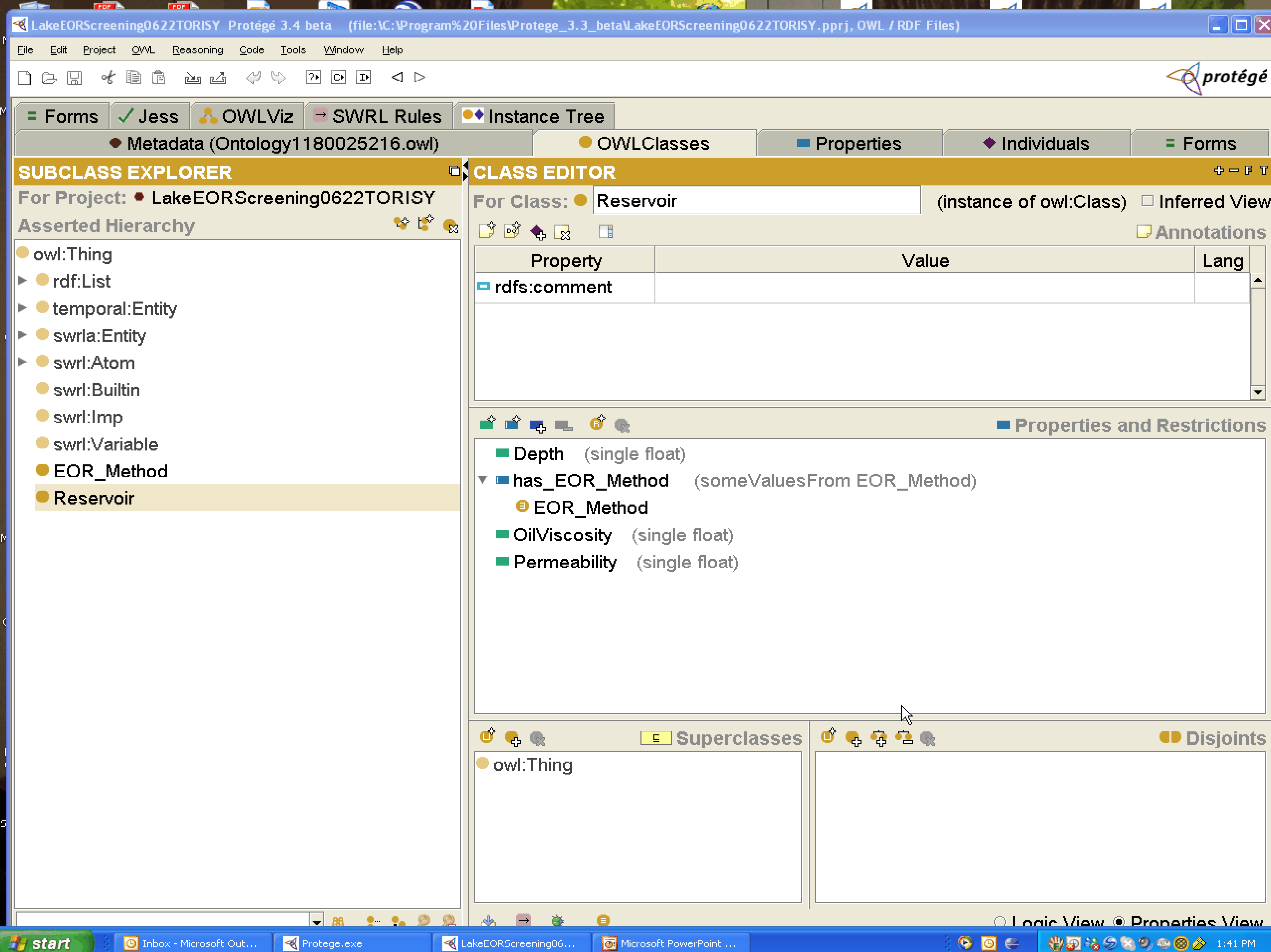
File Edit Project OWL Reasoning Code Tools Window Help
protégé
Forms Jess OWLViz SWRL Rules Instance Tree
Metadata (Ontology1180025216.owl) OWLClasses Properties Individuals Forms
CLASS BROWSER
For Project: LakeEORScreening0622TORISY
Class Hierarchy
owl:Thing
rdf:List (53)
temporal:Entity
swrla:Entity
swrl:Atom
swrl:Builtin (224)
swrl:Imp (8)
swrl:Variable (4)
EOR_Method (8 / 8)
Reservoir (26 / 26)
INSTANCE BROWSER
For Class: EOR_Method
Asserted Inferred
Asserted Instances
Alkaline_Method
CO2Flooding_Method
FireFlood_Method
HC-Misc_Method
NitrogenandFlueGas_Method
Polymer_Method
SteamDrive_Method
Surfactant_Polymer_Method
Asserted Types
EOR_Method
INDIVIDUAL EDITOR
For Individual: ne_Method (instance of EOR_Method)
Annotations
Property Value La...
dfs:com...
start Inbox - Microsoft Out... Protege.exe LakeEORScreening06... Microsoft PowerPoint ...
1:41 PM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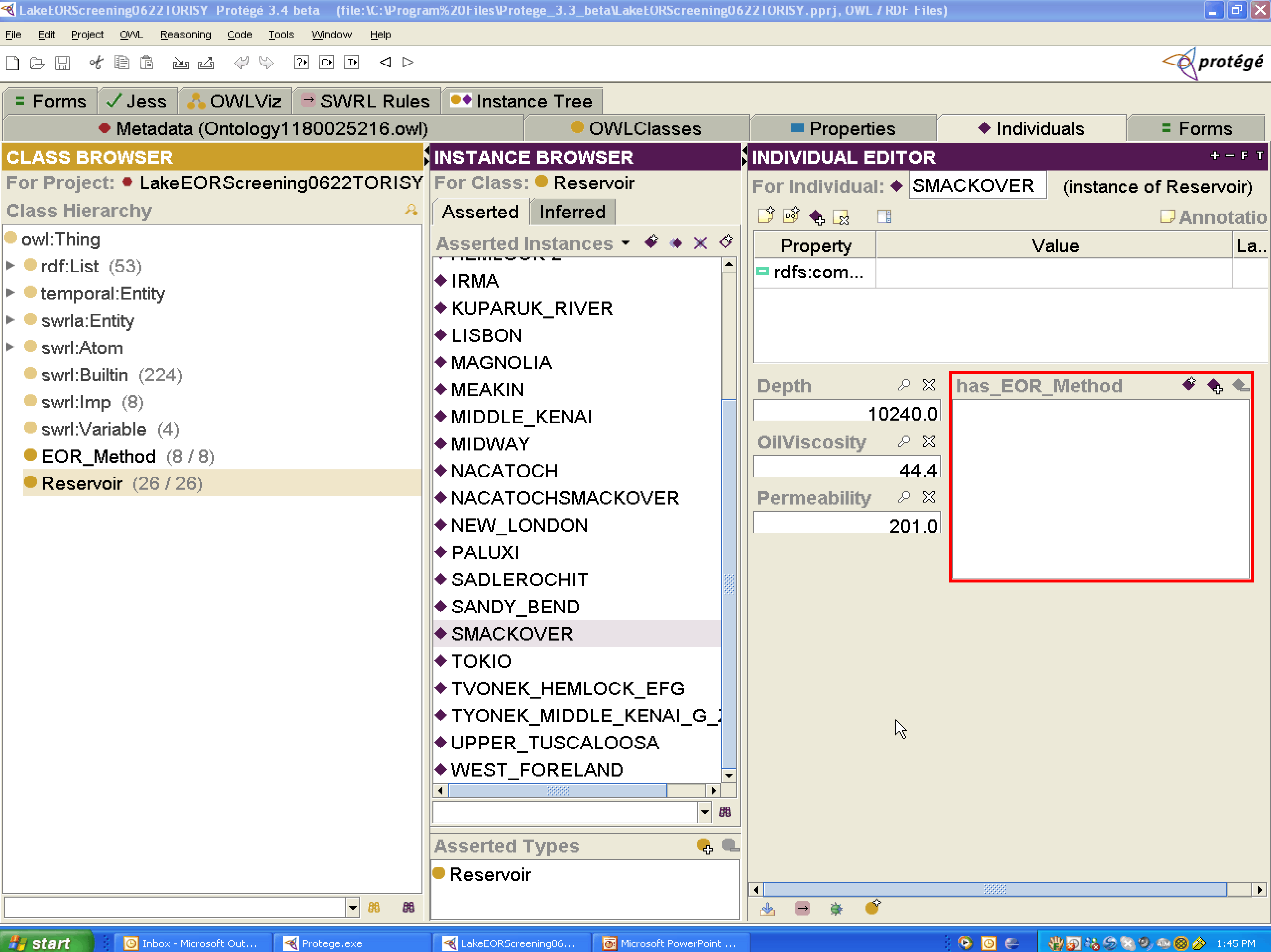
File Edit Project OWL Reasoning Code Tools Window Help
protégé
Forms
Jess
OWLViz
SWRL Rules
Instance Tree
Metadata (Ontology1180025216.owl)
OWLClasses
Properties
Individuals
Forms
SUBCLASS EXPLORER
For Project: LakeEORScreening0622TORISY
Asserted Hierarchy
owl:Thing
rdf:List
temporal:Entity
swrla:Entity
swrl:Atom
swrl:Builtin
swrl:Imp
swrl:Variable
EOR_Method
Reservoir
CLASS EDITOR
For Class: Reservoir
(instance of owl:Class)
Inferred View
Annotations
Property
Value
Lang
rdfs:comment
Properties and Restrictions
Depth (single float)
has_EOR_Method (someValuesFrom EOR_Method)
EOR_Method
OilViscosity (single float)
Permeability (single float)
Superclasses
owl:Thing
Disjoints
Logic View
Properties View
start
Inbox - Microsoft Out...
Protege.exe
LakeEORScreening06...
Microsoft PowerPoint ...
1:41 PM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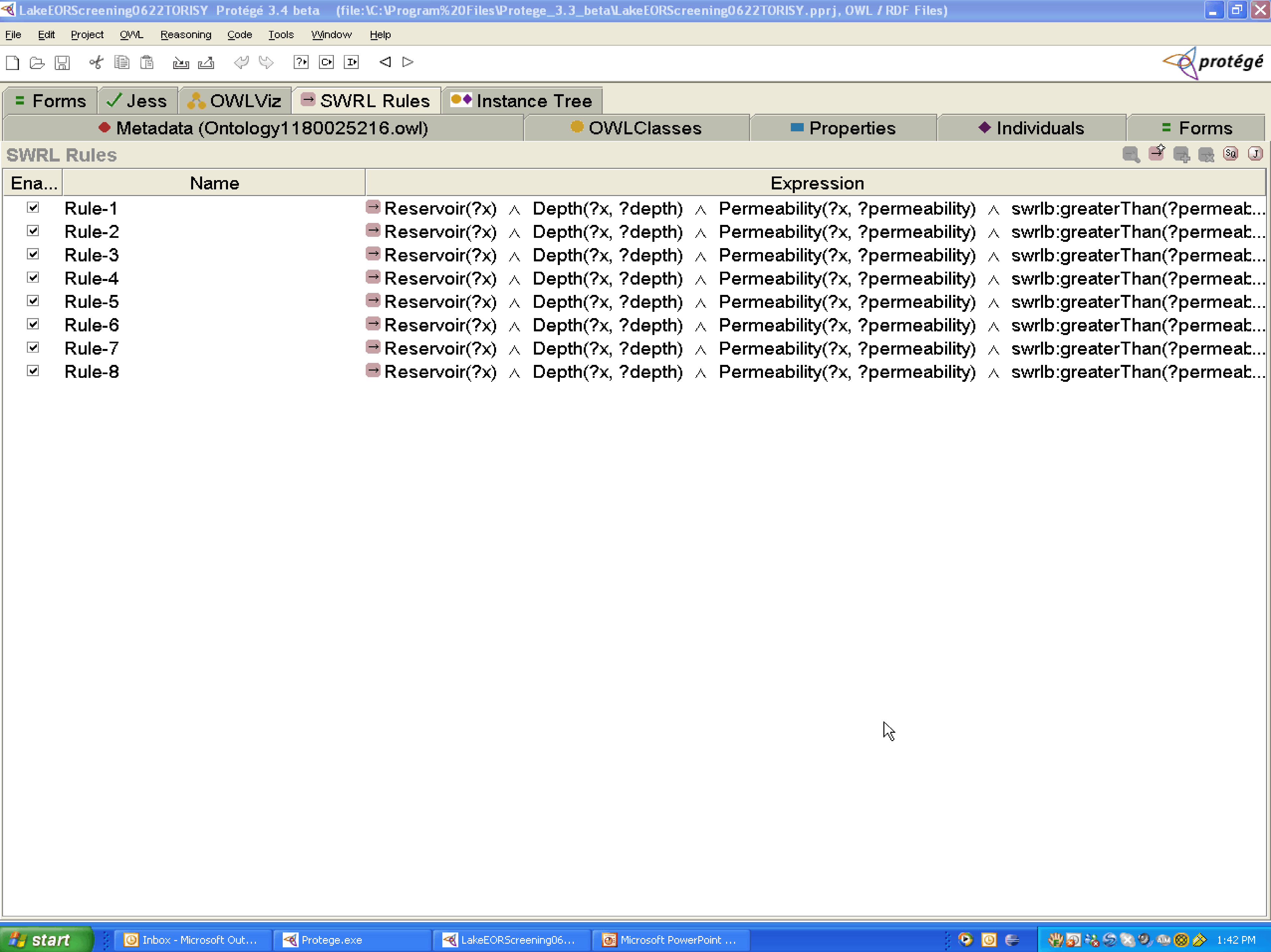
File Edit Project OWL Reasoning Code Tools Window Help
protégé
Forms Jess OWLViz SWRL Rules Instance Tree
Metadata (Ontology1180025216.owl) OWLClasses Properties Individuals Forms
CLASS BROWSER
For Project: LakeEORScreening0622TORISY
Class Hierarchy
owl:Thing
rdf:List (53)
temporal:Entity
swrla:Entity
swrl:Atom
swrl:Builtin (224)
swrl:Imp (8)
swrl:Variable (4)
EOR_Method (8 / 8)
Reservoir (26 / 26)
INSTANCE BROWSER
For Class: Reservoir
Asserted Inferred
Asserted Instances
IRMA
KUPARUK_RIVER
LISBON
MAGNOLIA
MEAKIN
MIDDLE_KENAI
MIDWAY
NACATOCH
NACATOCHSMACKOVER
NEW_LONDON
PALUXI
SADLEROCHIT
SANDY_BEND
SMACKOVER
TOKIO
TVONEK_HEMLOCK_EFG
TYONEK_MIDDLE_KENAI_G_
UPPER_TUSCALOOSA
WEST_FORELAND
Asserted Types
Reservoir
INDIVIDUAL EDITOR
For Individual: SMACKOVER (instance of Reservoir)
Annotatio
Property Value La..
rdfs:com...
Depth
10240.0
OilViscosity
44.4
Permeability
201.0
has_EOR_Method
start Inbox - Microsoft Out... Protege.exe LakeEORScreening06... Microsoft PowerPoint ... 1:45 PM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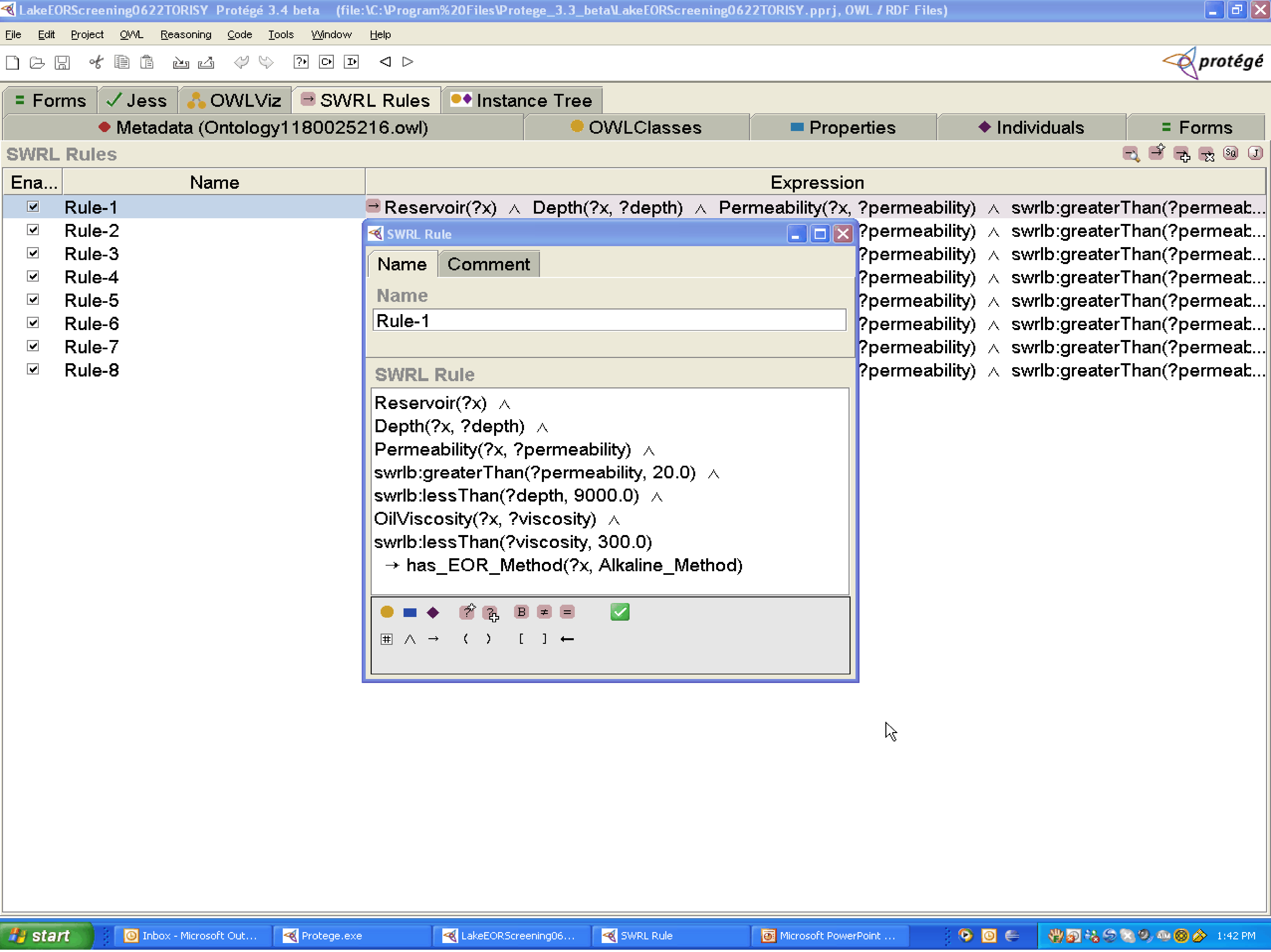
OWLClasses
Properties
Individuals
Forms
SWRL Rules
Ena...
Name
Expression
Rule-1 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-2 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-3 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-4 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-5 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-6 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-7 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-8 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
start
Inbox - Microsoft Out...
Protege.exe
LakeEORScreening06...
Microsoft PowerPoint ...
1:42 PM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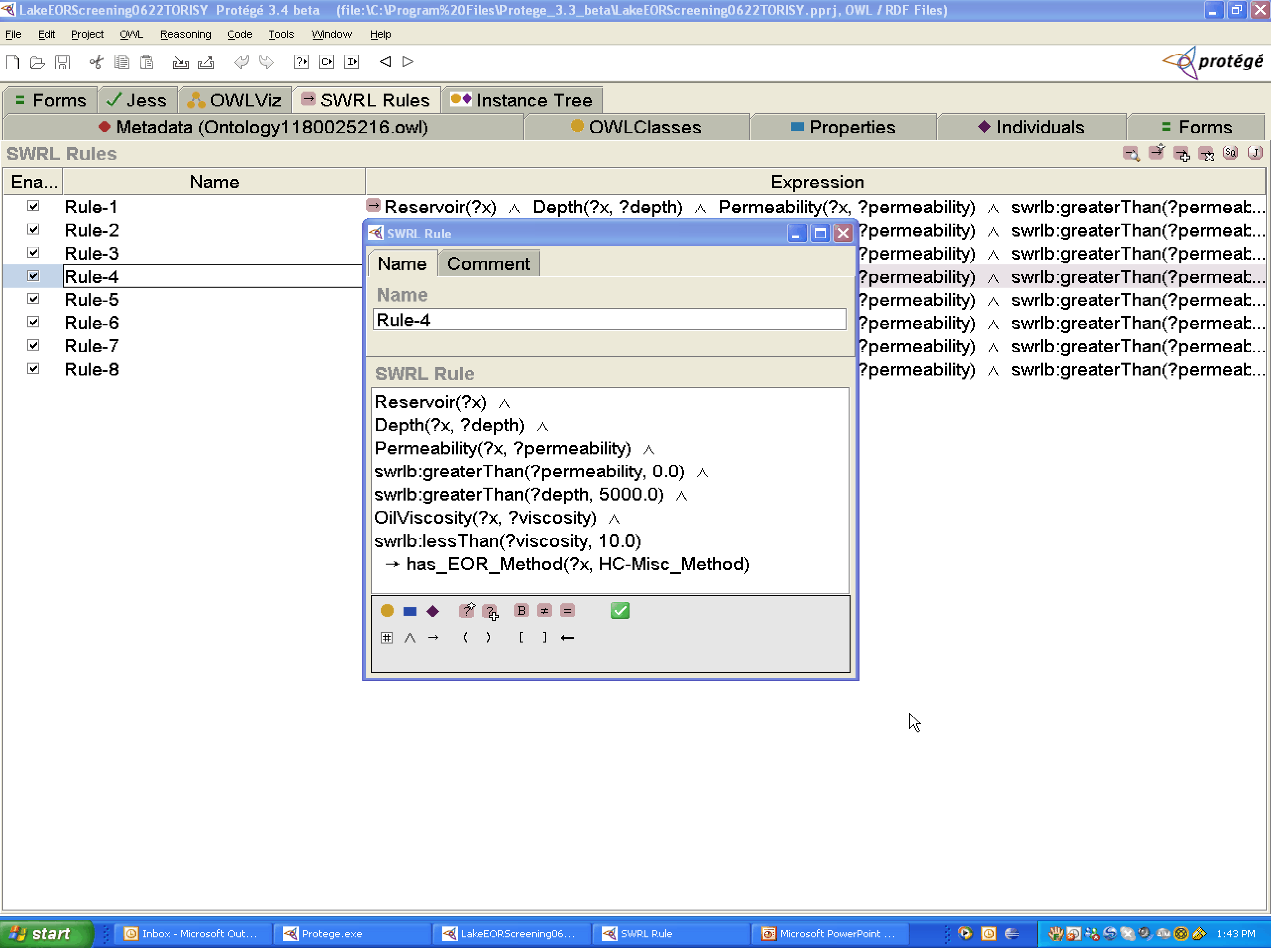
SWRL Rules
Ena... Name Expression
Rule-1 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-2
Rule-3
Rule-4
Rule-5
Rule-6
Rule-7
Rule-8
SWRL Rule
Name Comment
Name
Rule-1
SWRL Rule
Reservoir(?x) ∧
Depth(?x, ?depth) ∧
Permeability(?x, ?permeability) ∧
swrlb:greaterThan(?permeability, 20.0) ∧
swrlb:lessThan(?depth, 9000.0) ∧
OilViscosity(?x, ?viscosity) ∧
swrlb:lessThan(?viscosity, 300.0)
→ has_EOR_Method(?x, Alkaline_Method)
start Inbox - Microsoft Out... Protege.exe LakeEORScreening06... SWRL Rule Microsoft PowerPoint ...
1:42 PM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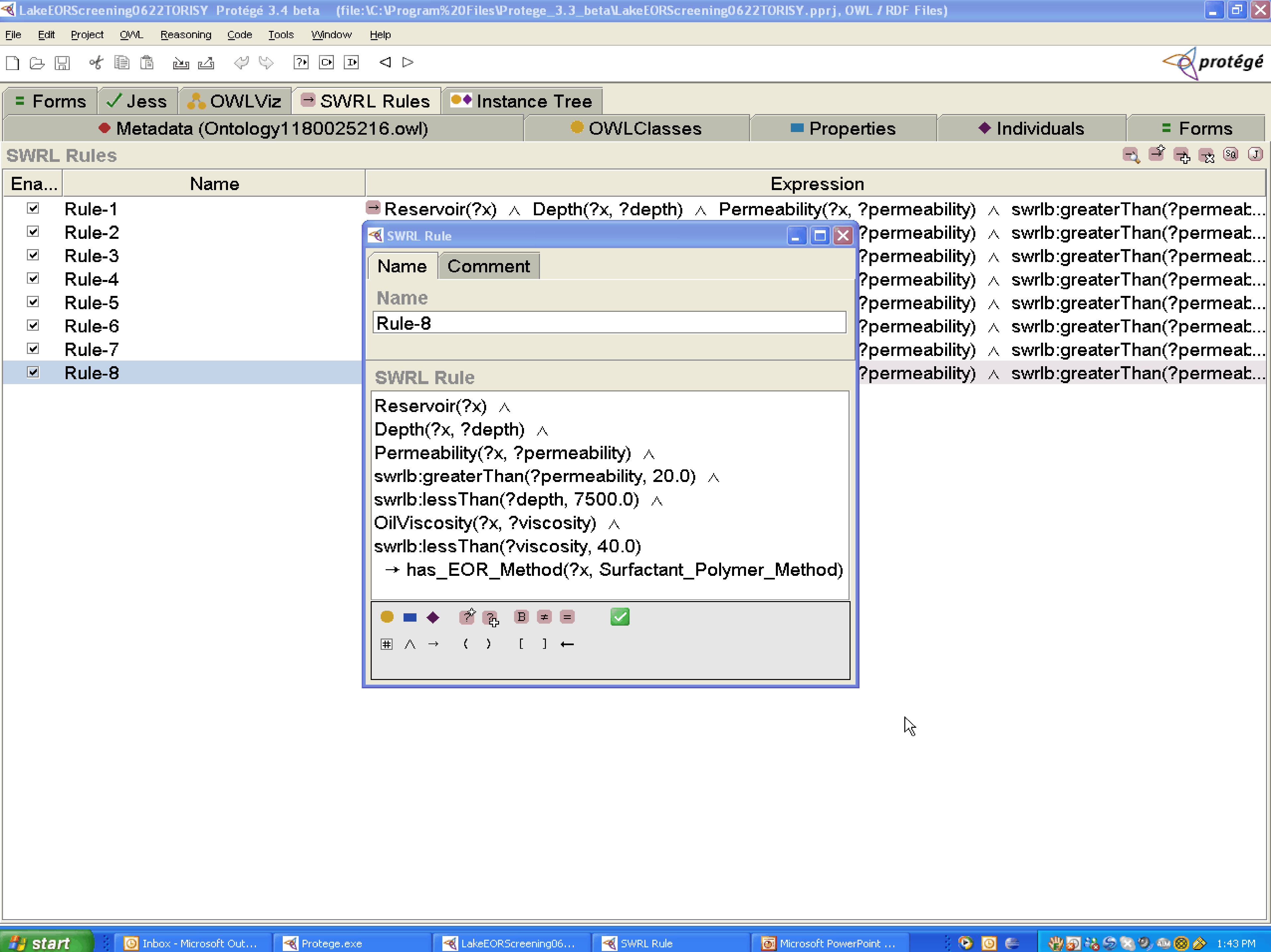
Ena...
Name
Expression
Rule-1
Rule-2
Rule-3
Rule-4
Rule-5
Rule-6
Rule-7
Rule-8
Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
SWRL Rule
Name
Comment
Name
Rule-4
SWRL Rule
Reservoir(?x) ∧
Depth(?x, ?depth) ∧
Permeability(?x, ?permeability) ∧
swrlb:greaterThan(?permeability, 0.0) ∧
swrlb:greaterThan(?depth, 5000.0) ∧
OilViscosity(?x, ?viscosity) ∧
swrlb:lessThan(?viscosity, 10.0)
→ has_EOR_Method(?x, HC-Misc_Method)
start
Inbox - Microsoft Out...
Protege.exe
LakeEORScreening06...
SWRL Rule
Microsoft PowerPoint ...
1:43 PM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protégé
Forms Jess OWLViz SWRL Rules Instance Tree
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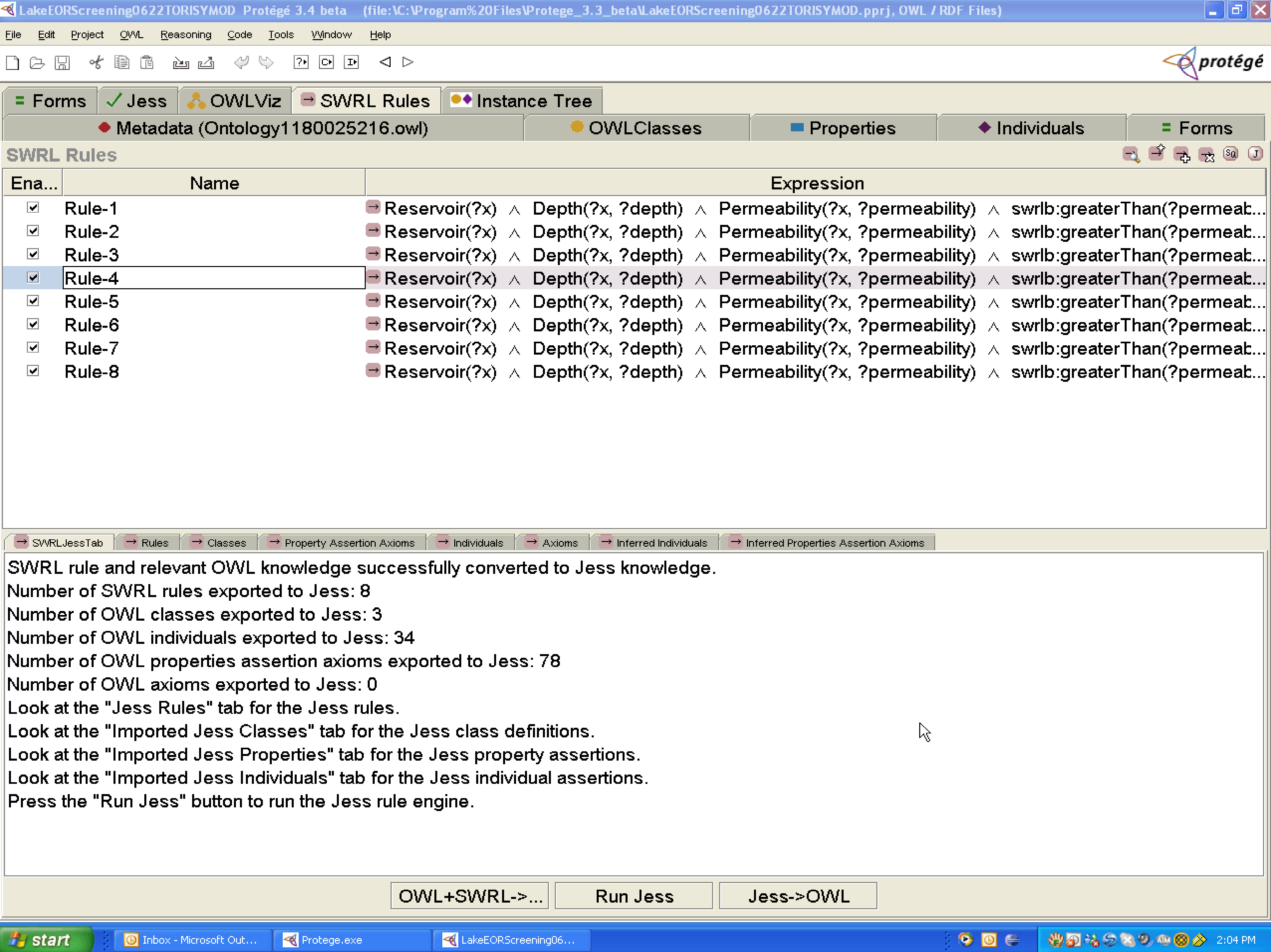
SWRL Rules
Ena... Name Expression
Rule-1 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeat...
Rule-2
Rule-3
Rule-4
Rule-5
Rule-6
Rule-7
Rule-8
SWRL Rule
Name Comment
Name
Rule-8
SWRL Rule
Reservoir(?x) ∧
Depth(?x, ?depth) ∧
Permeability(?x, ?permeability) ∧
swrlb:greaterThan(?permeability, 20.0) ∧
swrlb:lessThan(?depth, 7500.0) ∧
OilViscosity(?x, ?viscosity) ∧
swrlb:lessThan(?viscosity, 40.0)
→ has_EOR_Method(?x, Surfactant_Polymer_Method)
start Inbox - Microsoft Out... Protege.exe LakeEORScreening06... SWRL Rule Microsoft PowerPoint ... 1:43 PM


LakeEORScreening0622TORISYMOD Protégé 3.4 beta (file:\C:\Program%20Files\Protege_3.3_beta\LakeEORScreening0622TORISYMOD.pprj, OWL / RDF Files)
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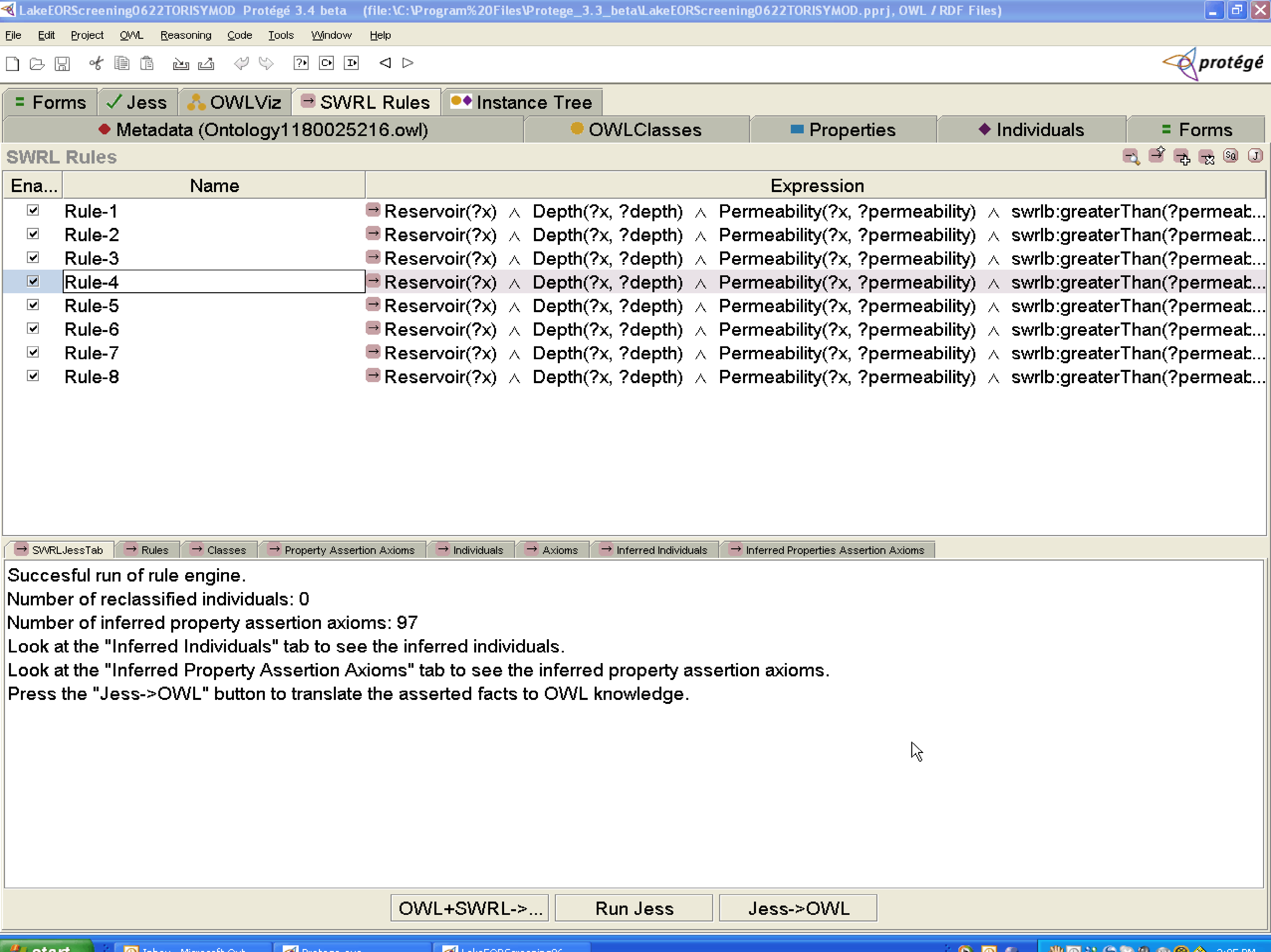
SWRL Rules
Ena...
Name
Expression
Rule-1 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-2 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-3 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-4 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-5 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-6 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-7 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-8 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
SWRLJessTab
Rules
Classes
Property Assertion Axioms
Individuals
Axioms
Inferred Individuals
Inferred Properties Assertion Axioms
SWRL rule and relevant OWL knowledge successfully converted to Jess knowledge.
Number of SWRL rules exported to Jess: 8
Number of OWL classes exported to Jess: 3
Number of OWL individuals exported to Jess: 34
Number of OWL properties assertion axioms exported to Jess: 78
Number of OWL axioms exported to Jess: 0
Look at the "Jess Rules" tab for the Jess rules.
Look at the "Imported Jess Classes" tab for the Jess class definitions.
Look at the "Imported Jess Properties" tab for the Jess property assertions.
Look at the "Imported Jess Individuals" tab for the Jess individual assertions.
Press the "Run Jess" button to run the Jess rule engine.
OWL+SWRL->...
Run Jess
Jess->OWL
start
Inbox - Microsoft Out...
Protege.exe
LakeEORScreening06...
2:04 PM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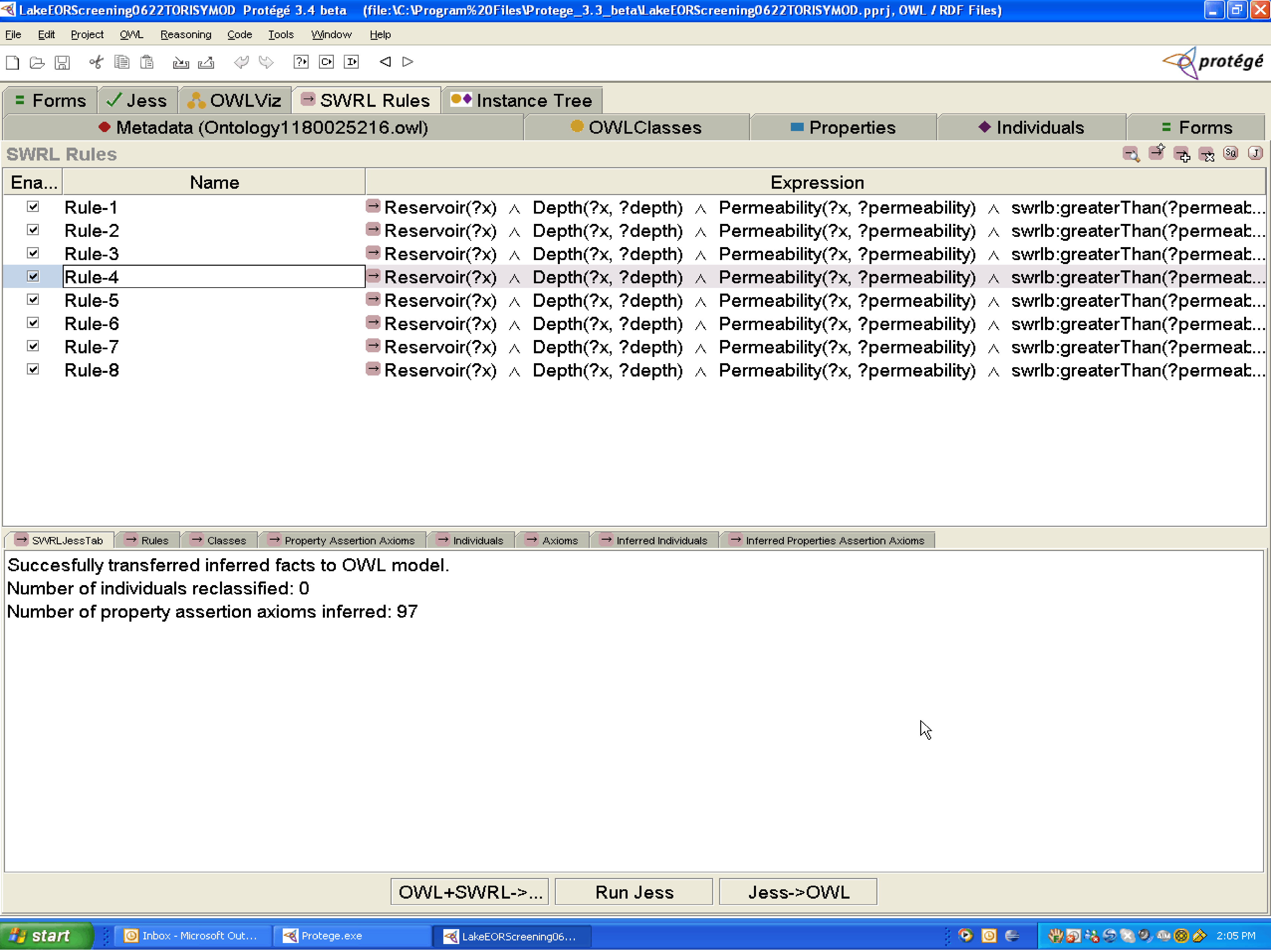
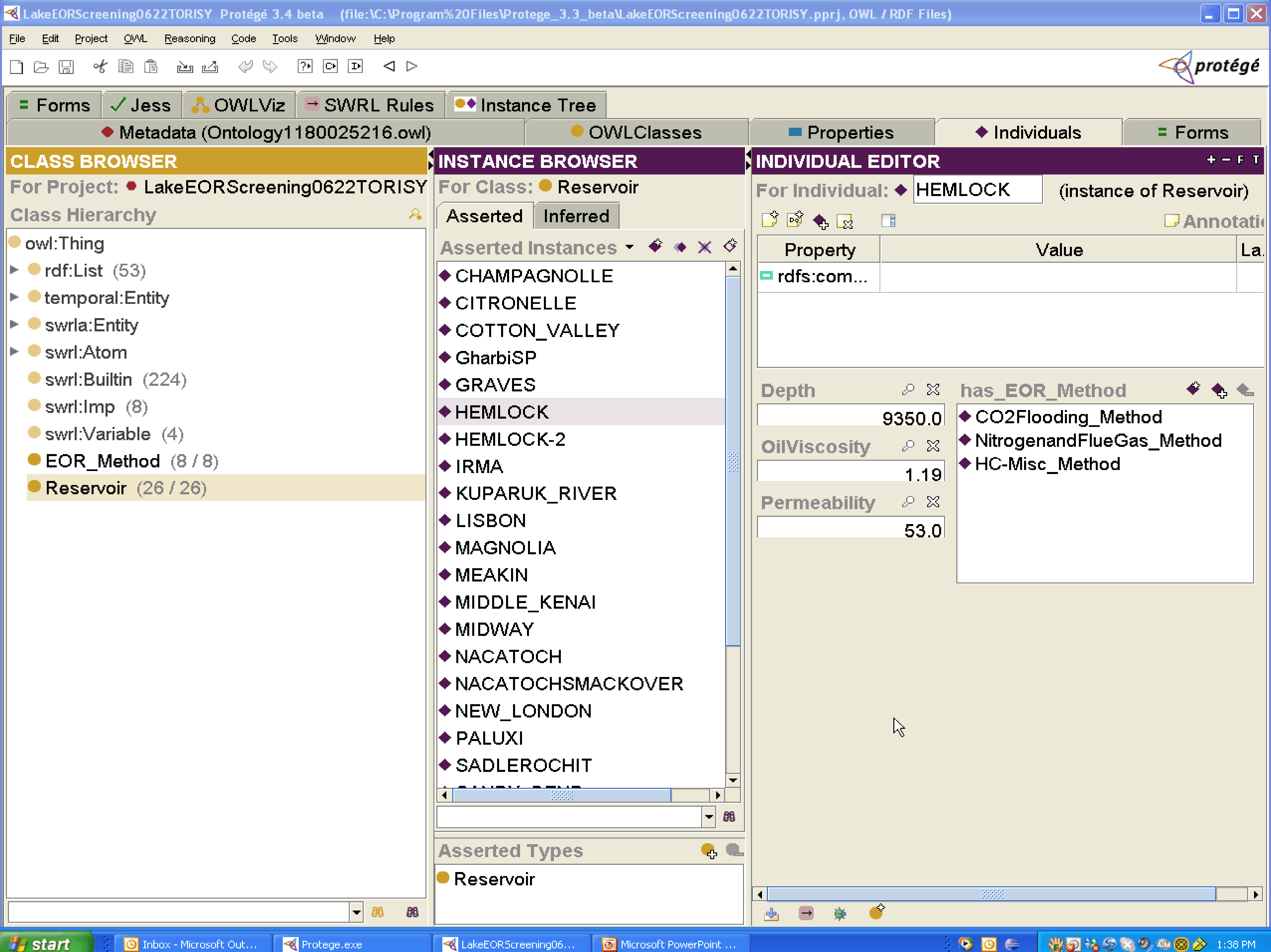
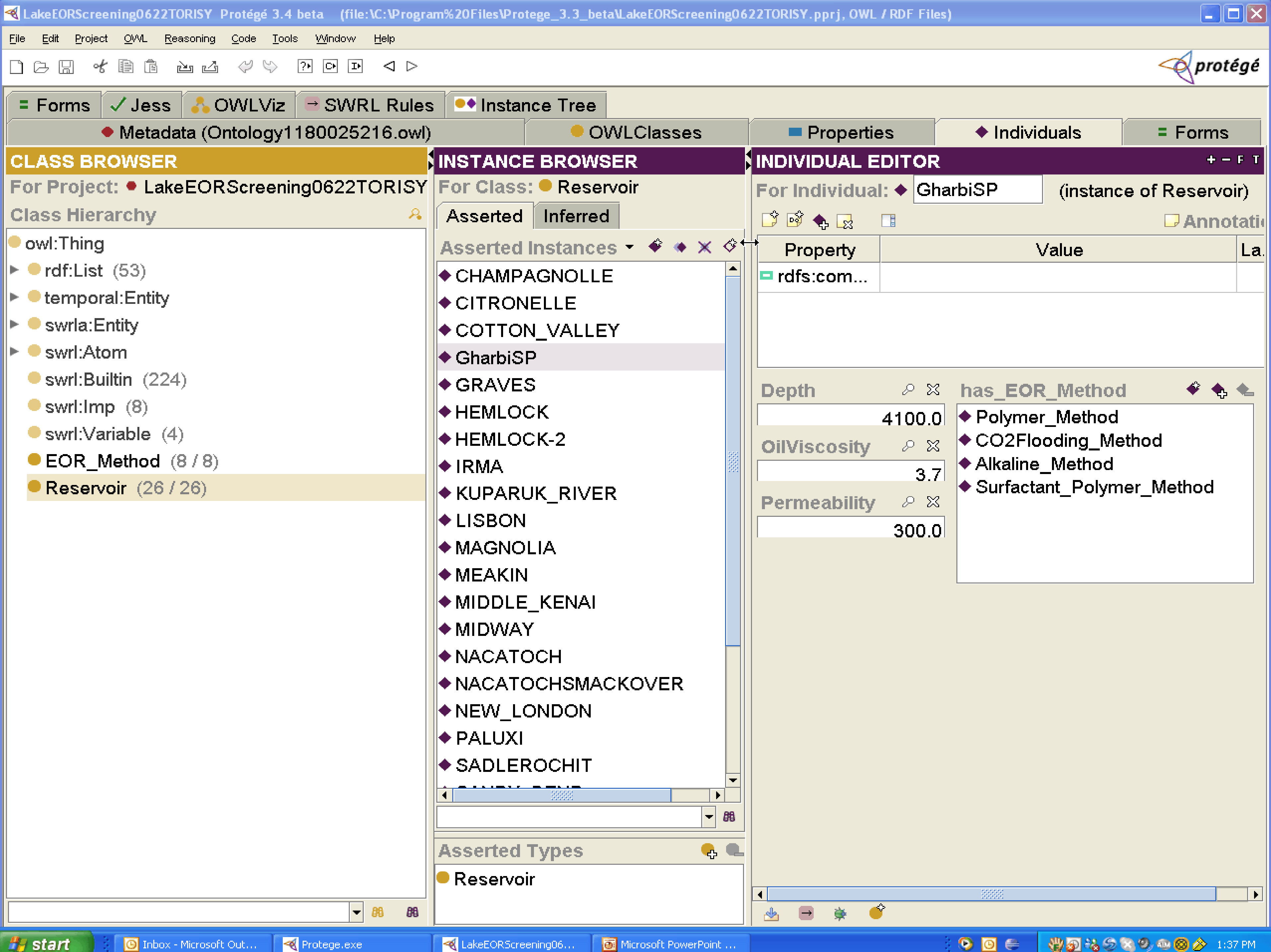
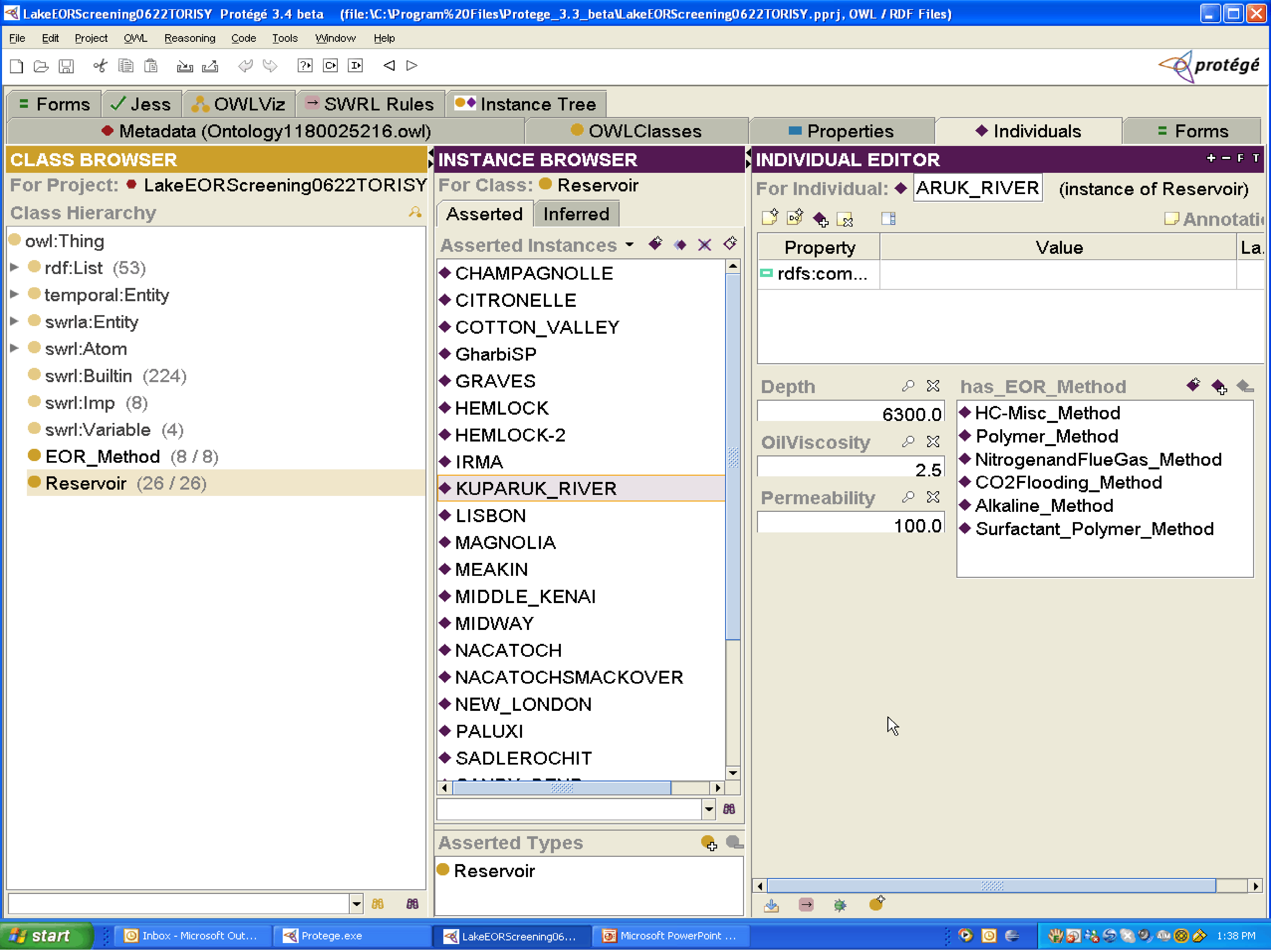
File Edit Project OWL Reasoning Code Tools Window Help
protégé
Forms Jess OWLViz SWRL Rules Instance Tree
Metadata (Ontology1180025216.owl) OWLClasses Properties Individuals Forms
SWRL Rules
Ena... Name Expression
Rule-1 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-2 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-3 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-4 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-5 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-6 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-7 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-8 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
SWRLJessTab Rules Classes Property Assertion Axioms Individuals Axioms Inferred Individuals Inferred Properties Assertion Axioms
Succesful run of rule engine.
Number of reclassified individuals: 0
Number of inferred property assertion axioms: 97
Look at the "Inferred Individuals" tab to see the inferred individuals.
Look at the "Inferred Property Assertion Axioms" tab to see the inferred property assertion axioms.
Press the "Jess->OWL" button to translate the asserted facts to OWL knowledge.
OWL+SWRL->...
Run Jess
Jess->OWL


LakeEORScreening0622TORISYMOD Protégé 3.4 beta (file:\C:\Program%20Files\Protege_3.3_beta\LakeEORScreening0622TORISYMOD.pprj, OWL / RDF Files)
File Edit Project OWL Reasoning Code Tools Window Help
protégé
Forms Jess OWLViz SWRL Rules Instance Tree
Metadata (Ontology1180025216.owl) OWLClasses Properties Individuals Forms
SWRL Rules
Ena... Name Expression
Rule-1 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-2 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-3 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-4 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-5 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-6 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-7 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
Rule-8 Reservoir(?x) ∧ Depth(?x, ?depth) ∧ Permeability(?x, ?permeability) ∧ swrlb:greaterThan(?permeab...
SWRLJessTab Rules Classes Property Assertion Axioms Individuals Axioms Inferred Individuals Inferred Properties Assertion Axioms
Succesfully transferred inferred facts to OWL model.
Number of individuals reclassified: 0
Number of property assertion axioms inferred: 97
OWL+SWRL->... Run Jess Jess->OWL
start Inbox - Microsoft Out... Protege.exe LakeEORScreening06...
2:05 PM


LakeEORScreening0622TORISY Protégé 3.4 beta (file:\C:\Program%20Files\Protege_3.3_beta\LakeEORScreening0622TORISY.pprj, OWL / RDF Files)
File Edit Project OWL Reasoning Code Tools Window Help
protégé
Forms
Jess
OWLViz
SWRL Rules
Instance Tree
Metadata (Ontology1180025216.owl)
OWLClasses
Properties
Individuals
Forms
CLASS BROWSER
For Project: LakeEORScreening0622TORISY
Class Hierarchy
owl:Thing
rdf:List (53)
temporal:Entity
swrla:Entity
swrl:Atom
swrl:Builtin (224)
swrl:Imp (8)
swrl:Variable (4)
EOR_Method (8 / 8)
Reservoir (26 / 26)
INSTANCE BROWSER
For Class: Reservoir
Asserted
Inferred
Asserted Instances
CHAMPAGNOLLE
CITRONELLE
COTTON_VALLEY
GharbiSP
GRAVES
HEMLOCK
HEMLOCK-2
IRMA
KUPARUK_RIVER
LISBON
MAGNOLIA
MEAKIN
MIDDLE_KENAI
MIDWAY
NACATOCH
NACATOCHSMACKOVER
NEW_LONDON
PALUXI
SADLEROCHIT
Asserted Types
Reservoir
INDIVIDUAL EDITOR
For Individual: HEMLOCK
(instance of Reservoir)
Annotati
Property
Value
La
rdfs:com...
Depth
9350.0
OilViscosity
1.19
Permeability
53.0
has_EOR_Method
CO2Flooding_Method
NitrogenandFlueGas_Method
HC-Misc_Method
start
Inbox - Microsoft Out...
Protege.exe
LakeEORScreening06...
Microsoft PowerPoint ...
1:38 PM


LakeEORScreening0622TORISY Protégé 3.4 beta (file:\C:\Program%20Files\Protege_3.3_beta\LakeEORScreening0622TORISY.pprj, OWL / RDF Files)
File Edit Project OWL Reasoning Code Tools Window Help
protégé
Forms
Jess
OWLViz
SWRL Rules
Instance Tree
Metadata (Ontology1180025216.owl)
OWLClasses
Properties
Individuals
Forms
CLASS BROWSER
For Project: LakeEORScreening0622TORISY
Class Hierarchy
owl:Thing
rdf:List (53)
temporal:Entity
swrla:Entity
swrl:Atom
swrl:Builtin (224)
swrl:Imp (8)
swrl:Variable (4)
EOR_Method (8 / 8)
Reservoir (26 / 26)
INSTANCE BROWSER
For Class: Reservoir
Asserted
Inferred
Asserted Instances
CHAMPAGNOLLE
CITRONELLE
COTTON_VALLEY
GharbiSP
GRAVES
HEMLOCK
HEMLOCK-2
IRMA
KUPARUK_RIVER
LISBON
MAGNOLIA
MEAKIN
MIDDLE_KENAI
MIDWAY
NACATOCH
NACATOCHSMACKOVER
NEW_LONDON
PALUXI
SADLEROCHIT
Asserted Types
Reservoir
INDIVIDUAL EDITOR
For Individual: GharbiSP (instance of Reservoir)
Annotati
Property
Value
La
rdfs:com...
Depth
4100.0
OilViscosity
3.7
Permeability
300.0
has_EOR_Method
Polymer_Method
CO2Flooding_Method
Alkaline_Method
Surfactant_Polymer_Method
start
Inbox - Microsoft Out...
Protege.exe
LakeEORScreening06...
Microsoft PowerPoint ...
1:37 PM

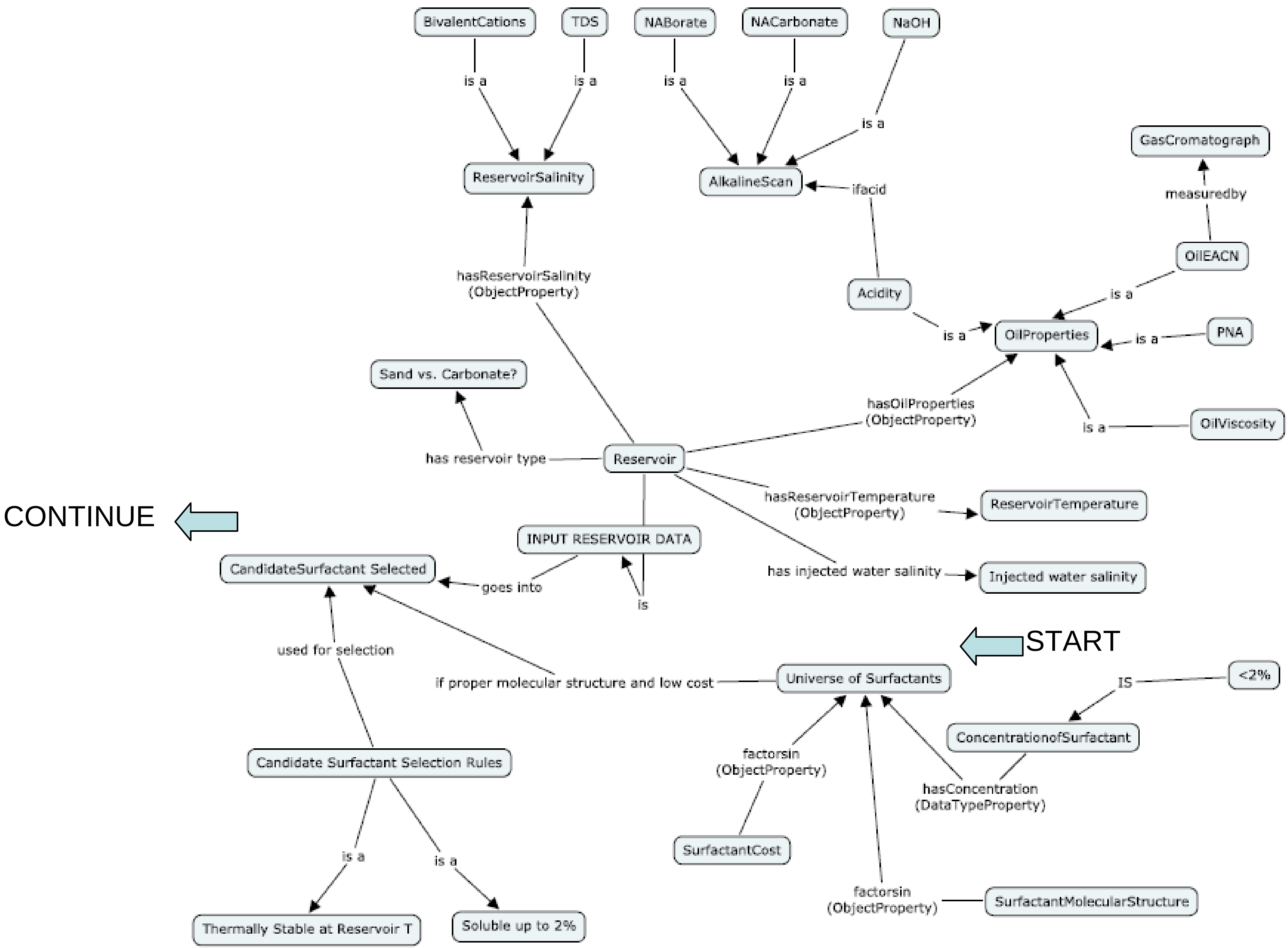


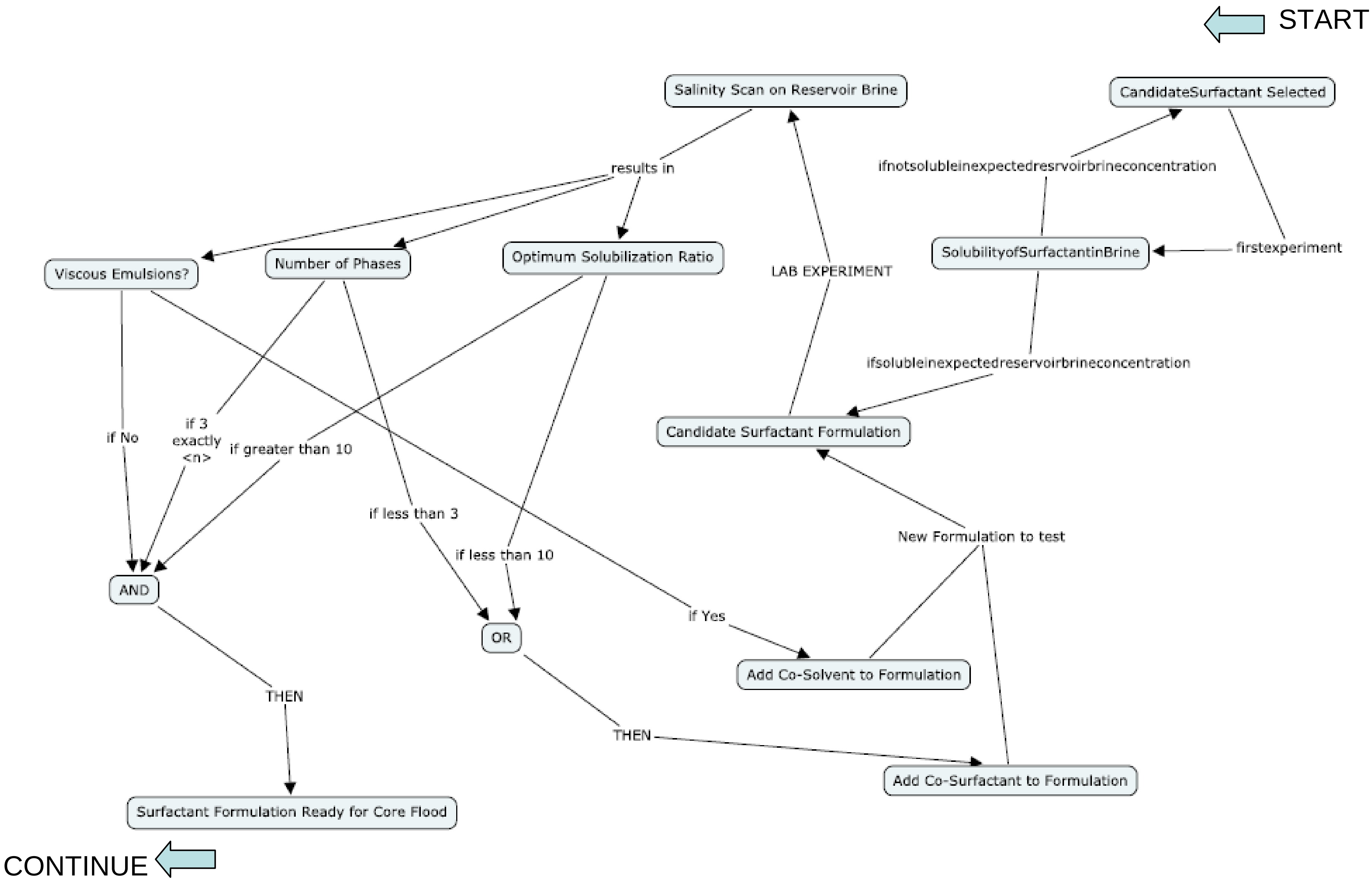
LakeEORScreening0622TORISY Protégé 3.4 beta (file:\C:\Program%20Files\Protege_3.3_beta\LakeEORScreening0622TORISY.pprj, OWL / RDF Files)
File Edit Project OWL Reasoning Code Tools Window Help
protégé
Forms
Jess
OWLViz
SWRL Rules
Instance Tree
Metadata (Ontology1180025216.owl)
OWLClasses
Properties
Individuals
Forms
CLASS BROWSER
For Project: LakeEORScreening0622TORISY
Class Hierarchy
owl:Thing
rdf:List (53)
temporal:Entity
swrla:Entity
swrl:Atom
swrl:Builtin (224)
swrl:Imp (8)
swrl:Variable (4)
EOR_Method (8 / 8)
Reservoir (26 / 26)
INSTANCE BROWSER
For Class: Reservoir
Asserted
Inferred
Asserted Instances
CHAMPAGNOLLE
CITRONELLE
COTTON_VALLEY
GharbiSP
GRAVES
HEMLOCK
HEMLOCK-2
IRMA
KUPARUK_RIVER
LISBON
MAGNOLIA
MEAKIN
MIDDLE_KENAI
MIDWAY
NACATOCH
NACATOCHSMACKOVER
NEW_LONDON
PALUXI
SADLEROCHIT
Asserted Types
Reservoir
INDIVIDUAL EDITOR
For Individual: ARUK_RIVER (instance of Reservoir)
Annotati
Property
Value
La
rdfs:com...
Depth
6300.0
OilViscosity
2.5
Permeability
100.0
has_EOR_Method
HC-Misc_Method
Polymer_Method
NitrogenandFlueGas_Method
CO2Flooding_Method
Alkaline_Method
Surfactant_Polymer_Method
start
Inbox - Microsoft Out...
Protege.exe
LakeEORScreening06...
Microsoft PowerPoint ...
1:38 PM

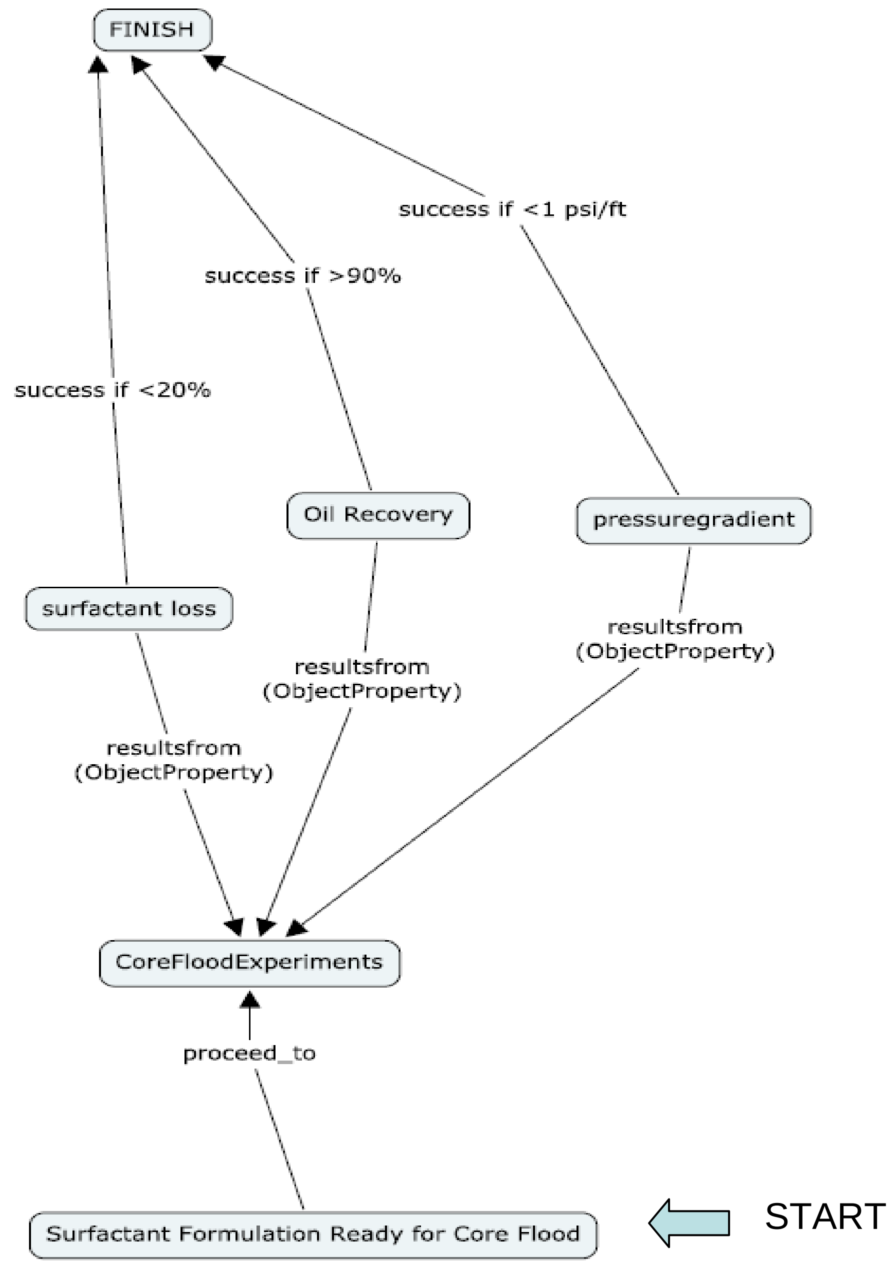
EOR Screening Ontology Pilot – Summary

- Use of SWRL.
- Use of Expert System Engine (JESS)
- Large numbers of reservoirs screened at once
- Relatively simple structure in ontology

Surfactant Selection Workflow

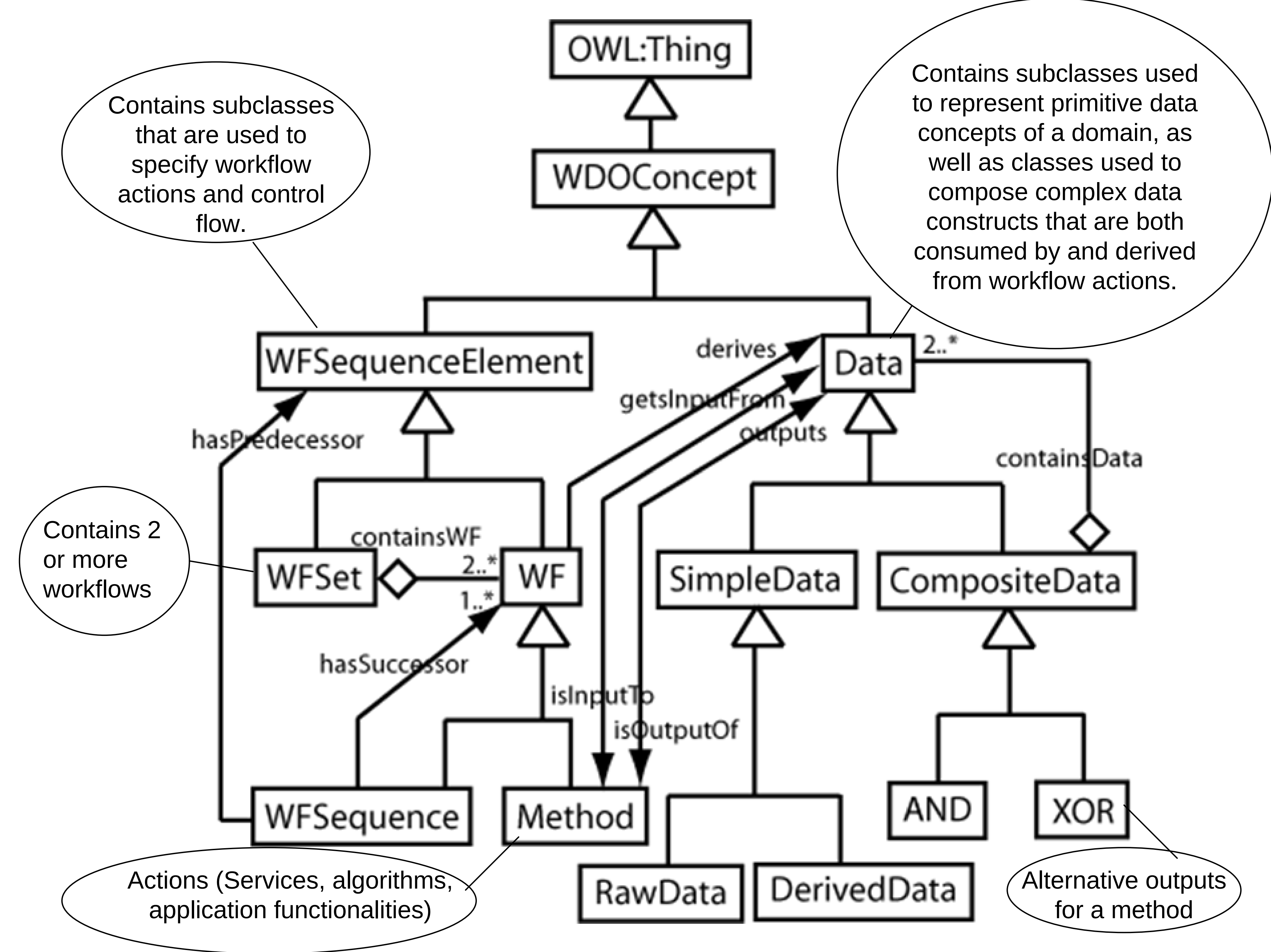

BivalentCations
TDS
NABorate
NACarbonate
NaOH
is a
ReservoirSalinity
AlkalineScan
ifacid
GasCromatograph
measuredby
OilEACN
Acidity
OilProperties
PNA
OilViscosity
hasReservoirSalinity (ObjectProperty)
Sand vs. Carbonate?
has reservoir type
Reservoir
hasOilProperties (ObjectProperty)
hasReservoirTemperature (ObjectProperty)
ReservoirTemperature
has injected water salinity
Injected water salinity
CONTINUE
INPUT RESERVOIR DATA
CandidateSurfactant Selected
goes into
is
START
used for selection
if proper molecular structure and low cost
Universe of Surfactants
IS
<2%
ConcentrationofSurfactant
factorsin (ObjectProperty)
hasConcentration (DataTypeProperty)
Candidate Surfactant Selection Rules
SurfactantCost
Thermally Stable at Reservoir T
Soluble up to 2%
SurfactantMolecularStructure


START
Salinity Scan on Reservoir Brine
CandidateSurfactant Selected
results in
ifnotsolubleinexpectedresrvoirbrineconcentration
firstexperiment
Viscous Emulsions?
Number of Phases
Optimum Solubilization Ratio
LAB EXPERIMENT
SolubilityofSurfactantinBrine
ifsolubleinexpectedreservoirbrineconcentration
Candidate Surfactant Formulation
if No
if 3 exactly <n>
if greater than 10
if less than 3
New Formulation to test
if less than 10
AND
OR
if Yes
Add Co-Solvent to Formulation
THEN
THEN
Add Co-Surfactant to Formulation
Surfactant Formulation Ready for Core Flood
CONTINUE


FINISH
success if <20%
success if >90%
success if <1 psi/ft
Oil Recovery
pressuregradient
surfactant loss
resultsfrom (ObjectProperty)
resultsfrom (ObjectProperty)
resultsfrom (ObjectProperty)
CoreFloodExperiments
proceed_to
Surfactant Formulation Ready for Core Flood
START

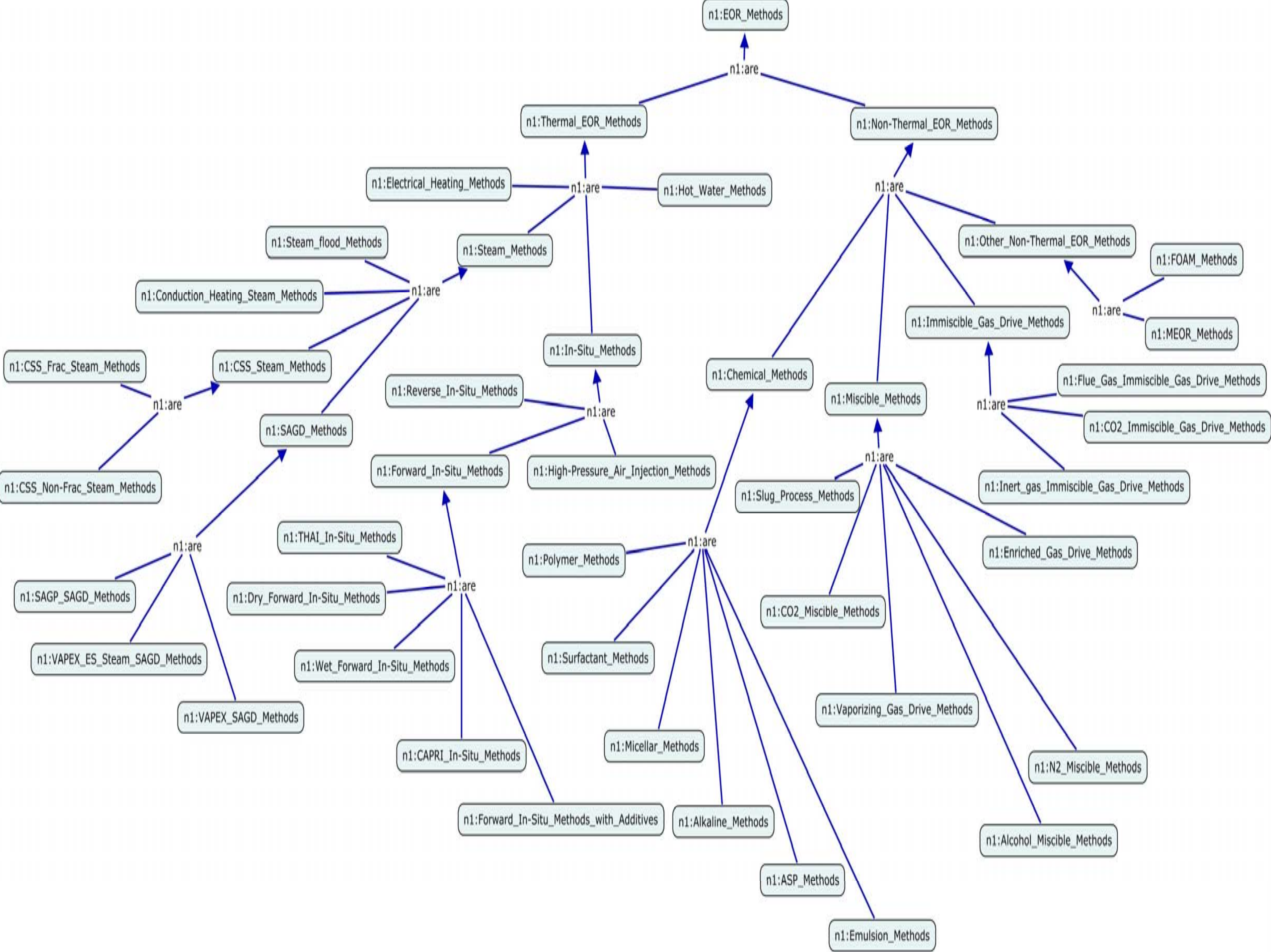
Workflow Driven Ontologies (WDO)

Leonardo Salayandía, University of Texas at El Paso

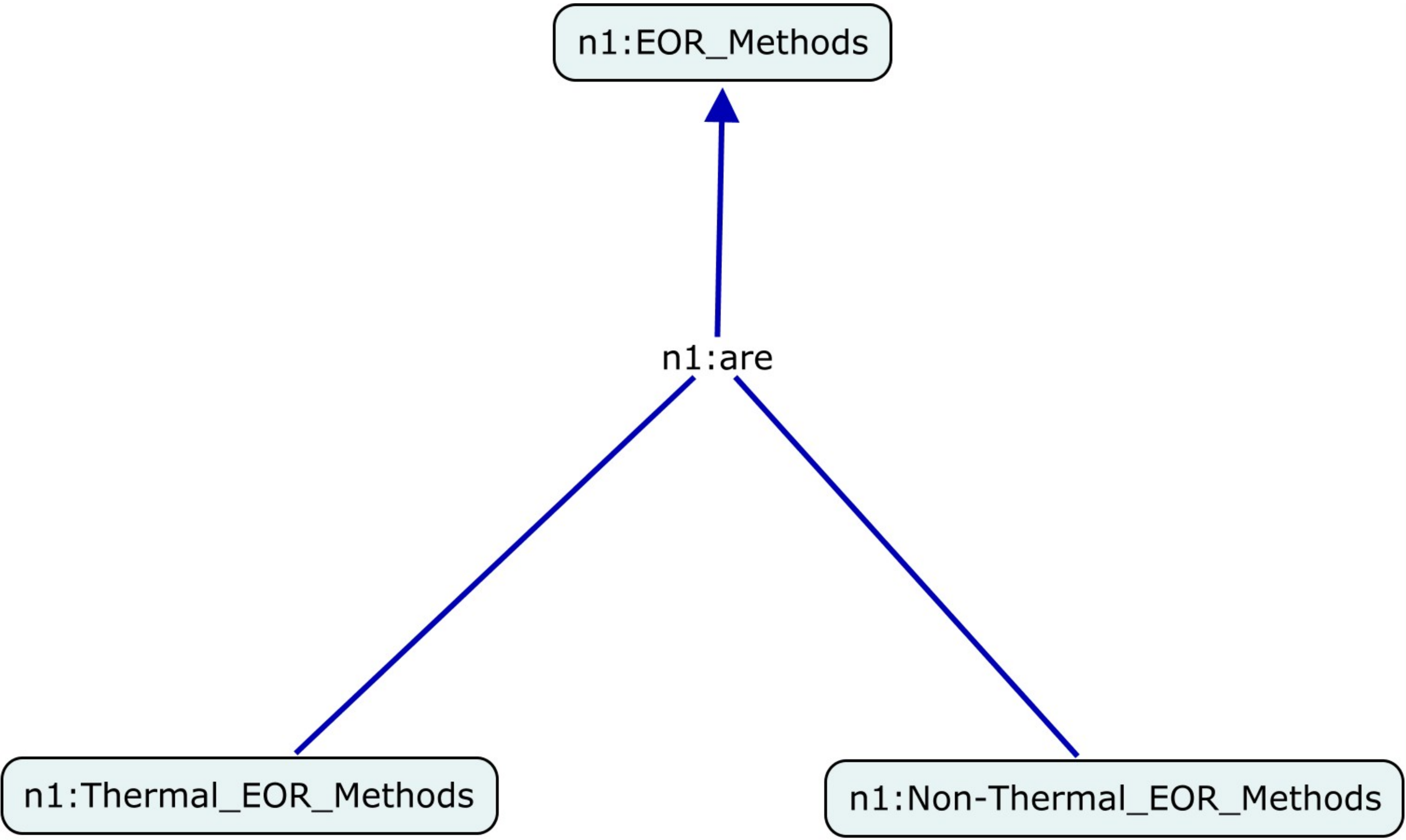


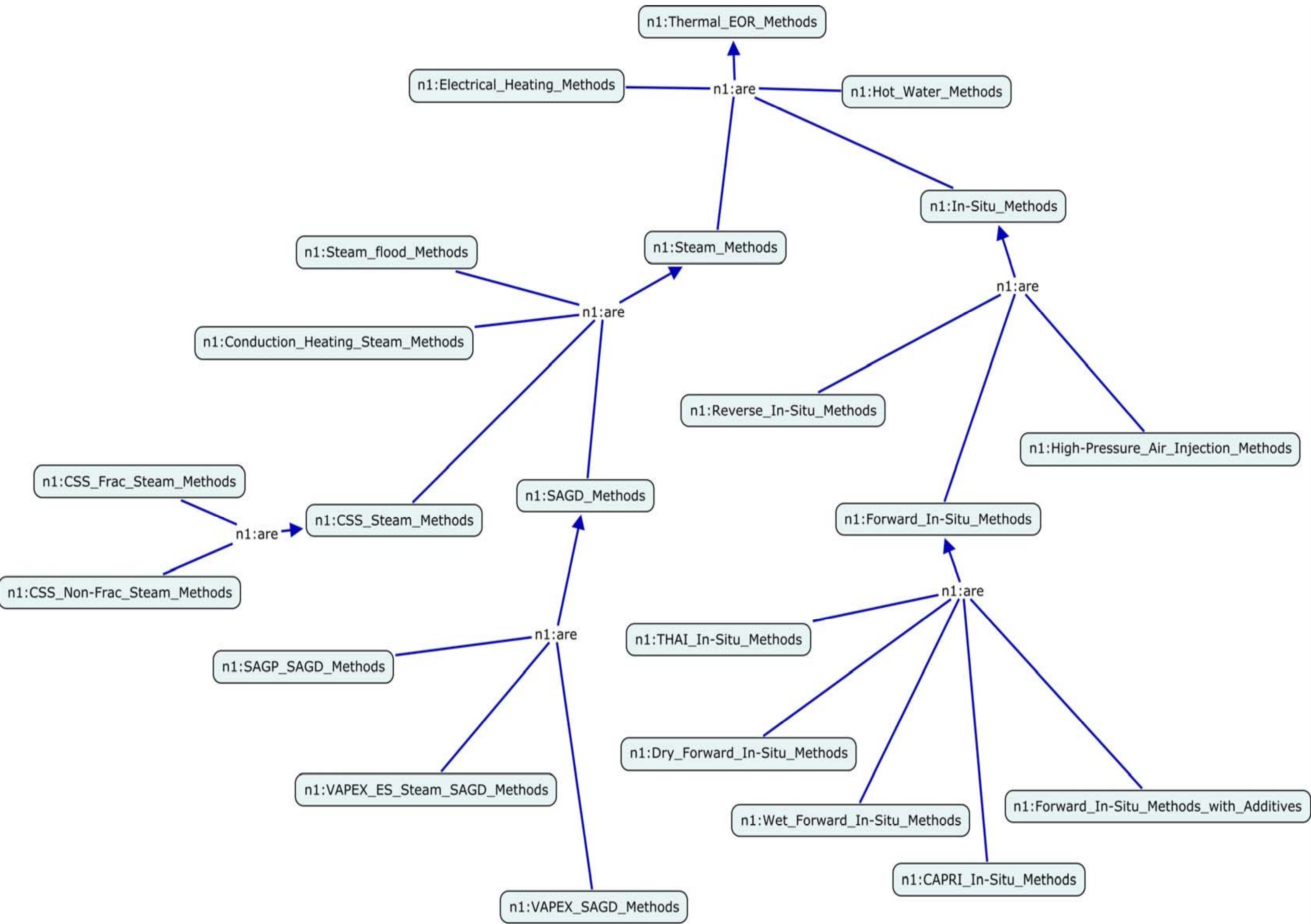
OWL:Thing
WDOConcept
Contains subclasses that are used to specify workflow actions and control flow.
Contains subclasses used to represent primitive data concepts of a domain, as well as classes used to compose complex data constructs that are both consumed by and derived from workflow actions.
WFSequenceElement
Data
derives
getsInputFrom
outputs
2..*
containsData
hasPredecessor
Contains 2 or more workflows
WFSet
containsWF
2..*
1..*
WF
SimpleData
CompositeData
hasSuccessor
isInputTo
isOutputOf
WFSequence
Method
AND
XOR
RawData
DerivedData
Actions (Services, algorithms, application functionalities)
Alternative outputs for a method

EOR General Ontology with Chemicals

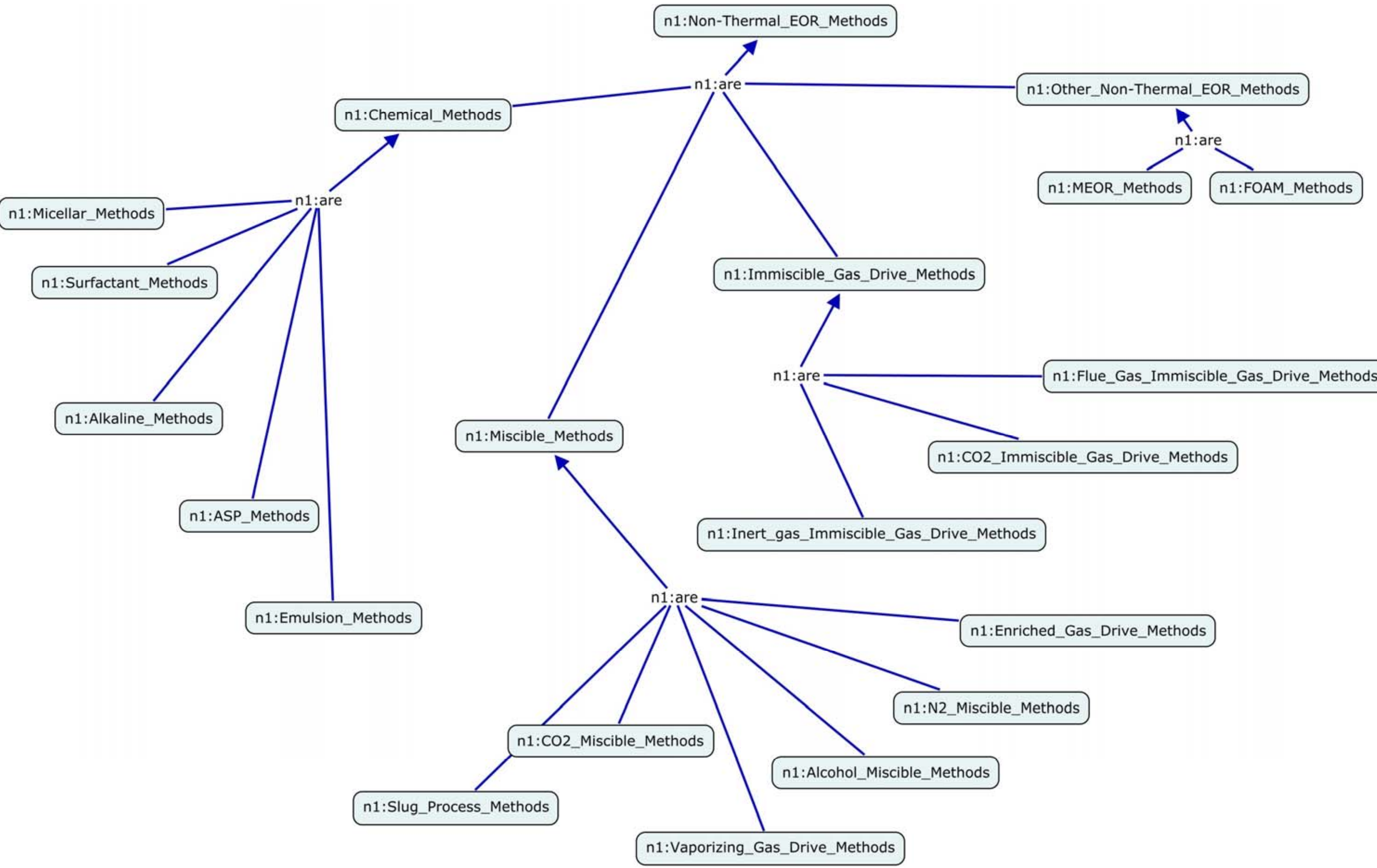


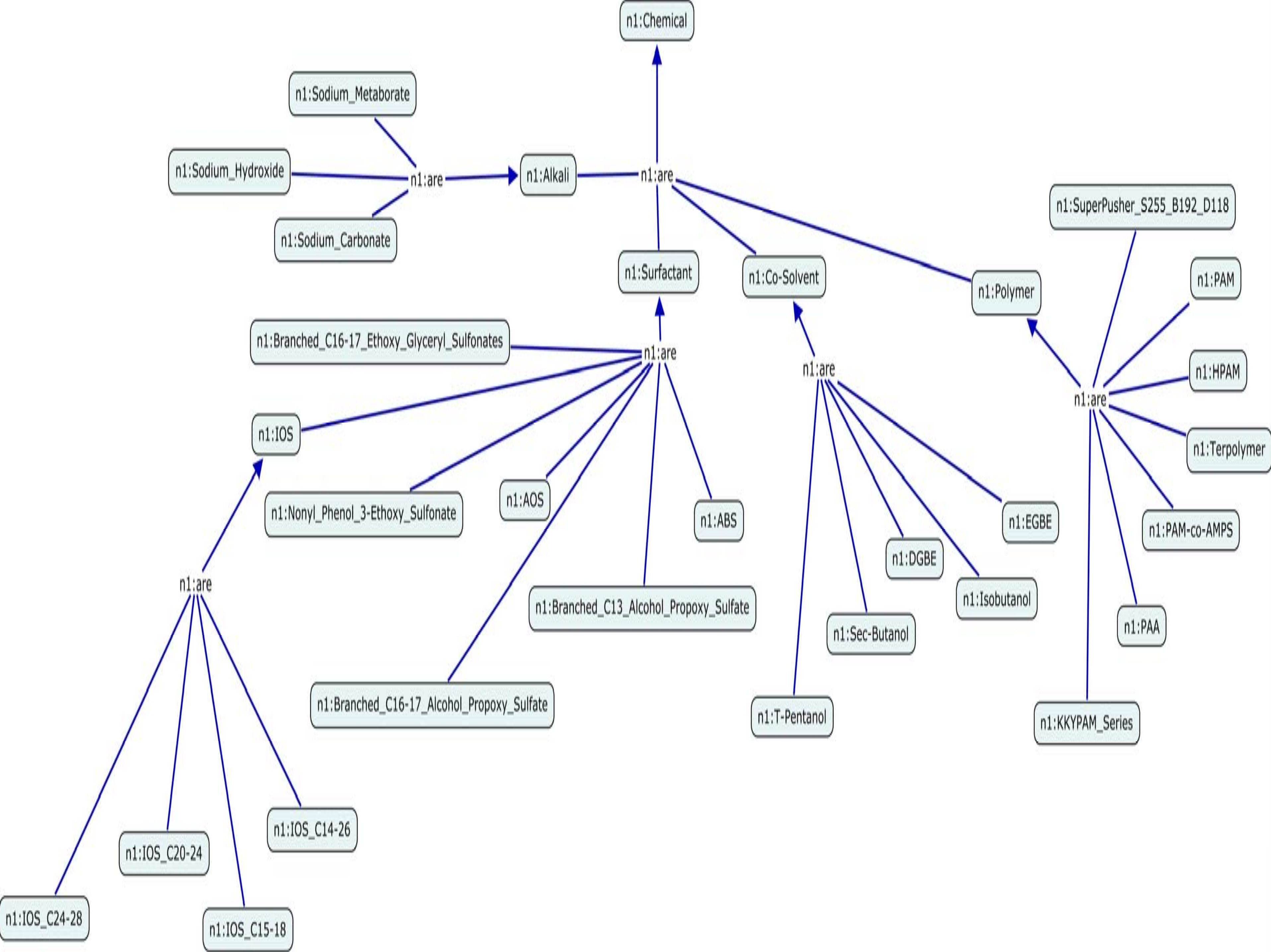
n1:EOR_Methods
n1:are
n1:Thermal_EOR_Methods
n1:Non-Thermal_EOR_Methods
n1:Electrical_Heating_Methods
n1:are
n1:Hot_Water_Methods
n1:are
n1:Steam_flood_Methods
n1:Steam_Methods
n1:Other_Non-Thermal_EOR_Methods
n1:FOAM_Methods
n1:Conduction_Heating_Steam_Methods
n1:are
n1:are
n1:Immiscible_Gas_Drive_Methods
n1:MEOR_Methods
n1:CSS_Frac_Steam_Methods
n1:CSS_Steam_Methods
n1:In-Situ_Methods
n1:Chemical_Methods
n1:Reverse_In-Situ_Methods
n1:Miscible_Methods
n1:Flue_Gas_Immiscible_Gas_Drive_Methods
n1:are
n1:are
n1:are
n1:SAGD_Methods
n1:CO2_Immiscible_Gas_Drive_Methods
n1:are
n1:Forward_In-Situ_Methods
n1:High-Pressure_Air_Injection_Methods
n1:CSS_Non-Frac_Steam_Methods
n1:Slug_Process_Methods
n1:Inert_gas_Immiscible_Gas_Drive_Methods
n1:are
n1:THAI_In-Situ_Methods
n1:are
n1:Polymer_Methods
n1:Enriched_Gas_Drive_Methods
n1:are
n1:SAGP_SAGD_Methods
n1:Dry_Forward_In-Situ_Methods
n1:CO2_Miscible_Methods
n1:VAPEX_ES_Steam_SAGD_Methods
n1:Surfactant_Methods
n1:Wet_Forward_In-Situ_Methods
n1:Vaporizing_Gas_Drive_Methods
n1:VAPEX_SAGD_Methods
n1:Micellar_Methods
n1:CAPRI_In-Situ_Methods
n1:N2_Miscible_Methods
n1:Forward_In-Situ_Methods_with_Additives
n1:Alkaline_Methods
n1:Alcohol_Miscible_Methods
n1:ASP_Methods
n1:Emulsion_Methods

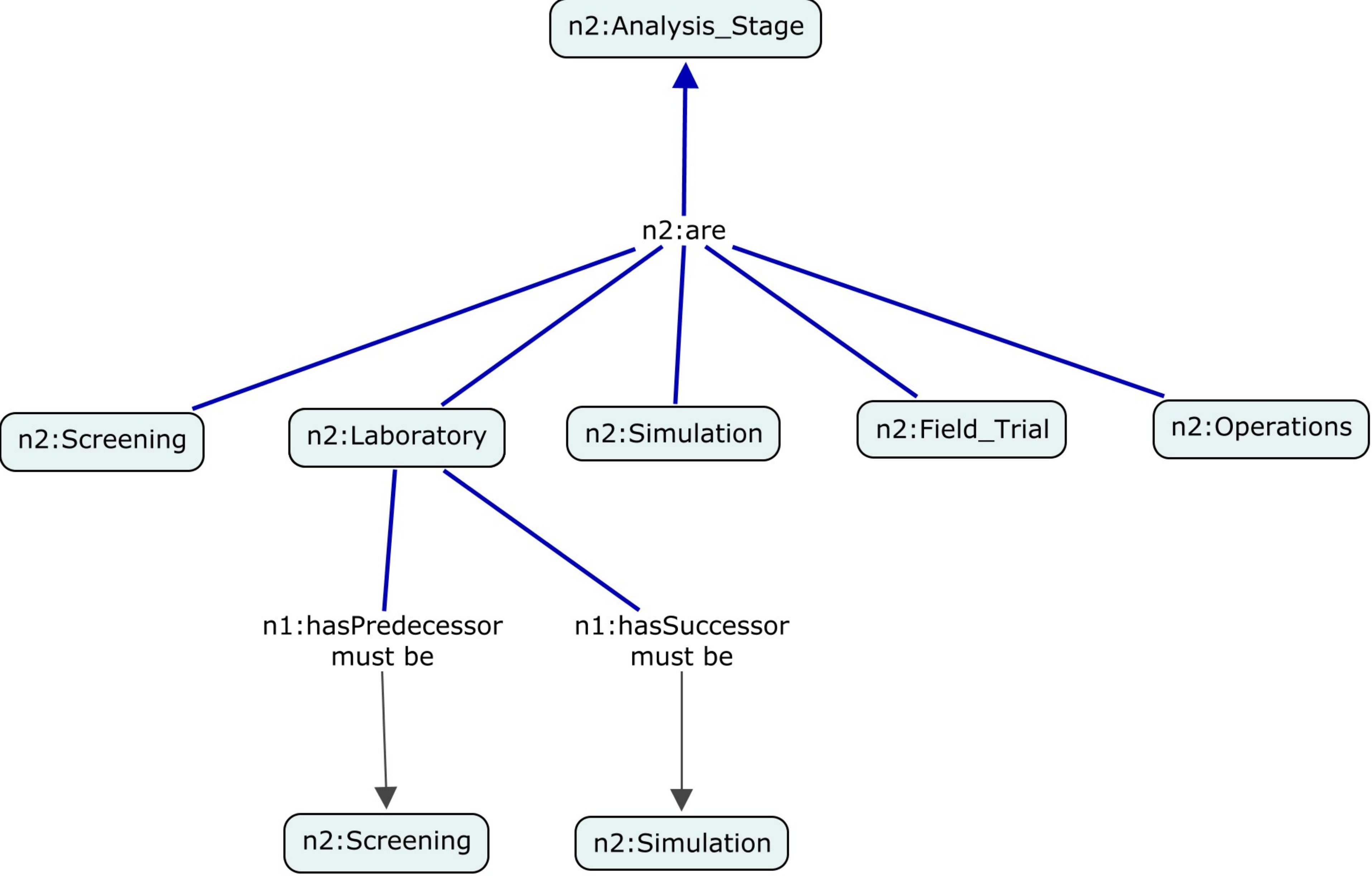

n1:EOR_Methods
n1:are
n1:Thermal_EOR_Methods
n1:Non-Thermal_EOR_Methods

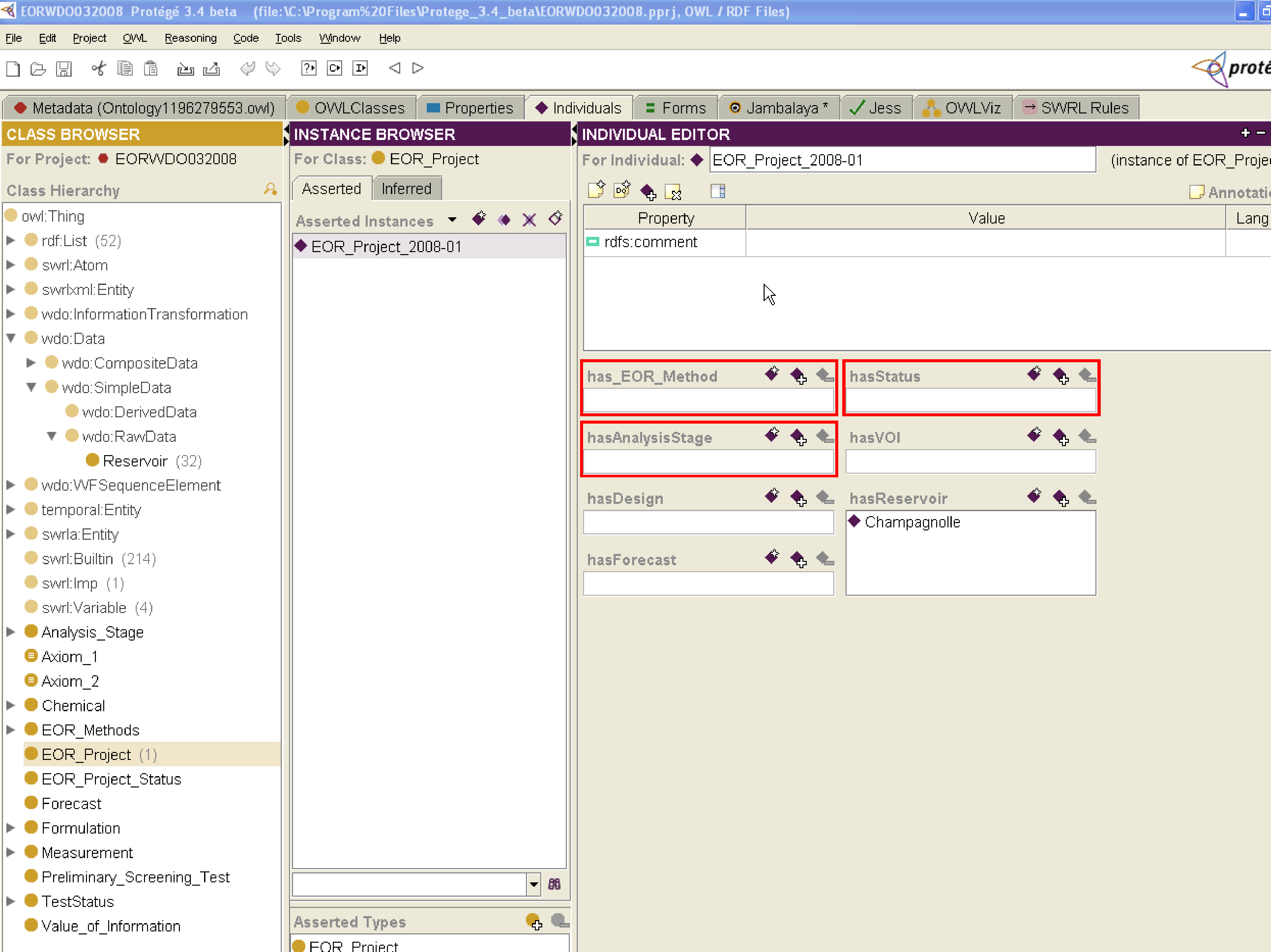


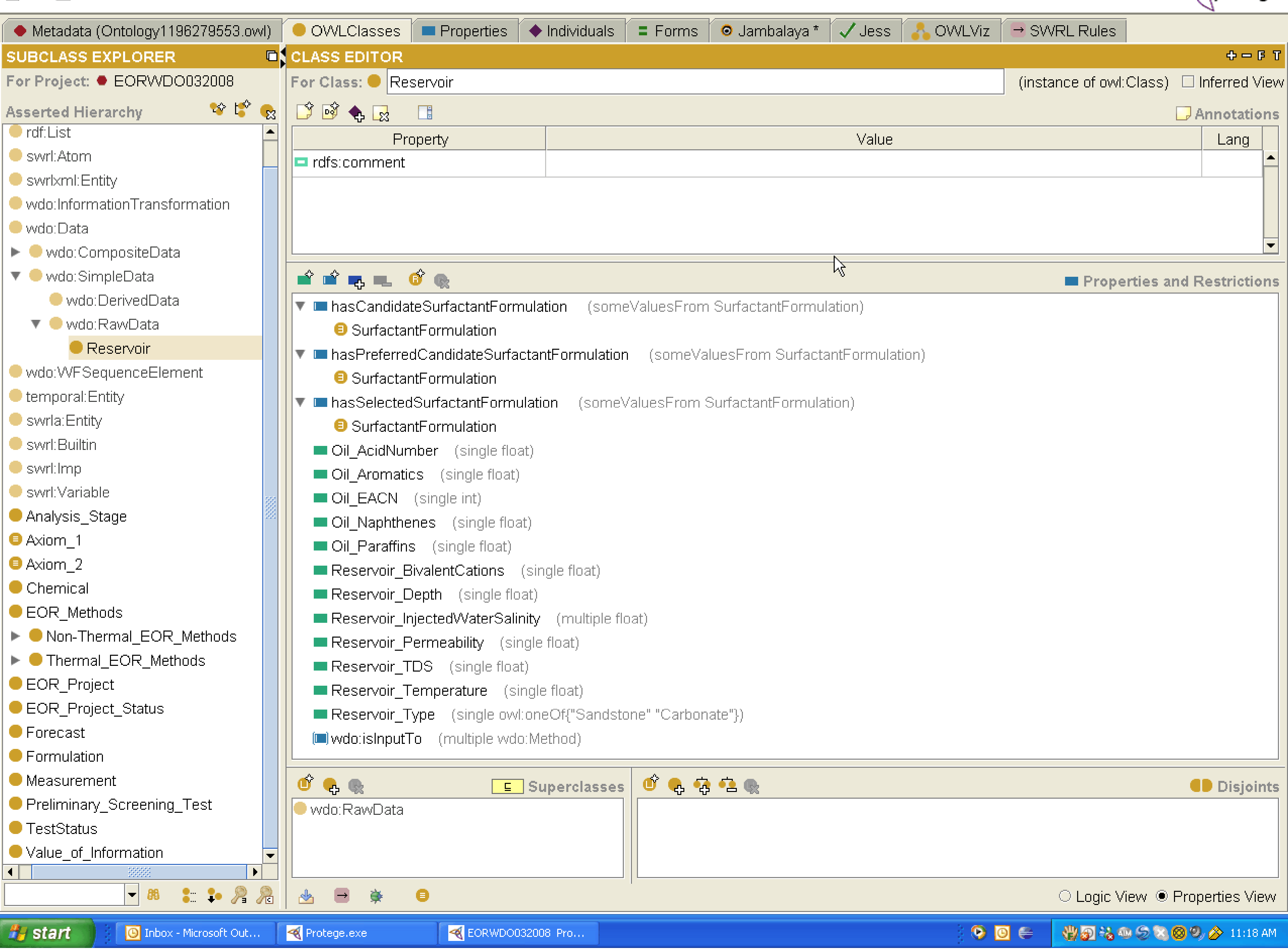
n1:Thermal_EOR_Methods
n1:Electrical_Heating_Methods
n1:are
n1:Hot_Water_Methods
n1:In-Situ_Methods
n1:Steam_flood_Methods
n1:Steam_Methods
n1:are
n1:Conduction_Heating_Steam_Methods
n1:are
n1:Reverse_In-Situ_Methods
n1:High-Pressure_Air_Injection_Methods
n1:CSS_Frac_Steam_Methods
n1:SAGD_Methods
n1:are
n1:CSS_Steam_Methods
n1:Forward_In-Situ_Methods
n1:CSS_Non-Frac_Steam_Methods
n1:are
n1:are
n1:THAI_In-Situ_Methods
n1:SAGP_SAGD_Methods
n1:Dry_Forward_In-Situ_Methods
n1:VAPEX_ES_Steam_SAGD_Methods
n1:Forward_In-Situ_Methods_with_Additives
n1:Wet_Forward_In-Situ_Methods
n1:CAPRI_In-Situ_Methods
n1:VAPEX_SAGD_Methods


n1:Non-Thermal_EOR_Methods
n1:are
n1:Chemical_Methods
n1:Other_Non-Thermal_EOR_Methods
n1:are
n1:MEOR_Methods
n1:FOAM_Methods
n1:are
n1:Micellar_Methods
n1:Surfactant_Methods
n1:Alkaline_Methods
n1:ASP_Methods
n1:Emulsion_Methods
n1:Immiscible_Gas_Drive_Methods
n1:are
n1:Flue_Gas_Immiscible_Gas_Drive_Methods
n1:CO2_Immiscible_Gas_Drive_Methods
n1:Inert_gas_Immiscible_Gas_Drive_Methods
n1:Miscible_Methods
n1:are
n1:Enriched_Gas_Drive_Methods
n1:N2_Miscible_Methods
n1:CO2_Miscible_Methods
n1:Alcohol_Miscible_Methods
n1:Slug_Process_Methods
n1:Vaporizing_Gas_Drive_Methods

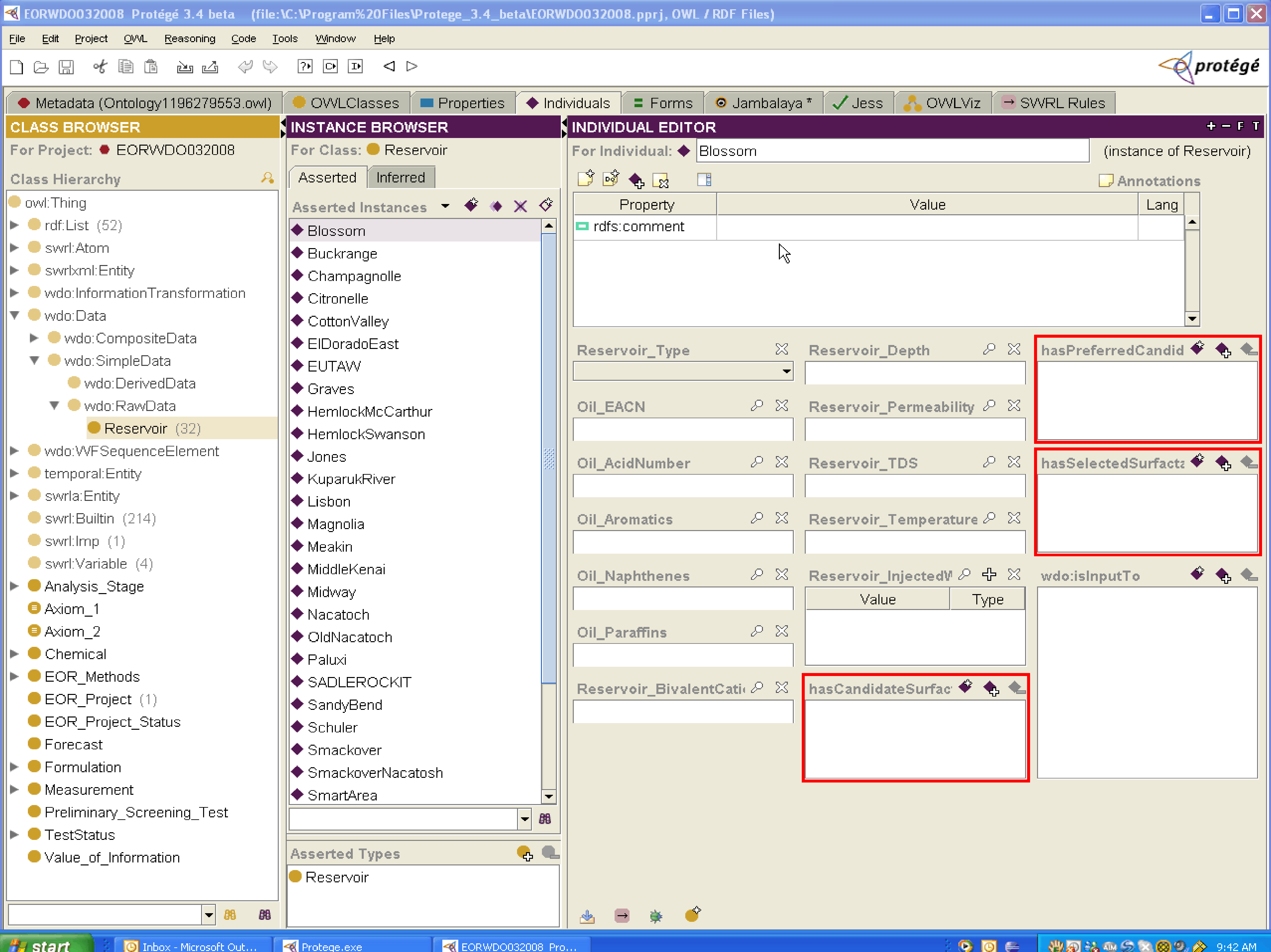

n1:Chemical
n1:Sodium_Metaborate
n1:Sodium_Hydroxide
n1:are
n1:Alkali
n1:are
n1:Sodium_Carbonate
n1:SuperPusher_S255_B192_D118
n1:Surfactant
n1:Co-Solvent
n1:Polymer
n1:PAM
n1:Branched_C16-17_Ethoxy_Glyceryl_Sulfonates
n1:are
n1:are
n1:HPAM
n1:are
n1:IOS
n1:Terpolymer
n1:AOS
n1:Nonyl_Phenol_3-Ethoxy_Sulfonate
n1:ABS
n1:EGBE
n1:PAM-co-AMPS
n1:DGBE
n1:are
n1:Isobutanol
n1:Branched_C13_Alcohol_Propoxy_Sulfate
n1:PAA
n1:Sec-Butanol
n1:Branched_C16-17_Alcohol_Propoxy_Sulfate
n1:T-Pentanol
n1:KKYPAM_Series
n1:IOS_C14-26
n1:IOS_C20-24
n1:IOS_C24-28
n1:IOS_C15-18


n2:Analysis_Stage
n2:are
n2:Screening
n2:Laboratory
n2:Simulation
n2:Field_Trial
n2:Operations
n1:hasPredecessor must be
n1:hasSuccessor must be
n2:Screening
n2:Simulation


EORWDO032008 Protégé 3.4 beta (file:\C:\Program%20Files\Protege_3.4_beta\EORWDO032008.pprj, OWL / RDF Files)
File Edit Project OWL Reasoning Code Tools Window Help
Metadata (Ontology1196279553.owl)
OWLClasses
Properties
Individuals
Forms
Jambalaya *
Jess
OWLViz
SWRL Rules
CLASS BROWSER
For Project: EORWDO032008
Class Hierarchy
owl:Thing
rdf:List (52)
swrl:Atom
swrlxml:Entity
wdo:InformationTransformation
wdo:Data
wdo:CompositeData
wdo:SimpleData
wdo:DerivedData
wdo:RawData
Reservoir (32)
wdo:WFSequenceElement
temporal:Entity
swrla:Entity
swrl:Builtin (214)
swrl:Imp (1)
swrl:Variable (4)
Analysis_Stage
Axiom_1
Axiom_2
Chemical
EOR_Methods
EOR_Project (1)
EOR_Project_Status
Forecast
Formulation
Measurement
Preliminary_Screening_Test
TestStatus
Value_of_Information
INSTANCE BROWSER
For Class: EOR_Project
Asserted
Inferred
Asserted Instances
EOR_Project_2008-01
Asserted Types
EOR_Project
INDIVIDUAL EDITOR
For Individual: EOR_Project_2008-01
(instance of EOR_Proje
Annotati
Property
Value
Lang
rdfs:comment
has_EOR_Method
hasStatus
hasAnalysisStage
hasVOI
hasDesign
hasReservoir
Champagnolle
hasForecast



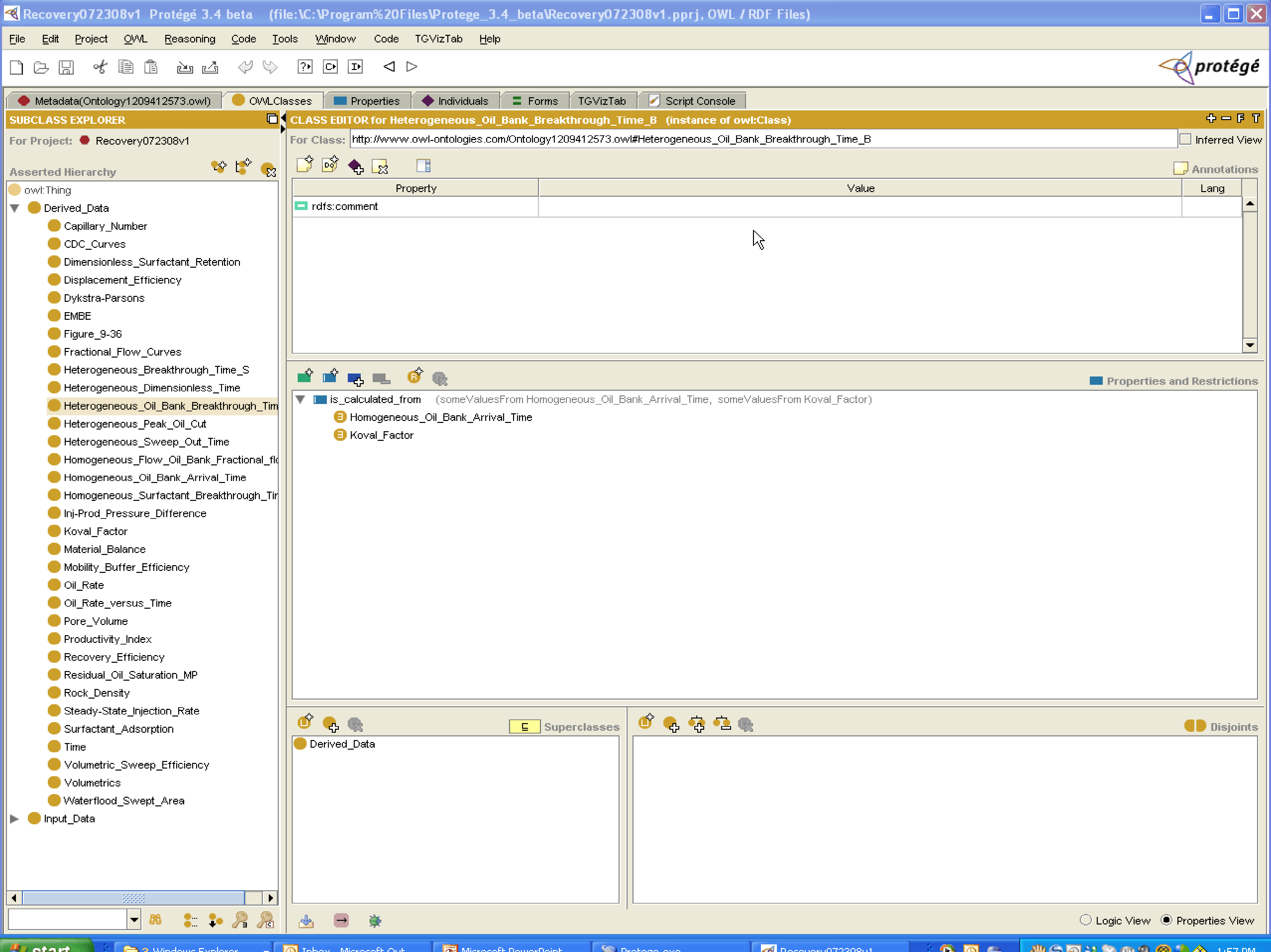
Metadata (Ontology1196279553.owl)
OWLClasses
Properties
Individuals
Forms
Jambalaya *
Jess
OWLViz
SWRL Rules
SUBCLASS EXPLORER
For Project: EORWDO032008
Asserted Hierarchy
rdf:List
swrl:Atom
swrlxml:Entity
wdo:InformationTransformation
wdo:Data
wdo:CompositeData
wdo:SimpleData
wdo:DerivedData
wdo:RawData
Reservoir
wdo:WFSequenceElement
temporal:Entity
swrla:Entity
swrl:Builtin
swrl:Imp
swrl:Variable
Analysis_Stage
Axiom_1
Axiom_2
Chemical
EOR_Methods
Non-Thermal_EOR_Methods
Thermal_EOR_Methods
EOR_Project
EOR_Project_Status
Forecast
Formulation
Measurement
Preliminary_Screening_Test
TestStatus
Value_of_Information
CLASS EDITOR
For Class: Reservoir
(instance of owl:Class)
Inferred View
Annotations
Property
Value
Lang
rdfs:comment
Properties and Restrictions
hasCandidateSurfactantFormulation (someValuesFrom SurfactantFormulation)
SurfactantFormulation
hasPreferredCandidateSurfactantFormulation (someValuesFrom SurfactantFormulation)
SurfactantFormulation
hasSelectedSurfactantFormulation (someValuesFrom SurfactantFormulation)
SurfactantFormulation
Oil_AcidNumber (single float)
Oil_Aromatics (single float)
Oil_EACN (single int)
Oil_Naphthenes (single float)
Oil_Paraffins (single float)
Reservoir_BivalentCations (single float)
Reservoir_Depth (single float)
Reservoir_InjectedWaterSalinity (multiple float)
Reservoir_Permeability (single float)
Reservoir_TDS (single float)
Reservoir_Temperature (single float)
Reservoir_Type (single owl:oneOf{"Sandstone" "Carbonate"})
wdo:isInputTo (multiple wdo:Method)
Superclasses
wdo:RawData
Disjoints
Logic View
Properties View
start
Inbox - Microsoft Out...
Protege.exe
EORWDO032008 Pro...
11:18 AM

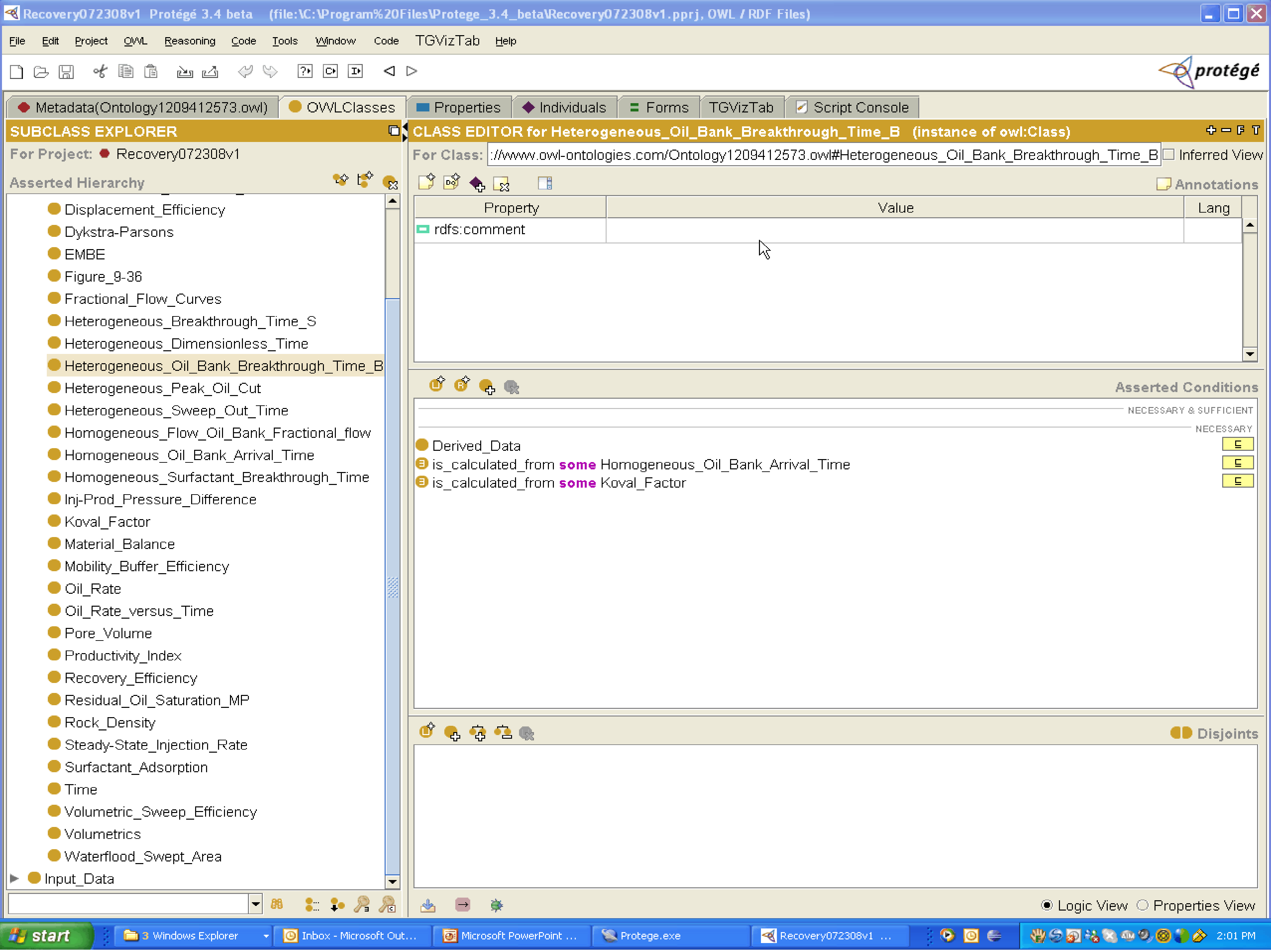

EORWDO032008 Protégé 3.4 beta (file:\C:\Program%20Files\Protege_3.4_beta\EORWDO032008.pprj, OWL / RDF Files)
File Edit Project OWL Reasoning Code Tools Window Help
protégé
Metadata (Ontology1196279553.owl)
OWLClasses
Properties
Individuals
Forms
Jambalaya *
Jess
OWLViz
SWRL Rules
CLASS BROWSER
For Project: EORWDO032008
Class Hierarchy
owl:Thing
rdf:List (52)
swrl:Atom
swrlxml:Entity
wdo:InformationTransformation
wdo:Data
wdo:CompositeData
wdo:SimpleData
wdo:DerivedData
wdo:RawData
Reservoir (32)
wdo:WFSequenceElement
temporal:Entity
swrla:Entity
swrl:Builtin (214)
swrl:Imp (1)
swrl:Variable (4)
Analysis_Stage
Axiom_1
Axiom_2
Chemical
EOR_Methods
EOR_Project (1)
EOR_Project_Status
Forecast
Formulation
Measurement
Preliminary_Screening_Test
TestStatus
Value_of_Information
INSTANCE BROWSER
For Class: Reservoir
Asserted
Inferred
Asserted Instances
Blossom
Buckrange
Champagnolle
Citronelle
CottonValley
ElDoradoEast
EUTAW
Graves
HemlockMcCarthur
HemlockSwanson
Jones
KuparukRiver
Lisbon
Magnolia
Meakin
MiddleKenai
Midway
Nacatoch
OldNacatoch
Paluxi
SADLEROCKIT
SandyBend
Schuler
Smackover
SmackoverNacatosh
SmartArea
Asserted Types
Reservoir
INDIVIDUAL EDITOR
For Individual: Blossom
(instance of Reservoir)
Annotations
Property
Value
Lang
rdfs:comment
Reservoir_Type
Reservoir_Depth
hasPreferredCandid
Oil_EACN
Reservoir_Permeability
Oil_AcidNumber
Reservoir_TDS
hasSelectedSurfacta
Oil_Aromatics
Reservoir_Temperature
Oil_Naphthenes
Reservoir_InjectedW
wdo:isInputTo
Value
Type
Oil_Paraffins
Reservoir_BivalentCati
hasCandidateSurfac
start
Inbox - Microsoft Out...
Protege.exe
EORWDO032008 Pro...
9:42 AM

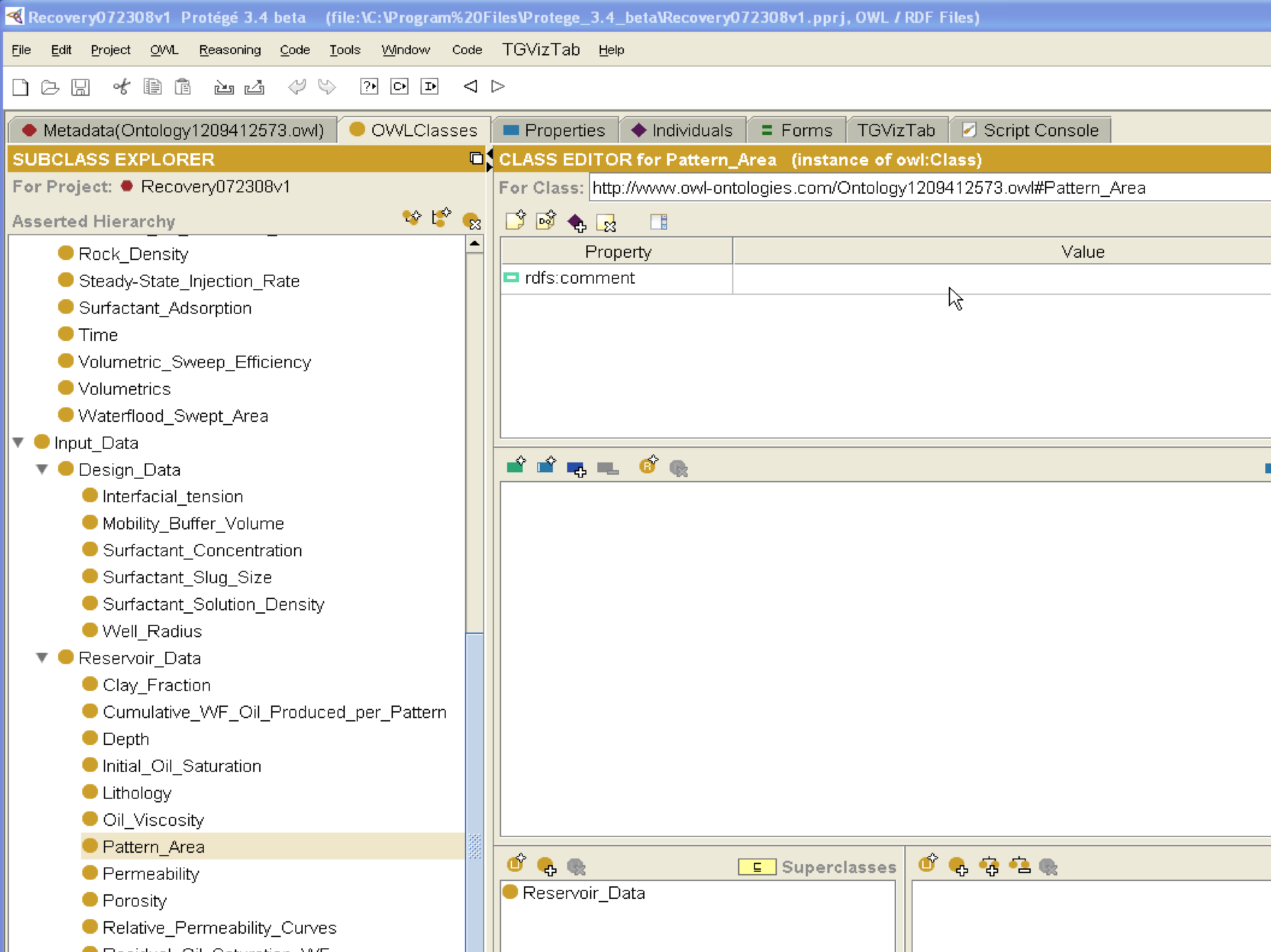
Surfactant Formulation Workflow and EOR Ontology with Chemicals Pilot – Summary

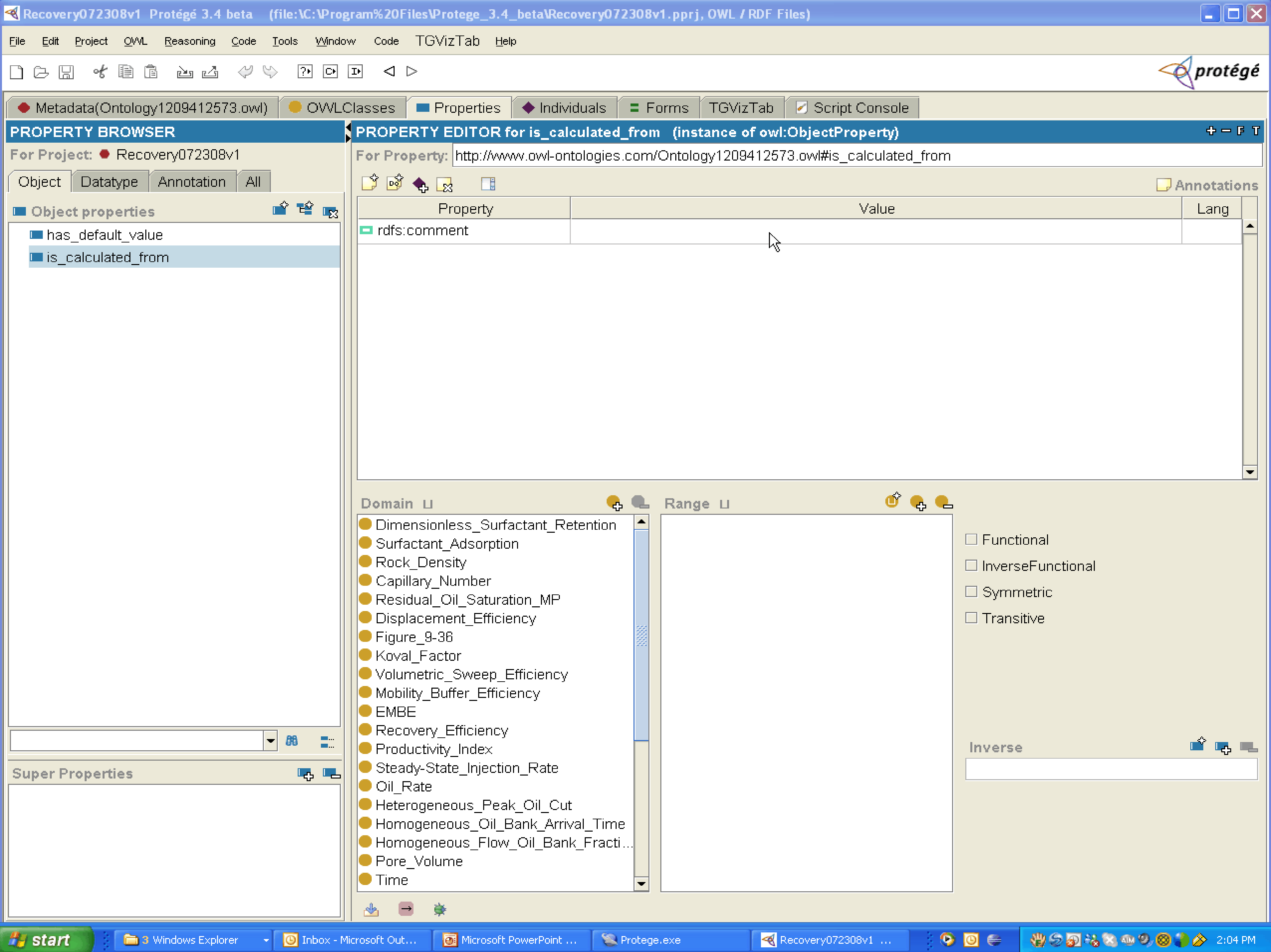
- Complex
- Basis for Decision Support System
- Organization of Concepts in Domain
- Workflow-based Ontology
- Work in progress

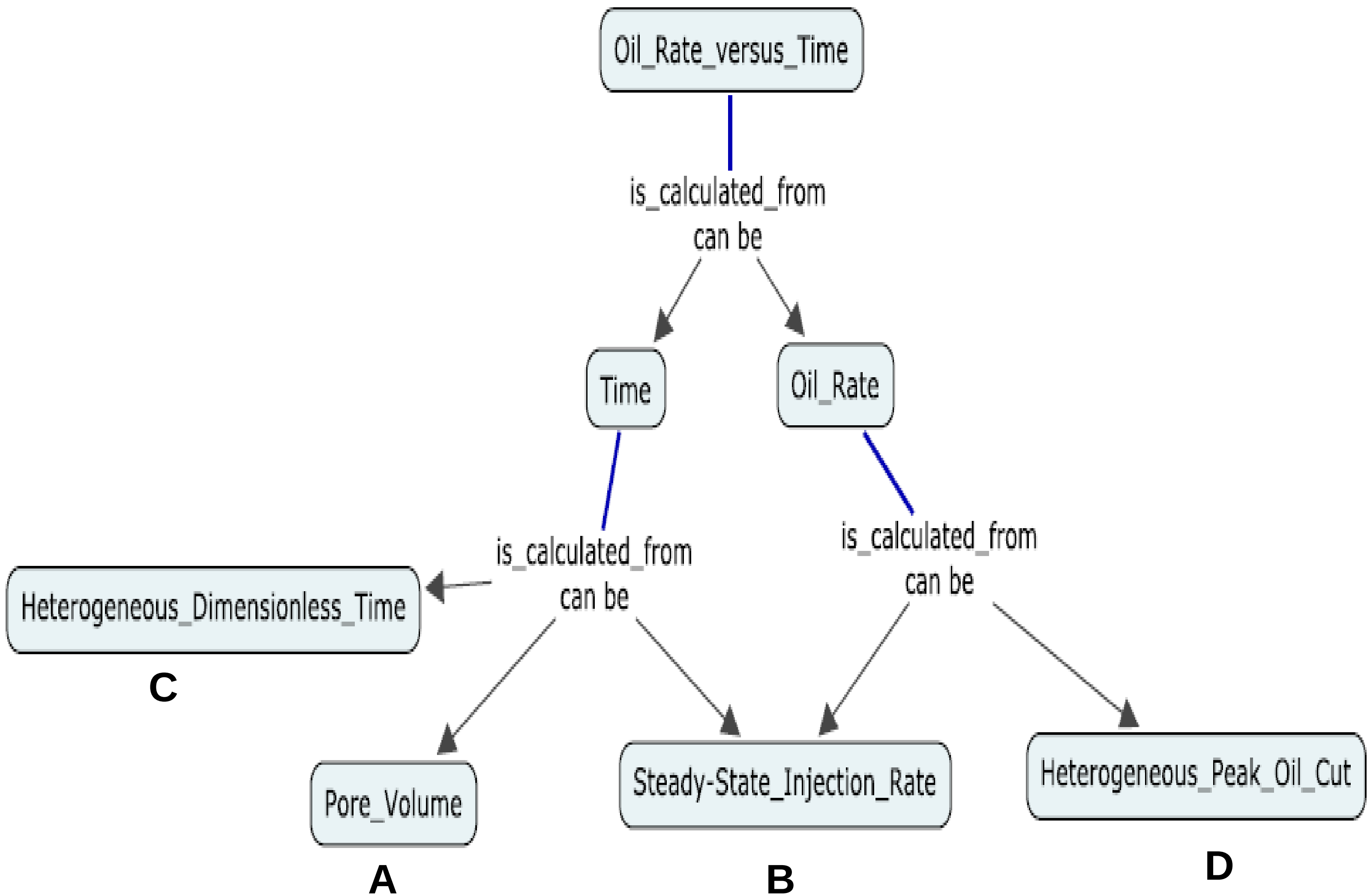
EOR Simplified Recovery Calculation Ontology


Recovery072308v1 Protégé 3.4 beta (file:\C:\Program%20Files\Protege_3.4_beta\Recovery072308v1.pprj, OWL / RDF Files)
File Edit Project OWL Reasoning Code Tools Window Code TGVizTab Help
protégé
Metadata(Ontology1209412573.owl) OWLClasses Properties Individuals Forms TGVizTab Script Console
SUBCLASS EXPLORER
For Project: Recovery072308v1
Asserted Hierarchy
owl:Thing
Derived_Data
Capillary_Number
CDC_Curves
Dimensionless_Surfactant_Retention
Displacement_Efficiency
Dykstra-Parsons
EMBE
Figure_9-36
Fractional_Flow_Curves
Heterogeneous_Breakthrough_Time_S
Heterogeneous_Dimensionless_Time
Heterogeneous_Oil_Bank_Breakthrough_Tim
Heterogeneous_Peak_Oil_Cut
Heterogeneous_Sweep_Out_Time
Homogeneous_Flow_Oil_Bank_Fractional_fl
Homogeneous_Oil_Bank_Arrival_Time
Homogeneous_Surfactant_Breakthrough_Ti
Inj-Prod_Pressure_Difference
Koval_Factor
Material_Balance
Mobility_Buffer_Efficiency
Oil_Rate
Oil_Rate_versus_Time
Pore_Volume
Productivity_Index
Recovery_Efficiency
Residual_Oil_Saturation_MP
Rock_Density
Steady-State_Injection_Rate
Surfactant_Adsorption
Time
Volumetric_Sweep_Efficiency
Volumetrics
Waterflood_Swept_Area
Input_Data
CLASS EDITOR for Heterogeneous_Oil_Bank_Breakthrough_Time_B (instance of owl:Class)
For Class: http://www.owl-ontologies.com/Ontology1209412573.owl#Heterogeneous_Oil_Bank_Breakthrough_Time_B
Inferred View
Annotations
Property
Value
Lang
rdfs:comment
Properties and Restrictions
is_calculated_from (someValuesFrom Homogeneous_Oil_Bank_Arrival_Time, someValuesFrom Koval_Factor)
Homogeneous_Oil_Bank_Arrival_Time
Koval_Factor
Superclasses
Derived_Data
Disjoints
Logic View
Properties View

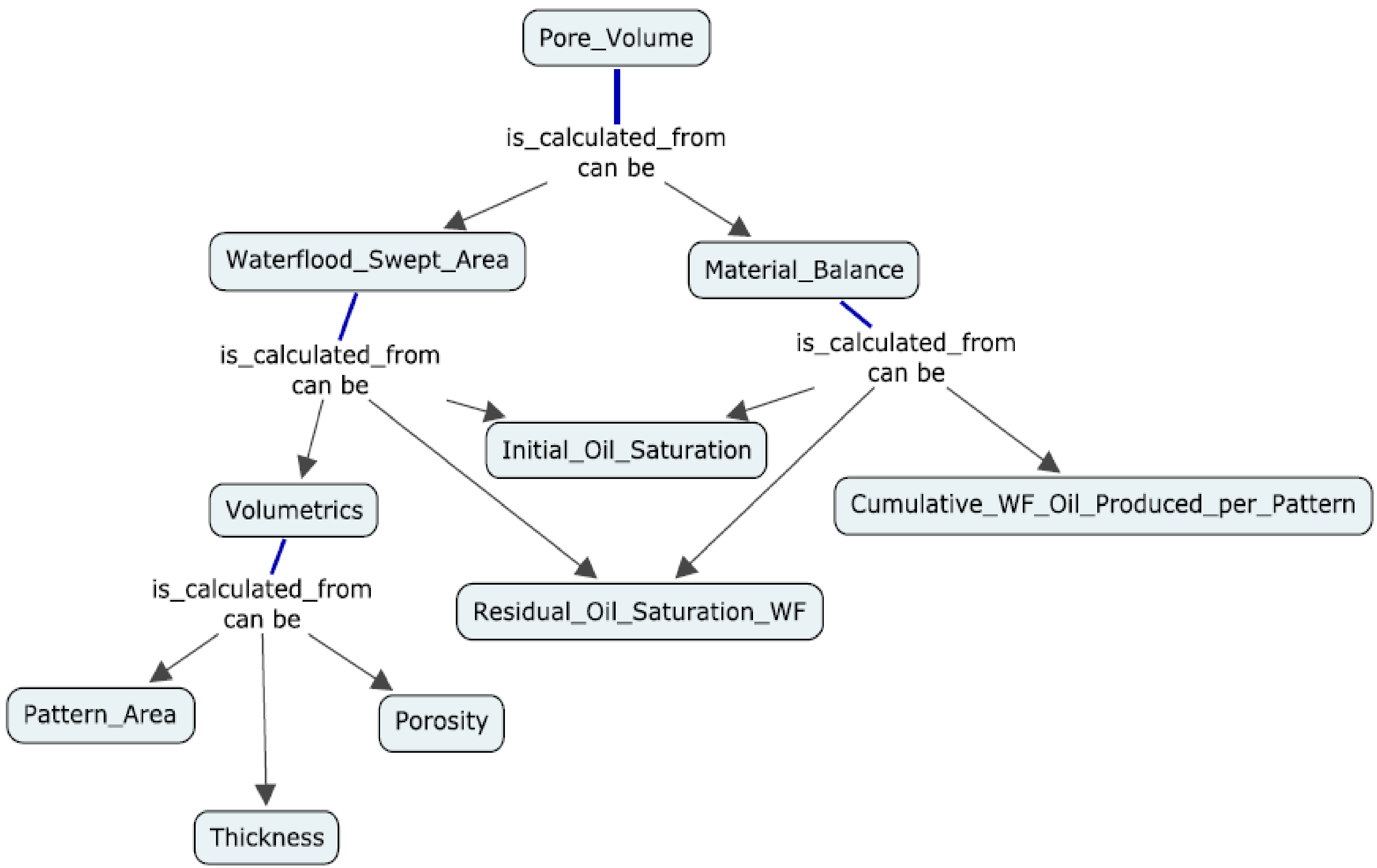

Recovery072308v1 Protégé 3.4 beta (file:\C:\Program%20Files\Protege_3.4_beta\Recovery072308v1.pprj, OWL / RDF Files)
File Edit Project OWL Reasoning Code Tools Window Code TGVizTab Help
protégé
Metadata(Ontology1209412573.owl)
OWLClasses
Properties
Individuals
Forms
TGVizTab
Script Console
SUBCLASS EXPLORER
For Project: Recovery072308v1
Asserted Hierarchy
Displacement_Efficiency
Dykstra-Parsons
EMBE
Figure_9-36
Fractional_Flow_Curves
Heterogeneous_Breakthrough_Time_S
Heterogeneous_Dimensionless_Time
Heterogeneous_Oil_Bank_Breakthrough_Time_B
Heterogeneous_Peak_Oil_Cut
Heterogeneous_Sweep_Out_Time
Homogeneous_Flow_Oil_Bank_Fractional_flow
Homogeneous_Oil_Bank_Arrival_Time
Homogeneous_Surfactant_Breakthrough_Time
Inj-Prod_Pressure_Difference
Koval_Factor
Material_Balance
Mobility_Buffer_Efficiency
Oil_Rate
Oil_Rate_versus_Time
Pore_Volume
Productivity_Index
Recovery_Efficiency
Residual_Oil_Saturation_MP
Rock_Density
Steady-State_Injection_Rate
Surfactant_Adsorption
Time
Volumetric_Sweep_Efficiency
Volumetrics
Waterflood_Swept_Area
Input_Data
CLASS EDITOR for Heterogeneous_Oil_Bank_Breakthrough_Time_B (instance of owl:Class)
For Class: ://www.owl-ontologies.com/Ontology1209412573.owl#Heterogeneous_Oil_Bank_Breakthrough_Time_B
Inferred View
Annotations
Property
Value
Lang
rdfs:comment
Asserted Conditions
NECESSARY & SUFFICIENT
NECESSARY
Derived_Data
is_calculated_from some Homogeneous_Oil_Bank_Arrival_Time
is_calculated_from some Koval_Factor
Disjoints
Logic View
Properties View
start
3 Windows Explorer
Inbox - Microsoft Out...
Microsoft PowerPoint ...
Protege.exe
Recovery072308v1 ...
2:01 PM

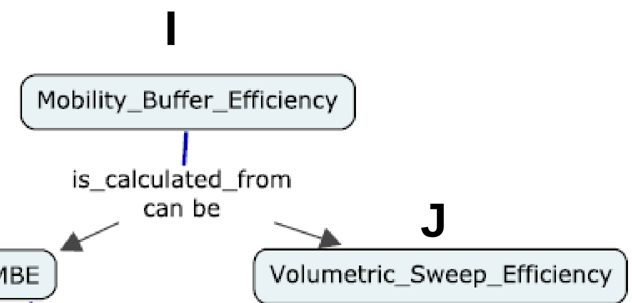

Recovery072308v1 Protégé 3.4 beta (file:\C:\Program%20Files\Protege_3.4_beta\Recovery072308v1.pprj, OWL / RDF Files)
File Edit Project OWL Reasoning Code Tools Window Code TGVizTab Help
Metadata(Ontology1209412573.owl)
OWLClasses
Properties
Individuals
Forms
TGVizTab
Script Console
SUBCLASS EXPLORER
For Project: Recovery072308v1
Asserted Hierarchy
Rock_Density
Steady-State_Injection_Rate
Surfactant_Adsorption
Time
Volumetric_Sweep_Efficiency
Volumetrics
Waterflood_Swept_Area
Input_Data
Design_Data
Interfacial_tension
Mobility_Buffer_Volume
Surfactant_Concentration
Surfactant_Slug_Size
Surfactant_Solution_Density
Well_Radius
Reservoir_Data
Clay_Fraction
Cumulative_WF_Oil_Produced_per_Pattern
Depth
Initial_Oil_Saturation
Lithology
Oil_Viscosity
Pattern_Area
Permeability
Porosity
Relative_Permeability_Curves
CLASS EDITOR for Pattern_Area (instance of owl:Class)
For Class: http://www.owl-ontologies.com/Ontology1209412573.owl#Pattern_Area
Property
Value
rdfs:comment
Superclasses
Reservoir_Data

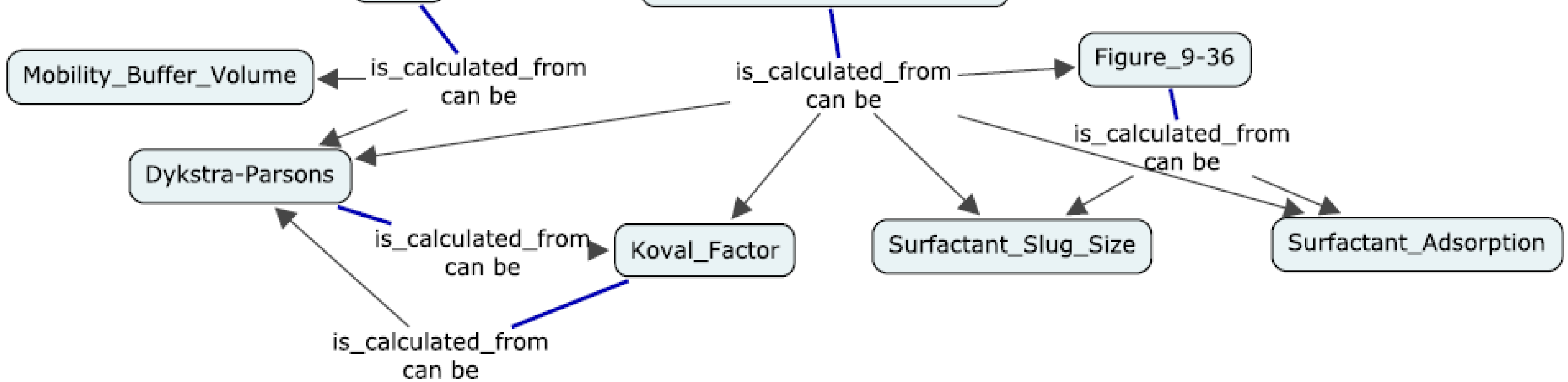

Recovery072308v1 Protégé 3.4 beta (file:\C:\Program%20Files\Protege_3.4_beta\Recovery072308v1.pprj, OWL / RDF Files)
File Edit Project OWL Reasoning Code Tools Window Code TGVizTab Help
protégé
Metadata(Ontology1209412573.owl)
OWLClasses
Properties
Individuals
Forms
TGVizTab
Script Console
PROPERTY BROWSER
For Project: Recovery072308v1
Object
Datatype
Annotation
All
Object properties
has_default_value
is_calculated_from
Super Properties
PROPERTY EDITOR for is_calculated_from (instance of owl:ObjectProperty)
For Property: http://www.owl-ontologies.com/Ontology1209412573.owl#is_calculated_from
Annotations
Property
Value
Lang
rdfs:comment
Domain ⊔
Dimensionless_Surfactant_Retention
Surfactant_Adsorption
Rock_Density
Capillary_Number
Residual_Oil_Saturation_MP
Displacement_Efficiency
Figure_9-36
Koval_Factor
Volumetric_Sweep_Efficiency
Mobility_Buffer_Efficiency
EMBE
Recovery_Efficiency
Productivity_Index
Steady-State_Injection_Rate
Oil_Rate
Heterogeneous_Peak_Oil_Cut
Homogeneous_Oil_Bank_Arrival_Time
Homogeneous_Flow_Oil_Bank_Fracti...
Pore_Volume
Time
Range ⊔
Functional
InverseFunctional
Symmetric
Transitive
Inverse
start
3 Windows Explorer
Inbox - Microsoft Out...
Microsoft PowerPoint ...
Protege.exe
Recovery072308v1 ...
2:04 PM

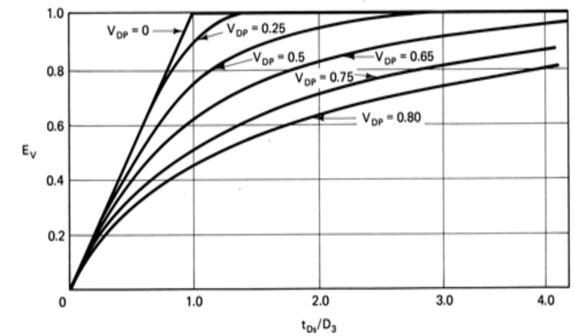

Oil_Rate_versus_Time
is_calculated_from
can be
Time
Oil_Rate
is_calculated_from
can be
is_calculated_from
can be
Heterogeneous_Dimensionless_Time
C
Pore_Volume
A
Steady-State_Injection_Rate
B
Heterogeneous_Peak_Oil_Cut
D

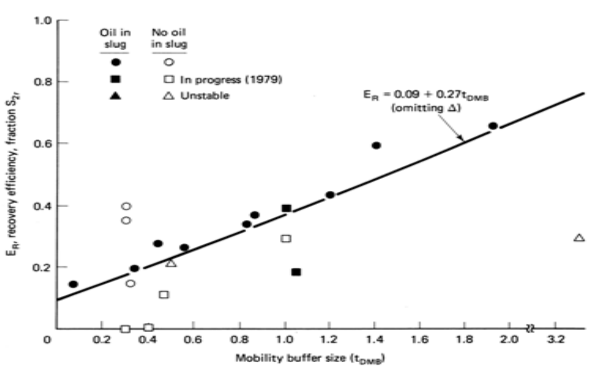
A

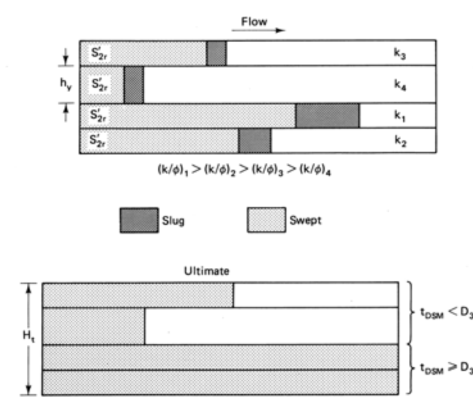

Pore_Volume
is_calculated_from
can be
Waterflood_Swept_Area
Material_Balance
is_calculated_from
can be
is_calculated_from
can be
Initial_Oil_Saturation
Cumulative_WF_Oil_Produced_per_Pattern
Volumetrics
Residual_Oil_Saturation_WF
is_calculated_from
can be
Pattern_Area
Porosity
Thickness

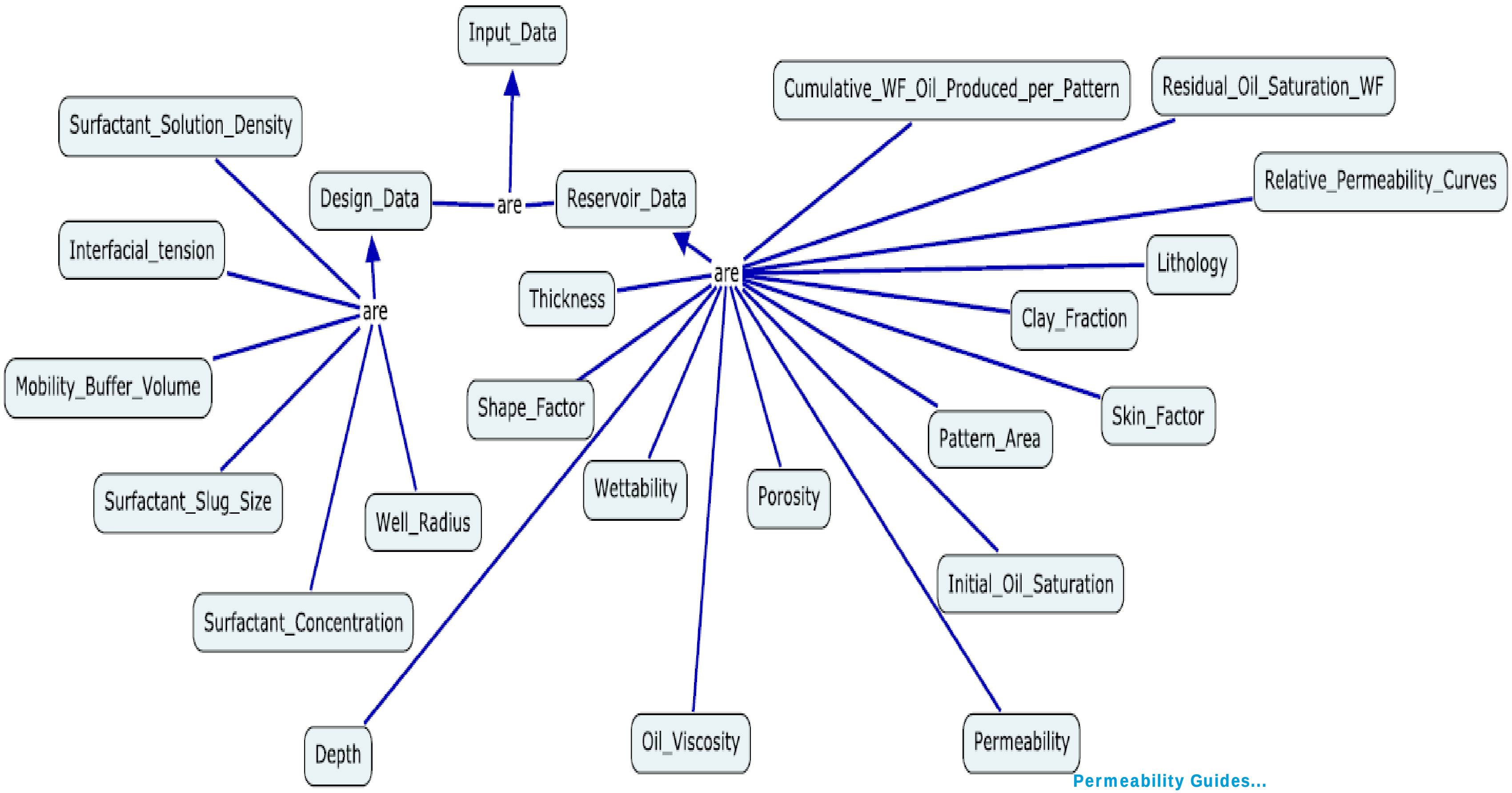

I
Mobility_Buffer_Efficiency
is_calculated_from
can be
J


EMBE
Volumetric_Sweep_Efficiency
Mobility_Buffer_Volume
is_calculated_from
can be
is_calculated_from
can be
Figure_9-36
is_calculated_from
can be
Dykstra-Parsons
is_calculated_from
can be
Koval_Factor
Surfactant_Slug_Size
Surfactant_Adsorption
is_calculated_from
can be

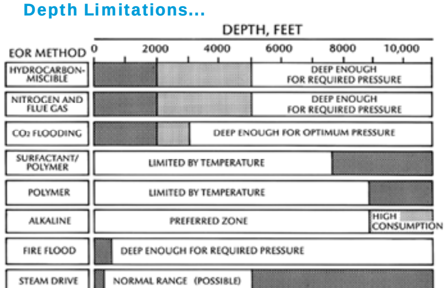

V_{DP} = 0
V_{DP} = 0.25
V_{DP} = 0.5
V_{DP} = 0.65
V_{DP} = 0.75
V_{DP} = 0.80
E_V
t_{Ds}/D_3


Oil in slug
No oil in slug
In progress (1979)
Unstable
E_R = 0.09 + 0.27t_{DMB} (omitting △)
E_R, recovery efficiency, fraction S_{2r}
Mobility buffer size (t_{DMB})

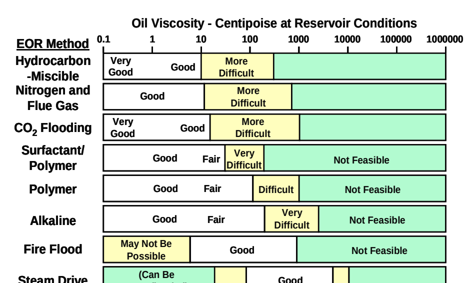

Flow
h_v
k_3
k_4
k_1
k_2
$(k/\phi)_1 > (k/\phi)_2 > (k/\phi)_3 > (k/\phi)_4$
Slug
Swept
Ultimate
H_t
$t_{DSM} < D_3$
$t_{DSM} > D_3$



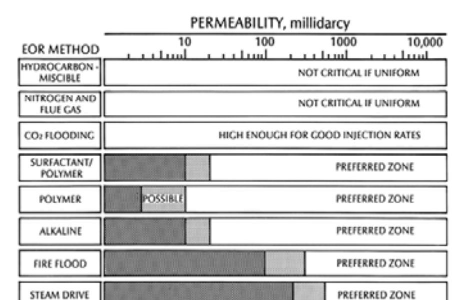
Depth Limitations...



Preferred Oil Viscosity Ranges...



Permeability Guides...

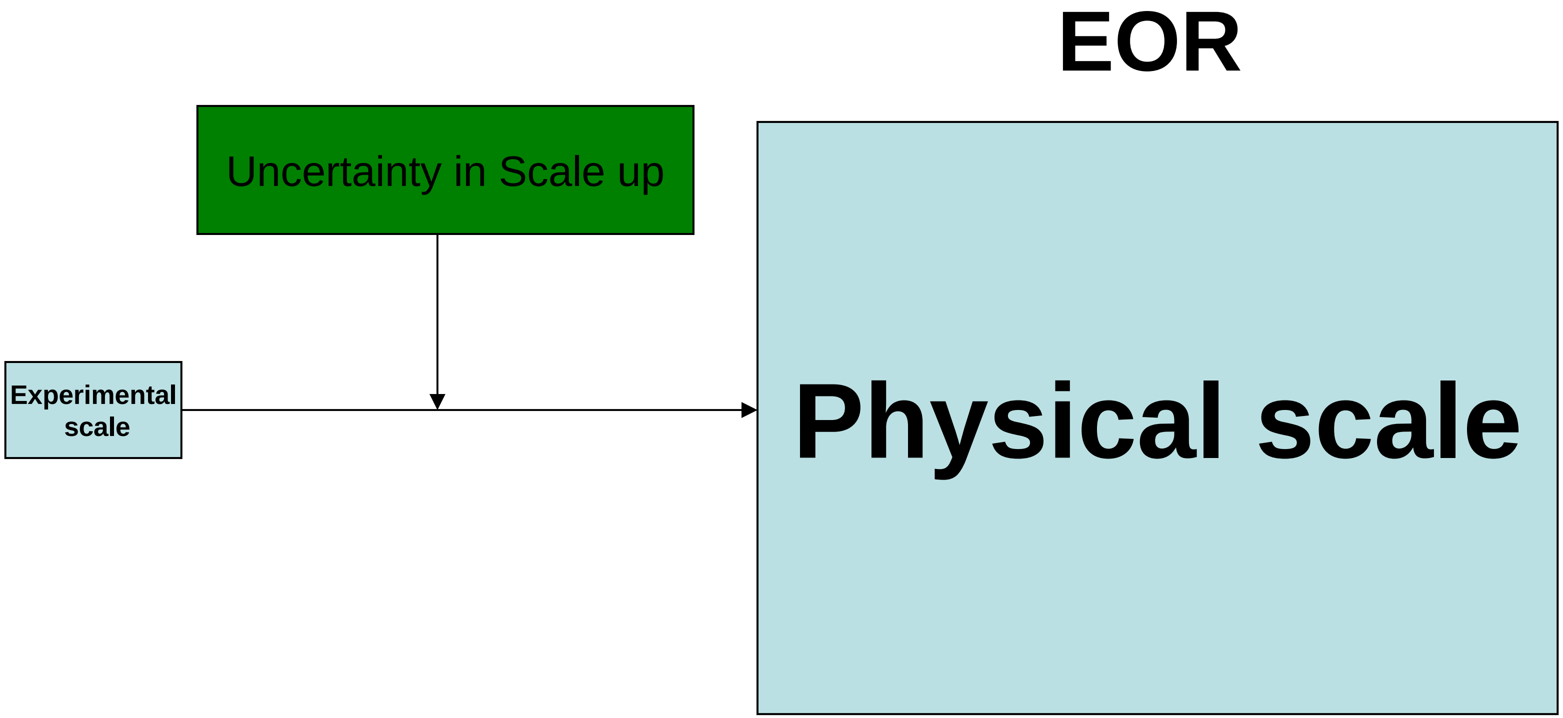


Simplified Recovery Calculation Ontology Pilot – Summary

- Large Complex Calculation
- Essentially one Property
  - “is calculated from”
- Errors, insights found when ontology and CMAP created
- Previously available only to students to read.
- Now available to software agents

Scale-Up Uncertainty Ontology

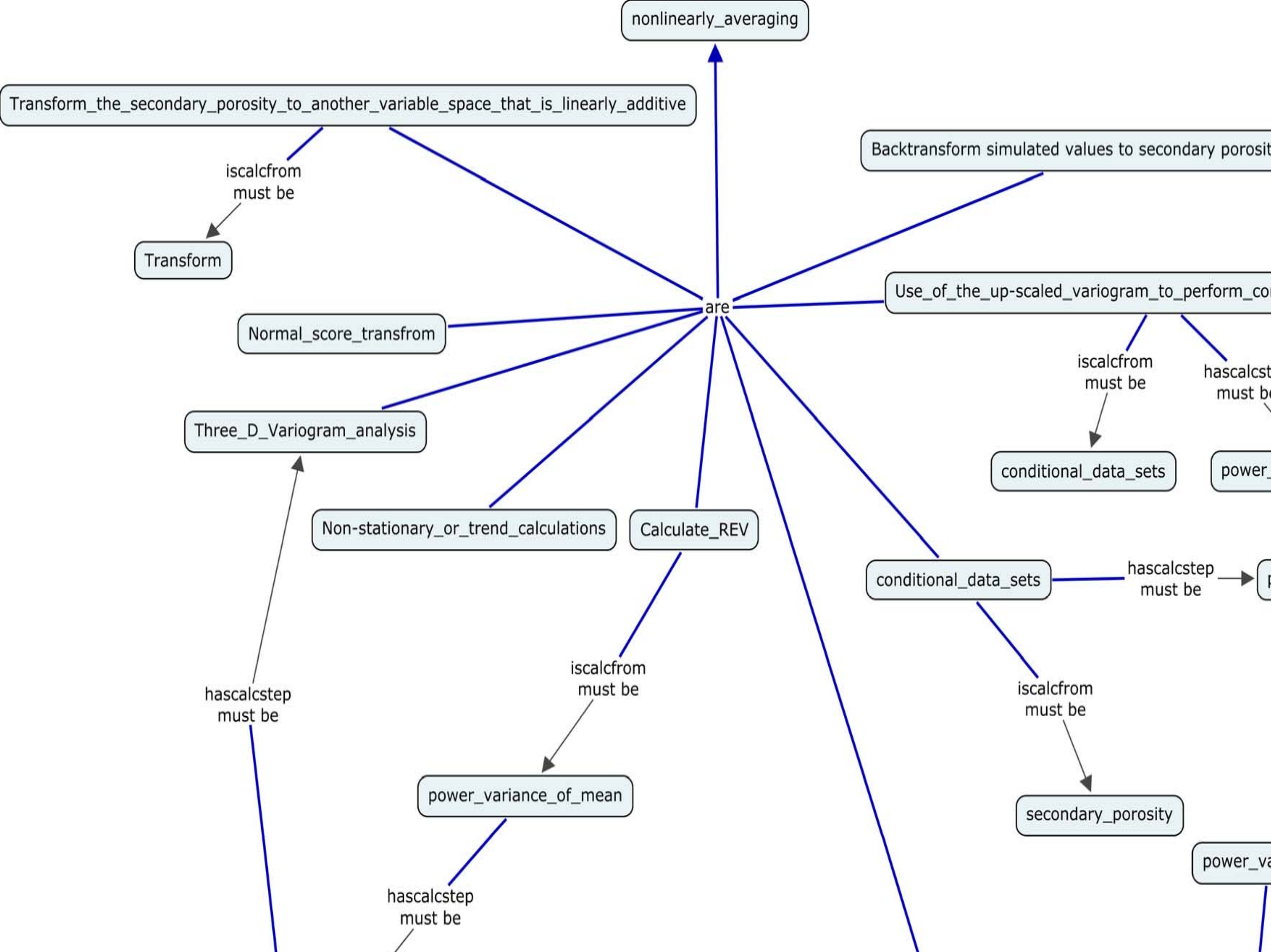
Motivation


EOR
Uncertainty in Scale up
Experimental scale
Physical scale

Workflow

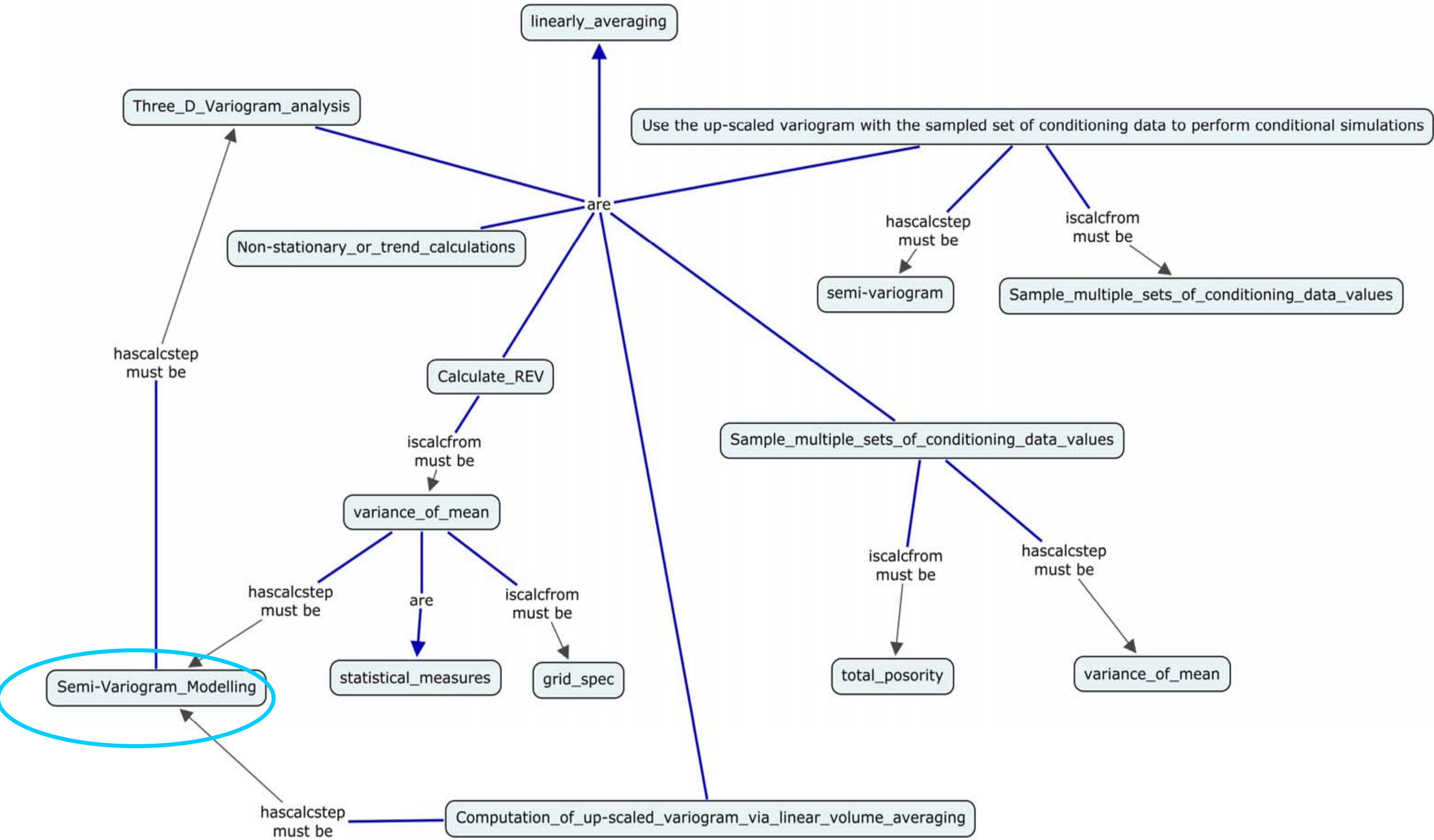
Non-Linearly Averaging – Second Porosity

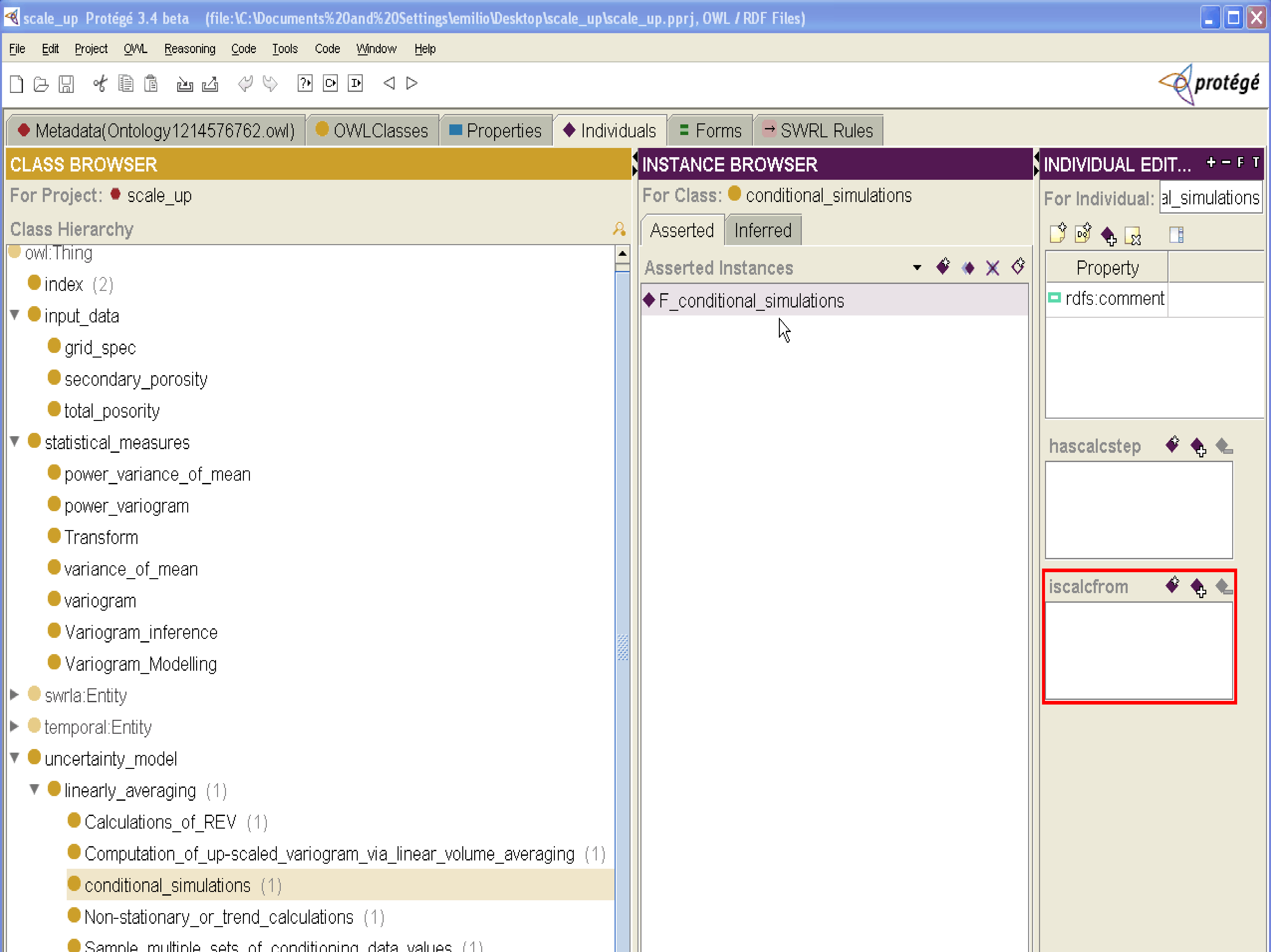
1. Transform the secondary porosity to another variable space that is linearly additive
2. Normal score transform the second porosity data and compute semi-variograms Construct a licit 3D variogram model with sill standardized to be 1.0.
3. Calculations of representative elementary volume and variance of mean using the 3D point- scale variogram from Step #2.
4. Computation of up-scaled variogram via linear volume averaging.
5. Use of the up-scaled variogram from Step #4 to perform conditional simulation.
6. Backtransform simulated values to secondary porosity units → scale up uncertainty

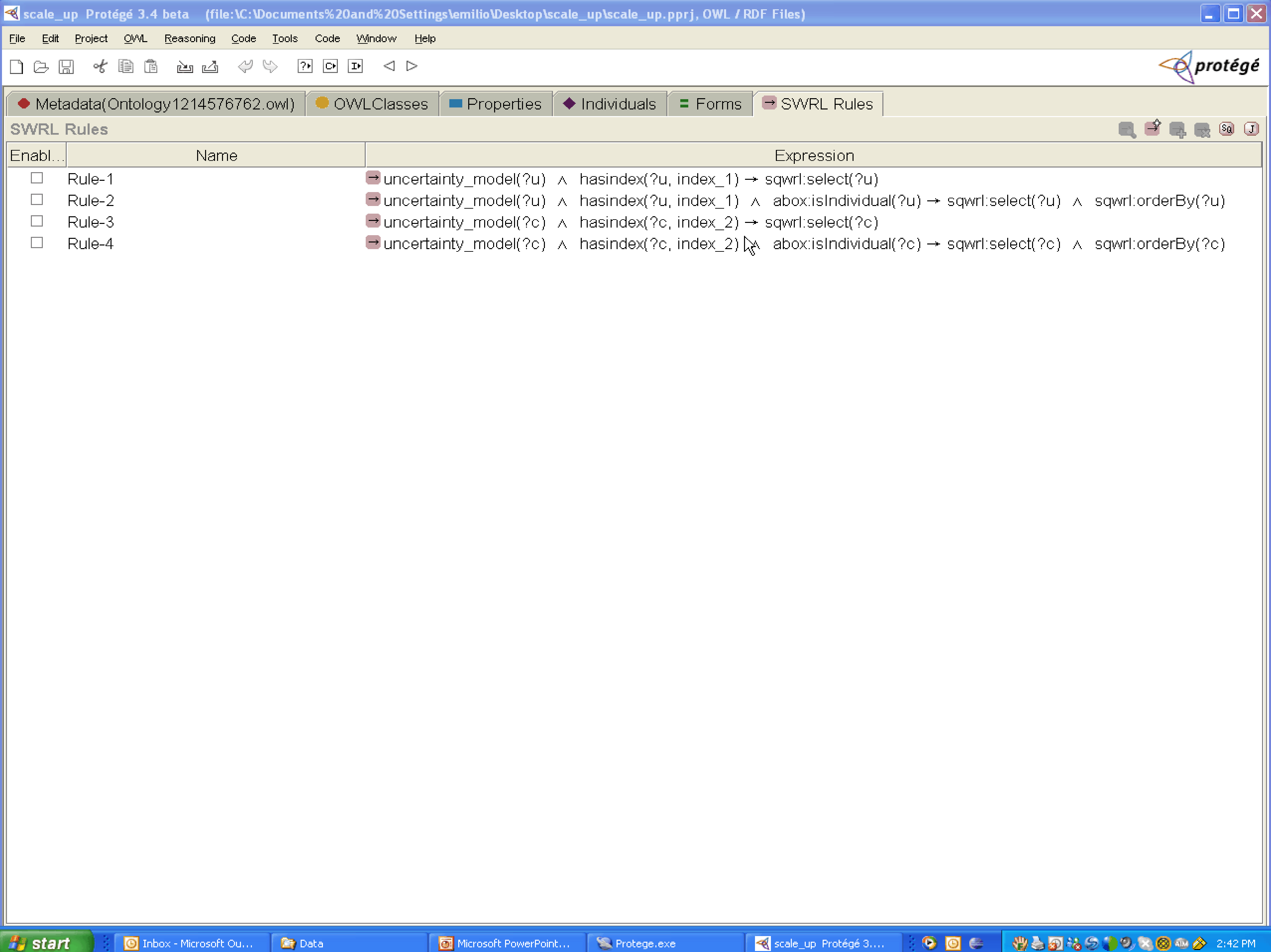


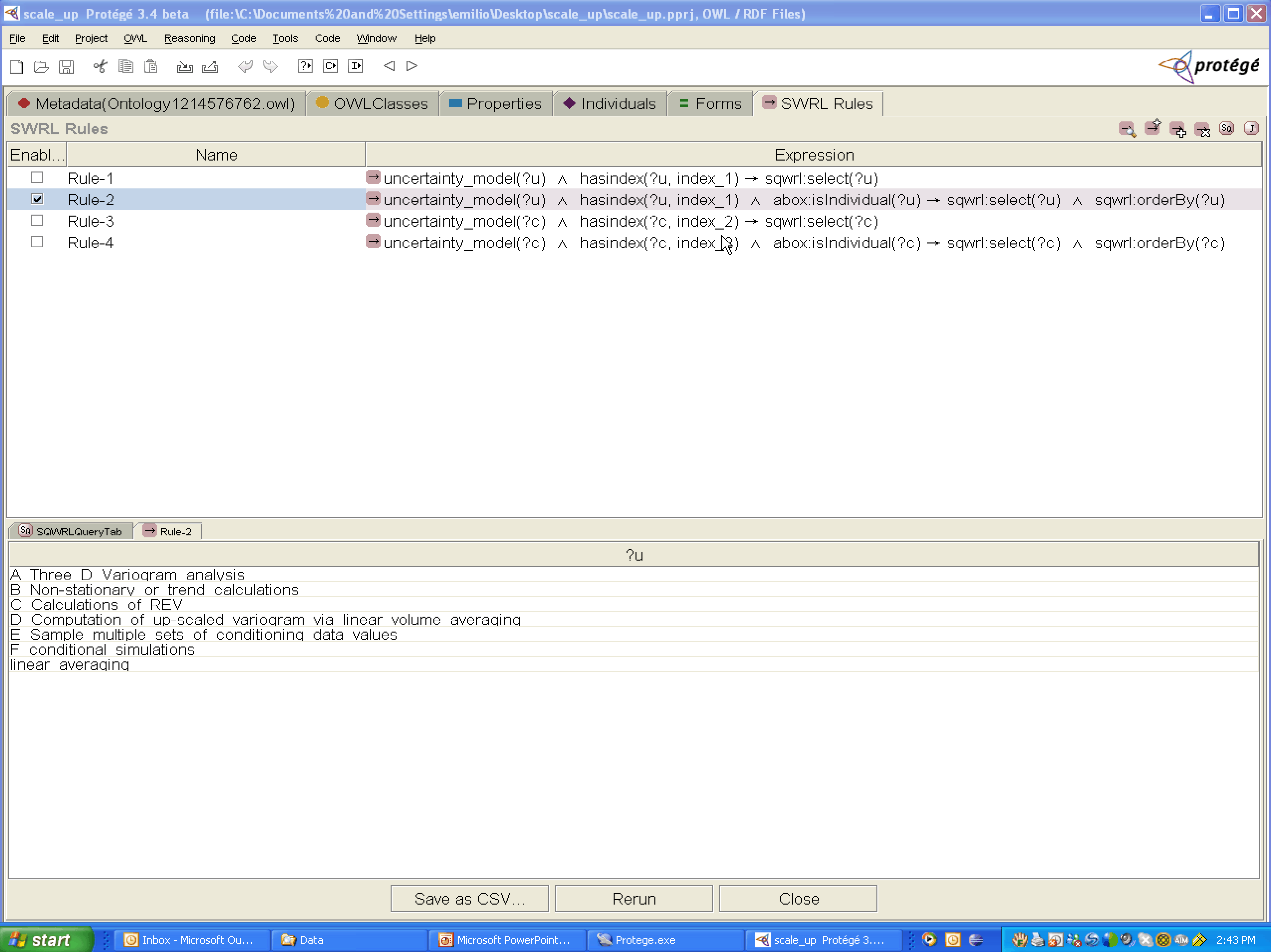
nonlinearly_averaging
Transform_the_secondary_porosity_to_another_variable_space_that_is_linearly_additive
iscalcfrom
must be
Transform
Backtransform simulated values to secondary porosit
are
Use_of_the_up-scaled_variogram_to_perform_co
Normal_score_transfrom
iscalcfrom
must be
hascalcst
must b
Three_D_Variogram_analysis
conditional_data_sets
power_
Non-stationary_or_trend_calculations
Calculate_REV
conditional_data_sets
hascalcstep
must be
iscalcfrom
must be
iscalcfrom
must be
hascalcstep
must be
power_variance_of_mean
secondary_porosity
power_va
hascalcstep
must be

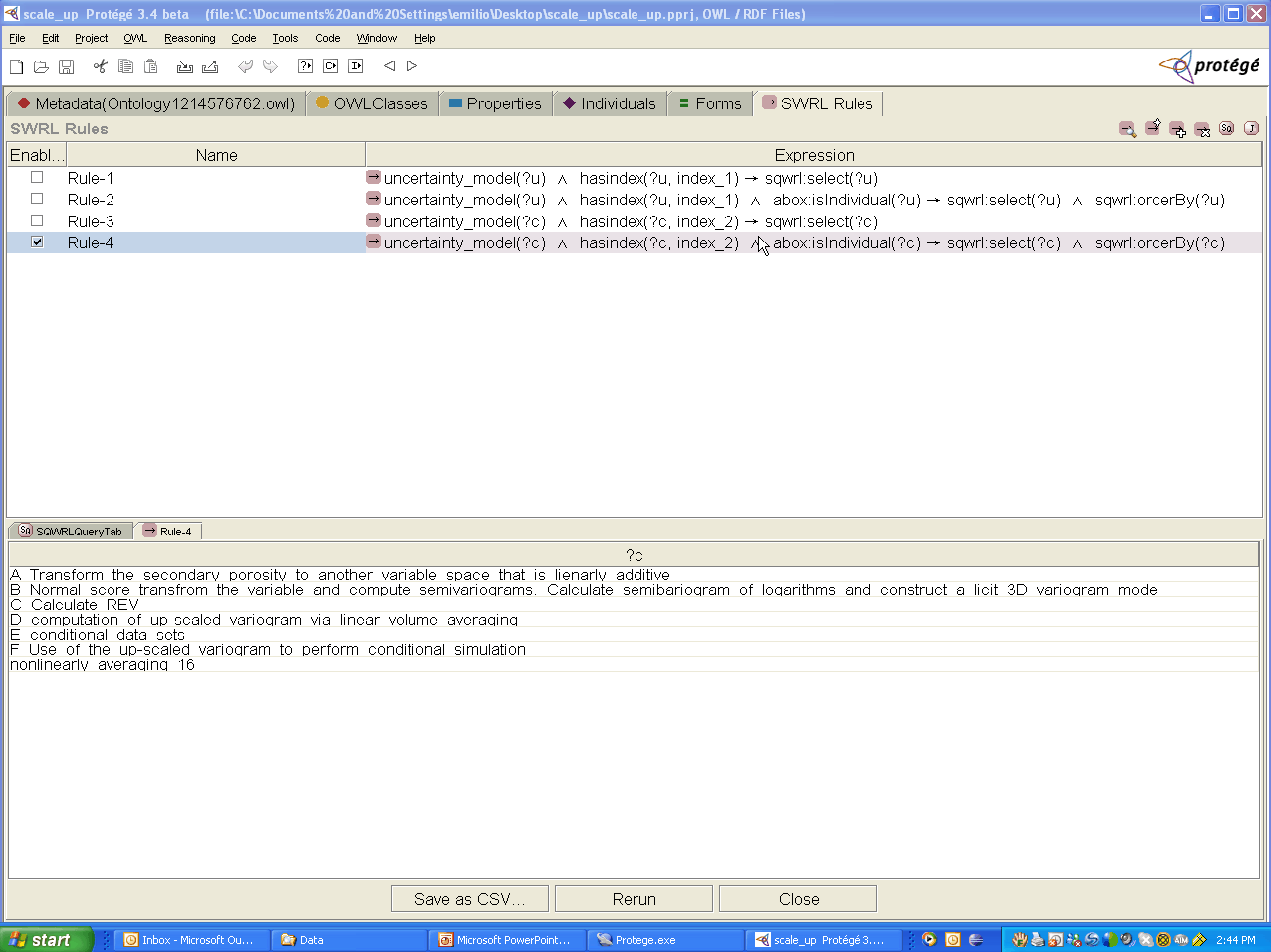
Example of Instances in the Ontology




scale_up Protégé 3.4 beta (file:\C:\Documents%20and%20Settings\emilio\Desktop\scale_up\scale_up.pprj, OWL / RDF Files)
File Edit Project OWL Reasoning Code Tools Code Window Help
protégé
Metadata(Ontology1214576762.owl)
OWLClasses
Properties
Individuals
Forms
SWRL Rules
CLASS BROWSER
For Project: scale_up
Class Hierarchy
owl:Thing
index (2)
input_data
grid_spec
secondary_porosity
total_posority
statistical_measures
power_variance_of_mean
power_variogram
Transform
variance_of_mean
variogram
Variogram_inference
Variogram_Modelling
swrla:Entity
temporal:Entity
uncertainty_model
linearly_averaging (1)
Calculations_of_REV (1)
Computation_of_up-scaled_variogram_via_linear_volume_averaging (1)
conditional_simulations (1)
Non-stationary_or_trend_calculations (1)
Sample_multiple_sets_of_conditioning_data_values (1)
INSTANCE BROWSER
For Class: conditional_simulations
Asserted
Inferred
Asserted Instances
F_conditional_simulations
INDIVIDUAL EDIT...
For Individual: al_simulations
Property
rdfs:comment
hascalcstep
iscalcfrom


scale_up Protégé 3.4 beta (file:\C:\Documents%20and%20Settings\emilio\Desktop\scale_up\scale_up.pprj, OWL / RDF Files)
File Edit Project OWL Reasoning Code Tools Code Window Help
protégé
Metadata(Ontology1214576762.owl)
OWLClasses
Properties
Individuals
Forms
SWRL Rules
SWRL Rules
Enabl...
Name
Expression
Rule-1
uncertainty_model(?u) ∧ hasindex(?u, index_1) → sqwrl:select(?u)
Rule-2
uncertainty_model(?u) ∧ hasindex(?u, index_1) ∧ abox:isIndividual(?u) → sqwrl:select(?u) ∧ sqwrl:orderBy(?u)
Rule-3
uncertainty_model(?c) ∧ hasindex(?c, index_2) → sqwrl:select(?c)
Rule-4
uncertainty_model(?c) ∧ hasindex(?c, index_2) ∧ abox:isIndividual(?c) → sqwrl:select(?c) ∧ sqwrl:orderBy(?c)
start
Inbox - Microsoft Ou...
Data
Microsoft PowerPoint...
Protege.exe
scale_up Protégé 3....
2:42 PM


scale_up Protégé 3.4 beta (file:\C:\Documents%20and%20Settings\emilio\Desktop\scale_up\scale_up.pprj, OWL / RDF Files)
File Edit Project OWL Reasoning Code Tools Code Window Help
protégé
Metadata(Ontology1214576762.owl)
OWLClasses
Properties
Individuals
Forms
SWRL Rules
SWRL Rules
Enabl...
Name
Expression
Rule-1
uncertainty_model(?u) ∧ hasindex(?u, index_1) → sqwrl:select(?u)
Rule-2
uncertainty_model(?u) ∧ hasindex(?u, index_1) ∧ abox:isIndividual(?u) → sqwrl:select(?u) ∧ sqwrl:orderBy(?u)
Rule-3
uncertainty_model(?c) ∧ hasindex(?c, index_2) → sqwrl:select(?c)
Rule-4
uncertainty_model(?c) ∧ hasindex(?c, index_2) ∧ abox:isIndividual(?c) → sqwrl:select(?c) ∧ sqwrl:orderBy(?c)
SQWRLQueryTab
Rule-2
?u
A Three D Variogram analysis
B Non-stationary or trend calculations
C Calculations of REV
D Computation of up-scaled variogram via linear volume averaging
E Sample multiple sets of conditioning data values
F conditional simulations
linear averaging
Save as CSV...
Rerun
Close
start
Inbox - Microsoft Ou...
Data
Microsoft PowerPoint...
Protege.exe
scale_up Protégé 3....
2:43 PM


scale_up Protégé 3.4 beta (file:\C:\Documents%20and%20Settings\emilio\Desktop\scale_up\scale_up.pprj, OWL / RDF Files)
File Edit Project OWL Reasoning Code Tools Code Window Help
protégé
Metadata(Ontology1214576762.owl) OWLClasses Properties Individuals Forms SWRL Rules
SWRL Rules
Enabl... Name Expression
Rule-1 uncertainty_model(?u) ∧ hasindex(?u, index_1) → sqwrl:select(?u)
Rule-2 uncertainty_model(?u) ∧ hasindex(?u, index_1) ∧ abox:isIndividual(?u) → sqwrl:select(?u) ∧ sqwrl:orderBy(?u)
Rule-3 uncertainty_model(?c) ∧ hasindex(?c, index_2) → sqwrl:select(?c)
Rule-4 uncertainty_model(?c) ∧ hasindex(?c, index_2) ∧ abox:isIndividual(?c) → sqwrl:select(?c) ∧ sqwrl:orderBy(?c)
SQWRLQueryTab Rule-4
?c
A Transform the secondary porosity to another variable space that is lienarly additive
B Normal score transfrom the variable and compute semivariograms. Calculate semibariogram of logarithms and construct a licit 3D variogram model
C Calculate REV
D computation of up-scaled variogram via linear volume averaging
E conditional data sets
F Use of the up-scaled variogram to perform conditional simulation
nonlinearly averaging 16
Save as CSV... Rerun Close
start Inbox - Microsoft Ou... Data Microsoft PowerPoint... Protege.exe scale_up Protégé 3.... 2:44 PM

Scale-Up Ontology
Pilot –
Summary

- Captured Knowledge of Different Scale-Up Methods
- Use SQWRL to answer queries on steps involved in particular scale-up procedure

EOR Ontology: Risk Based Decision Making Pilot

SPE 109628

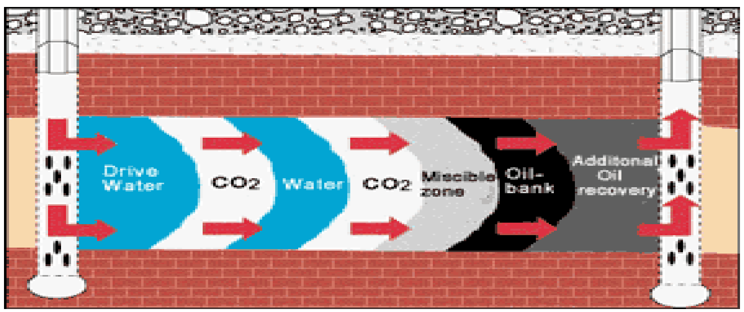
A Procedure for Assessing the Value of Oilfield Sensors

R. B. Gilbert, L. W. Lake, SPE, C. J. Jablonowski, SPE, J.W. Jennings, SPE, E.J. Nunez, SPE, The University of Texas at Austin

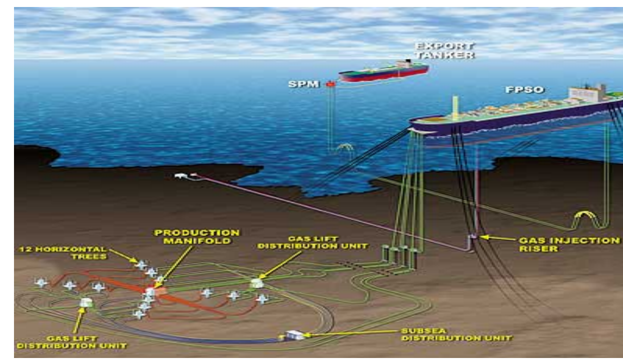
Portfolio Decisions

Estimate the value of implementing sensors in four different advanced hydrocarbon recovery scenarios.

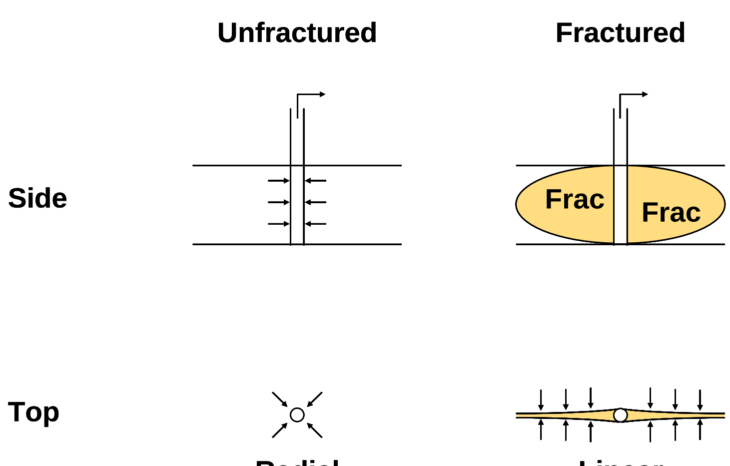
Mature Onshore



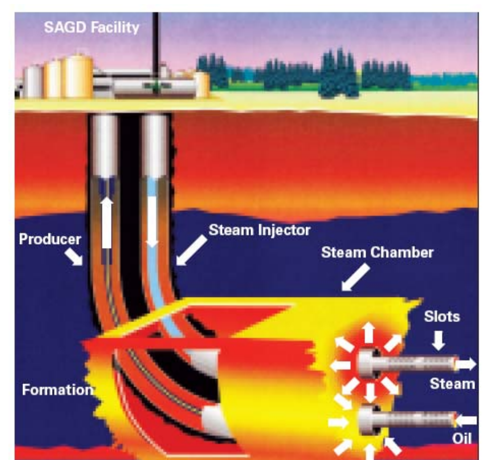
Deepwater



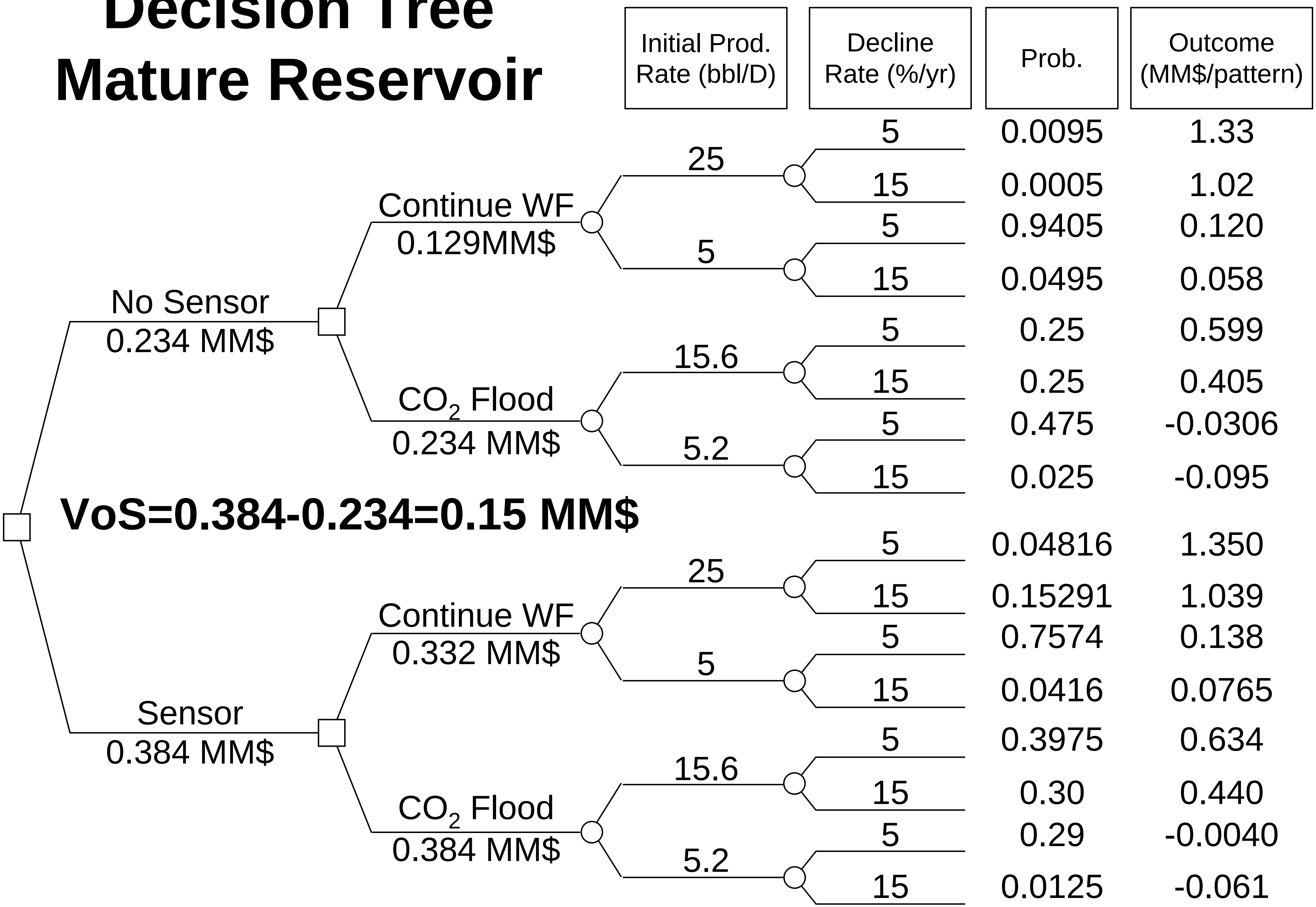
Tight Gas



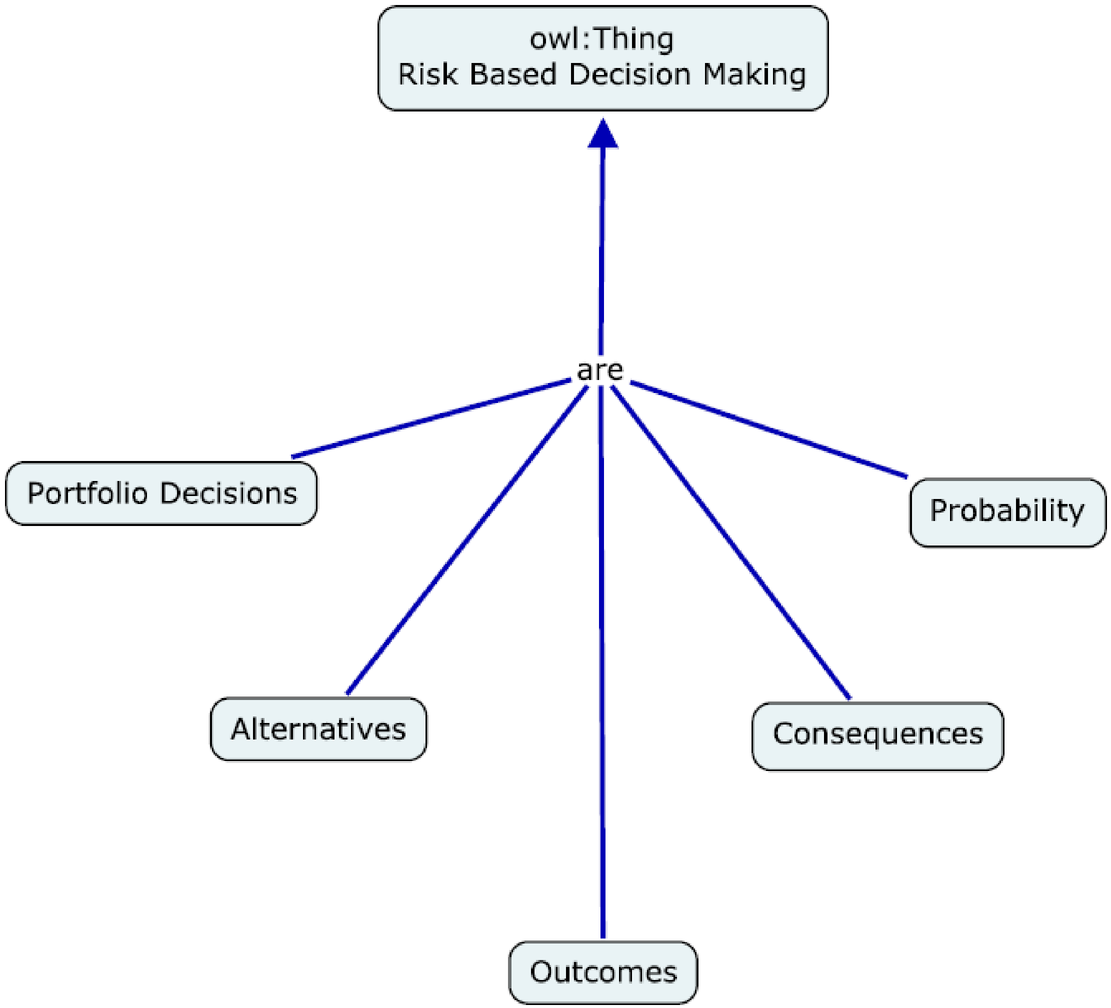
Heavy Oil



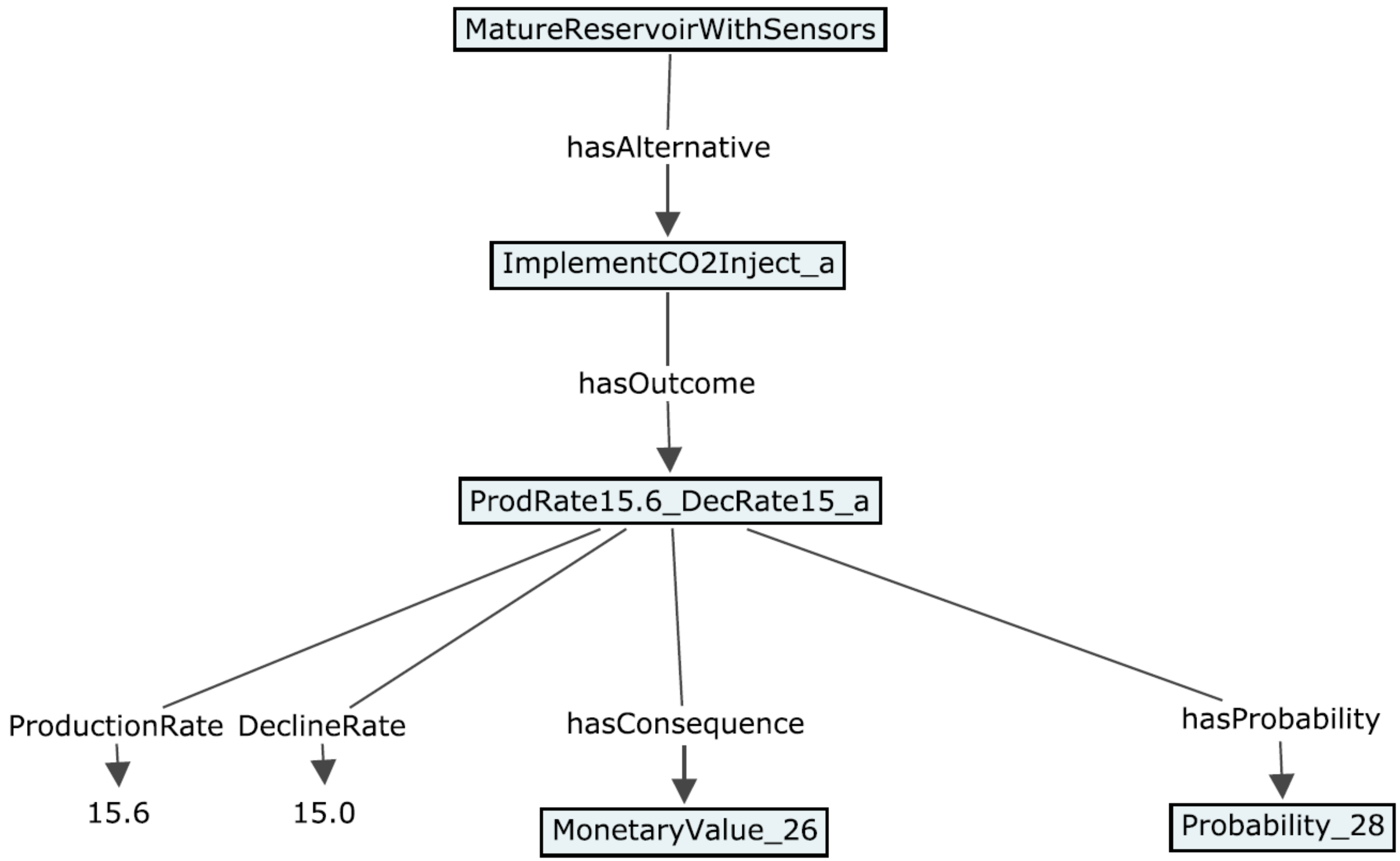
Decision Tree
Mature Reservoir

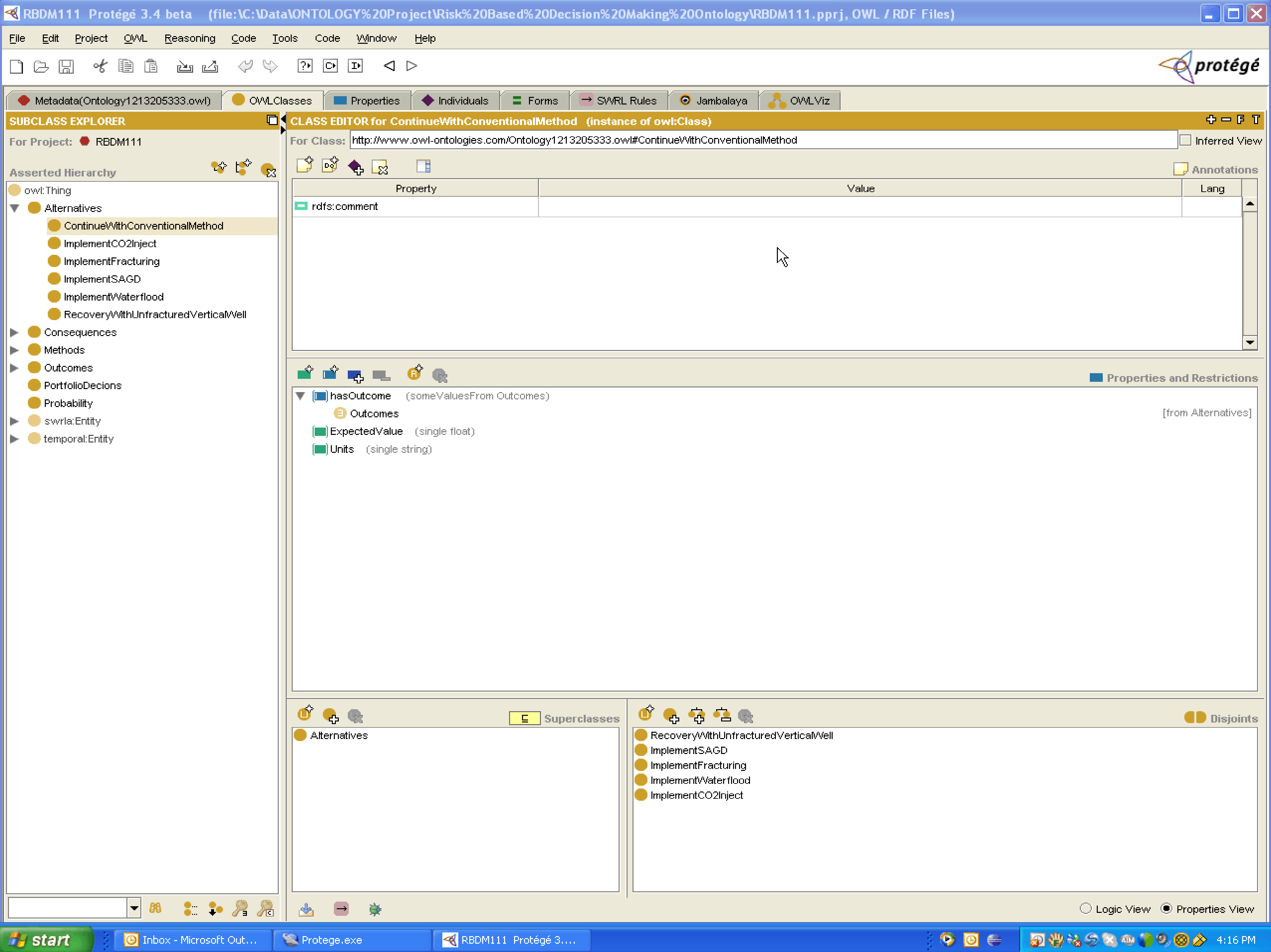


Framework of Classes



Mature Reservoir Instances




RBDM111 Protégé 3.4 beta (file:\C:\Data\ONTOLOGY%20Project\Risk%20Based%20Decision%20Making%20Ontology\RBDM111.pprj, OWL / RDF Files)
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ImplementFracturing
ImplementSAGD
ImplementWaterflood
RecoveryWithUnfracturedVerticalWell
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Outcomes
PortfolioDecions
Probability
swrla:Entity
temporal:Entity
CLASS EDITOR for ContinueWithConventionalMethod (instance of owl:Class)
For Class: http://www.owl-ontologies.com/Ontology1213205333.owl#ContinueWithConventionalMethod
Inferred View
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rdfs:comment
Properties and Restrictions
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[from Alternatives]
ExpectedValue (single float)
Units (single string)
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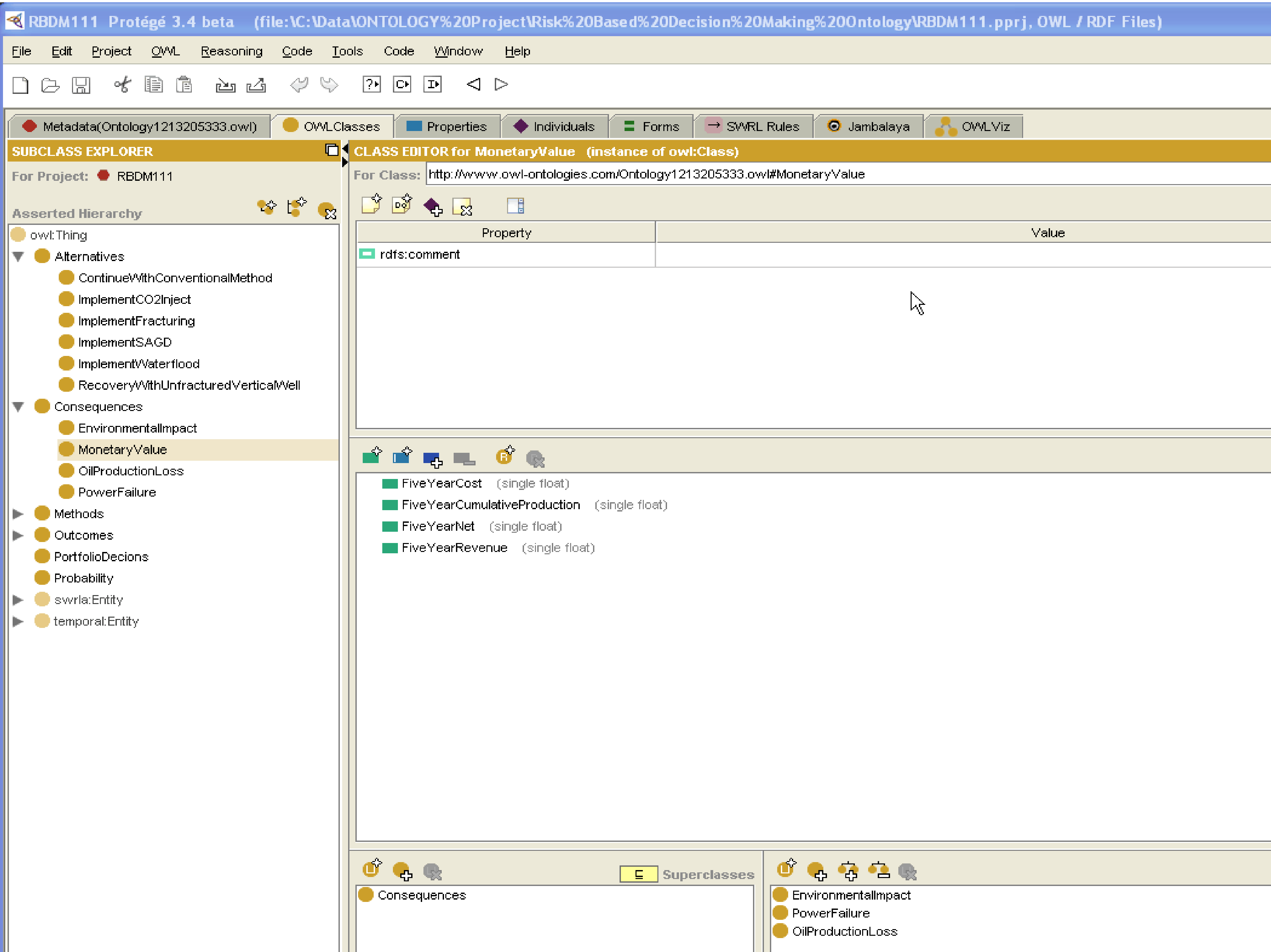
Disjoints
RecoveryWithUnfracturedVerticalWell
ImplementSAGD
ImplementFracturing
ImplementWaterflood
ImplementCO2Inject
Logic View
Properties View
start
Inbox - Microsoft Out...
Protege.exe
RBDM111 Protégé 3....
4:16 PM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CLASS EDITOR for MonetaryValue (instance of owl:Class)
For Class: http://www.owl-ontologies.com/Ontology1213205333.owl#MonetaryValue
Property
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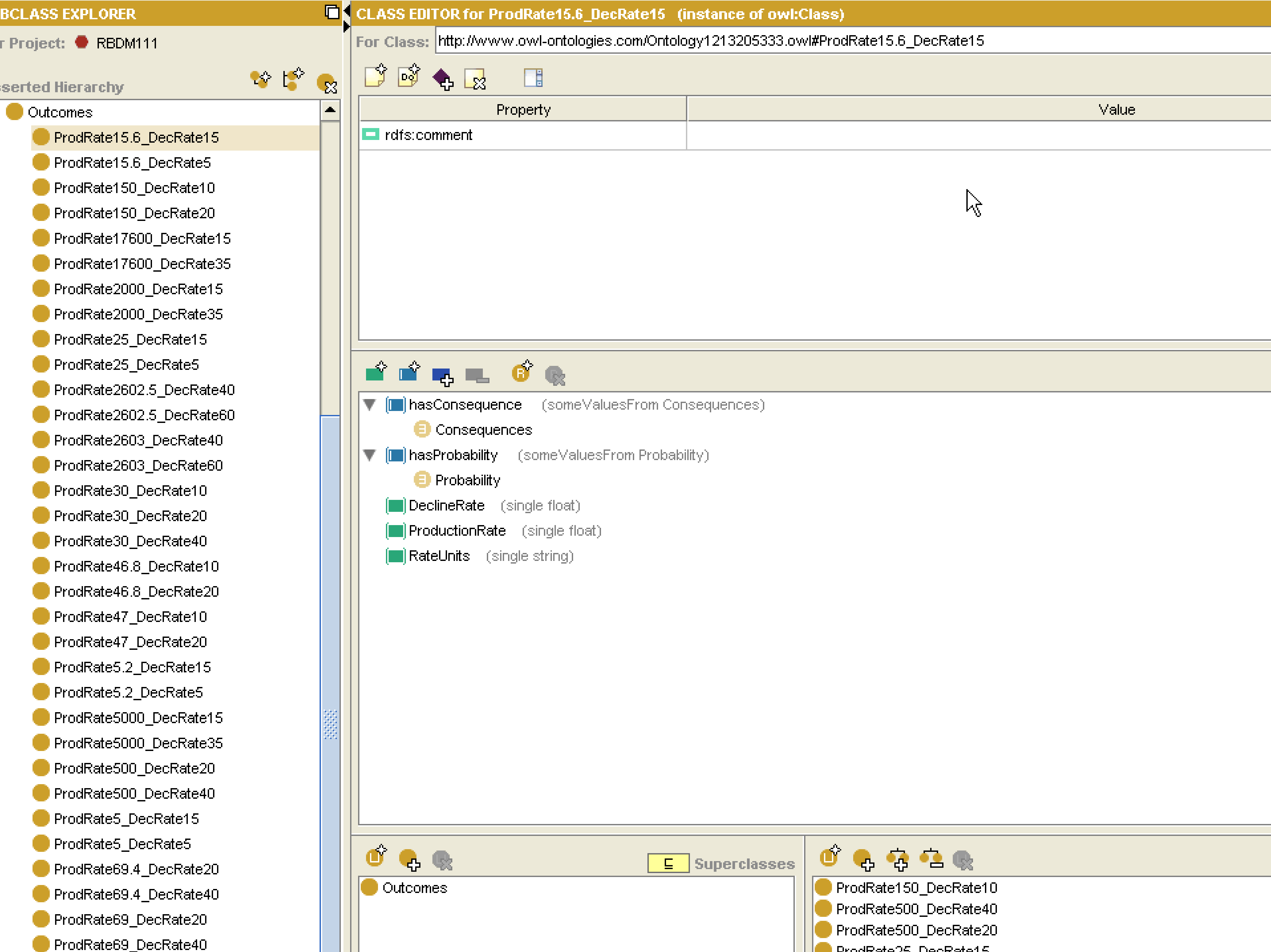
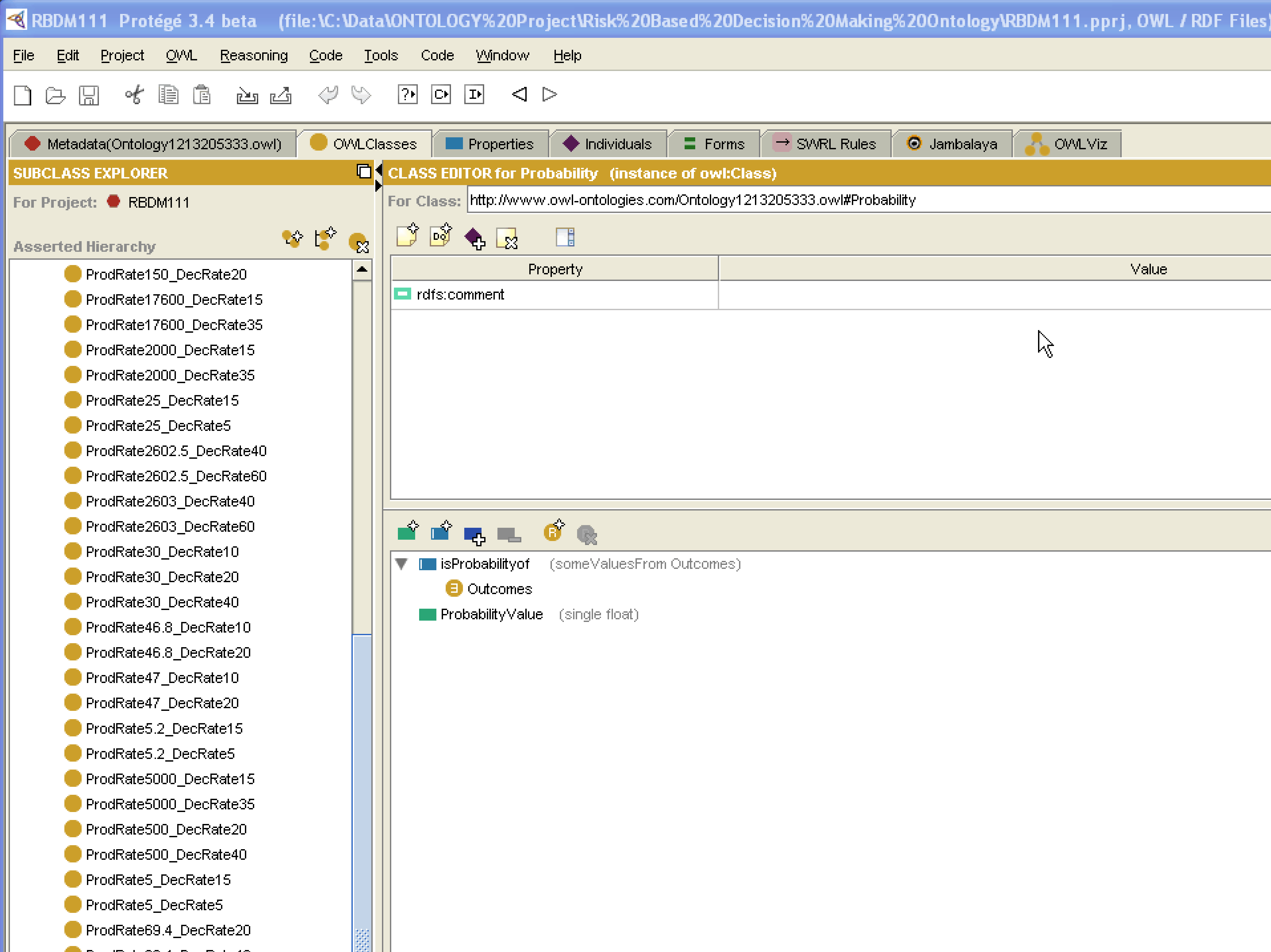
rdfs:comment
FiveYearCost (single float)
FiveYearCumulativeProduction (single float)
FiveYearNet (single float)
FiveYearRevenue (single float)
Superclasses
Consequences
EnvironmentalImpact
PowerFailure
OilProductionLoss


BCLASS EXPLORER
r Project: RBDM111
serted Hierarchy
Outcomes
ProdRate15.6_DecRate15
ProdRate15.6_DecRate5
ProdRate150_DecRate10
ProdRate150_DecRate20
ProdRate17600_DecRate15
ProdRate17600_DecRate35
ProdRate2000_DecRate15
ProdRate2000_DecRate35
ProdRate25_DecRate15
ProdRate25_DecRate5
ProdRate2602.5_DecRate40
ProdRate2602.5_DecRate60
ProdRate2603_DecRate40
ProdRate2603_DecRate60
ProdRate30_DecRate10
ProdRate30_DecRate20
ProdRate30_DecRate40
ProdRate46.8_DecRate10
ProdRate46.8_DecRate20
ProdRate47_DecRate10
ProdRate47_DecRate20
ProdRate5.2_DecRate15
ProdRate5.2_DecRate5
ProdRate5000_DecRate15
ProdRate5000_DecRate35
ProdRate500_DecRate20
ProdRate500_DecRate40
ProdRate5_DecRate15
ProdRate5_DecRate5
ProdRate69.4_DecRate20
ProdRate69.4_DecRate40
ProdRate69_DecRate20
ProdRate69_DecRate40
CLASS EDITOR for ProdRate15.6_DecRate15 (instance of owl:Class)
For Class: http://www.owl-ontologies.com/Ontology1213205333.owl#ProdRate15.6_DecRate15
Property
Value
rdfs:comment
hasConsequence (someValuesFrom Consequences)
Consequences
hasProbability (someValuesFrom Probability)
Probability
DeclineRate (single float)
ProductionRate (single float)
RateUnits (single string)
Superclasses
Outcomes
ProdRate150_DecRate10
ProdRate500_DecRate40
ProdRate500_DecRate20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ProdRate17600_DecRate15
ProdRate17600_DecRate35
ProdRate2000_DecRate15
ProdRate2000_DecRate35
ProdRate25_DecRate15
ProdRate25_DecRate5
ProdRate2602.5_DecRate40
ProdRate2602.5_DecRate60
ProdRate2603_DecRate40
ProdRate2603_DecRate60
ProdRate30_DecRate10
ProdRate30_DecRate20
ProdRate30_DecRate40
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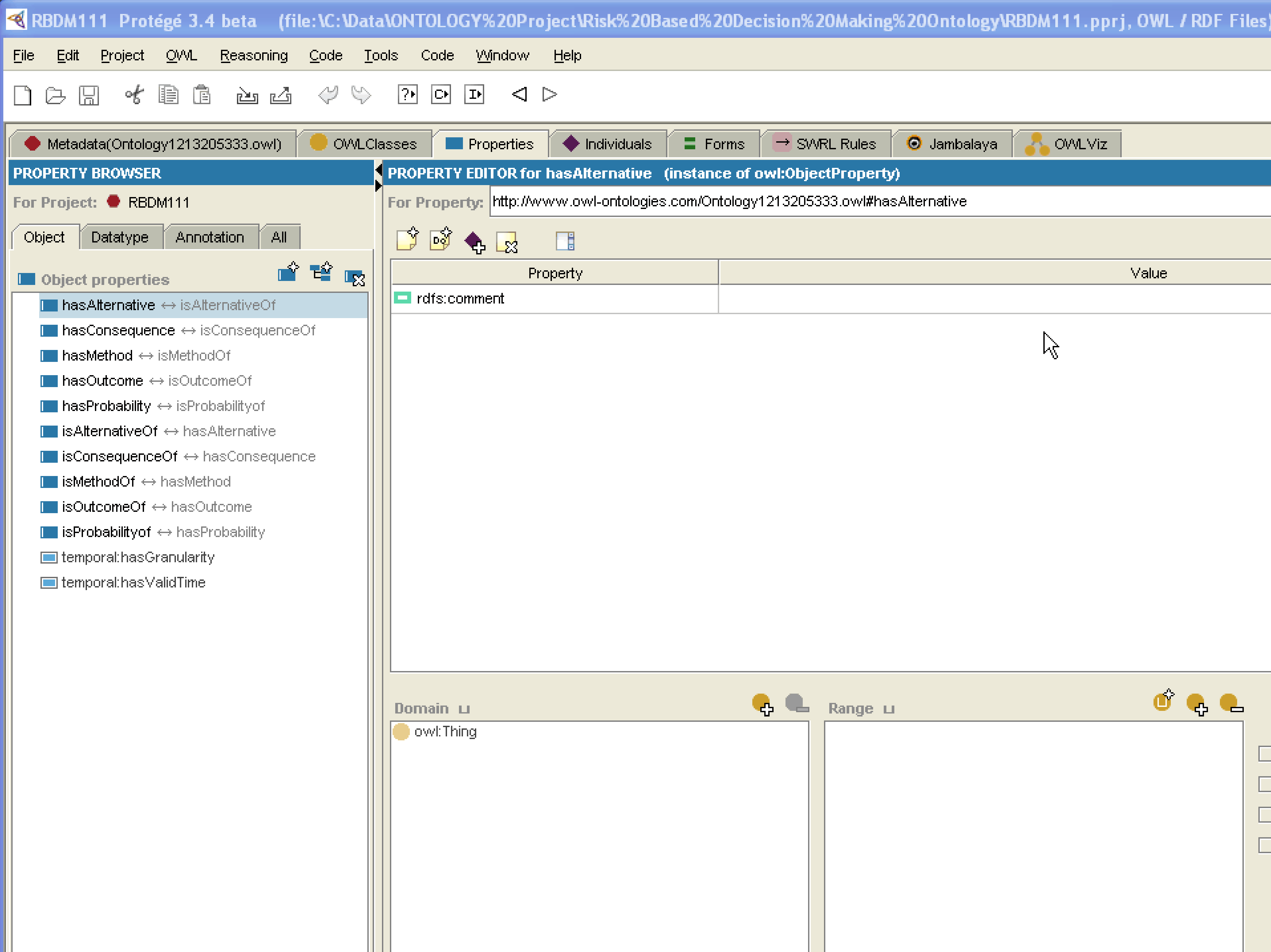
ProdRate46.8_DecRate20
ProdRate47_DecRate10
ProdRate47_DecRate20
ProdRate5.2_DecRate15
ProdRate5.2_DecRate5
ProdRate5000_DecRate15
ProdRate5000_DecRate35
ProdRate500_DecRate20
ProdRate500_DecRate40
ProdRate5_DecRate15
ProdRate5_DecRate5
ProdRate69.4_DecRate20
CLASS EDITOR for Probability (instance of owl:Class)
For Class: http://www.owl-ontologies.com/Ontology1213205333.owl#Probability
Property
Value
rdfs:comment
isProbabilityof (someValuesFrom Outcomes)
Outcomes
ProbabilityValue (single float)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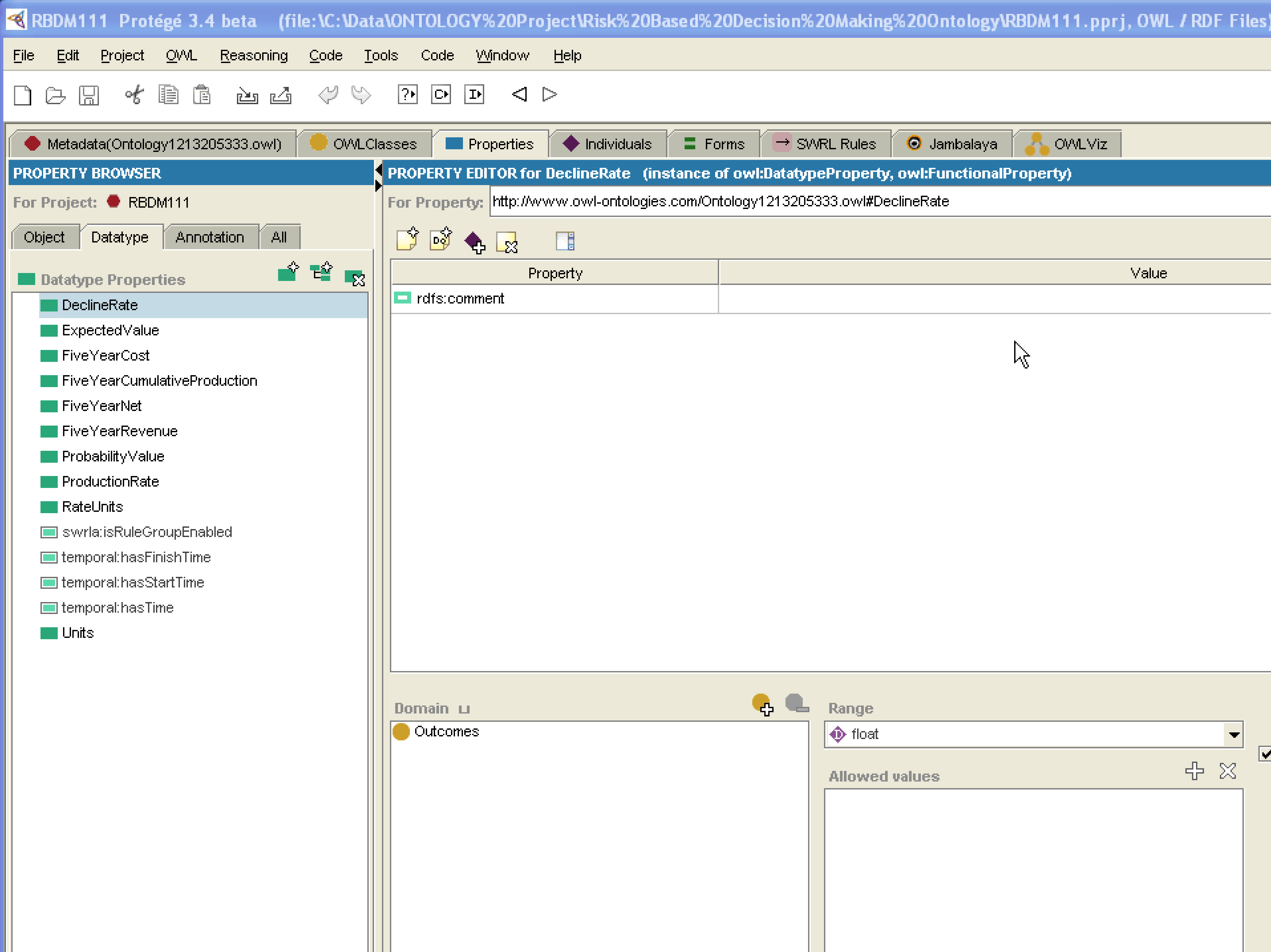
PROPERTY BROWSER
For Project: RBDM111
Object Datatype Annotation All
Object properties
hasAlternative ↔ isAlternativeOf
hasConsequence ↔ isConsequenceOf
hasMethod ↔ isMethodOf
hasOutcome ↔ isOutcomeOf
hasProbability ↔ isProbabilityof
isAlternativeOf ↔ hasAlternative
isConsequenceOf ↔ hasConsequence
isMethodOf ↔ hasMethod
isOutcomeOf ↔ hasOutcome
isProbabilityof ↔ hasProbability
temporal:hasGranularity
temporal:hasValidTime
PROPERTY EDITOR for hasAlternative (instance of owl:ObjectProperty)
For Property: http://www.owl-ontologies.com/Ontology1213205333.owl#hasAlternative
Property
Value
rdfs:comment
Domain ⊔
owl:Thing
Range ⊔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FiveYearNet
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temporal:hasFinishTime
temporal:hasStartTime
temporal:hasTime
Units
PROPERTY EDITOR for DeclineRate (instance of owl:DatatypeProperty, owl:FunctionalProperty)
For Property: http://www.owl-ontologies.com/Ontology1213205333.owl#DeclineRate
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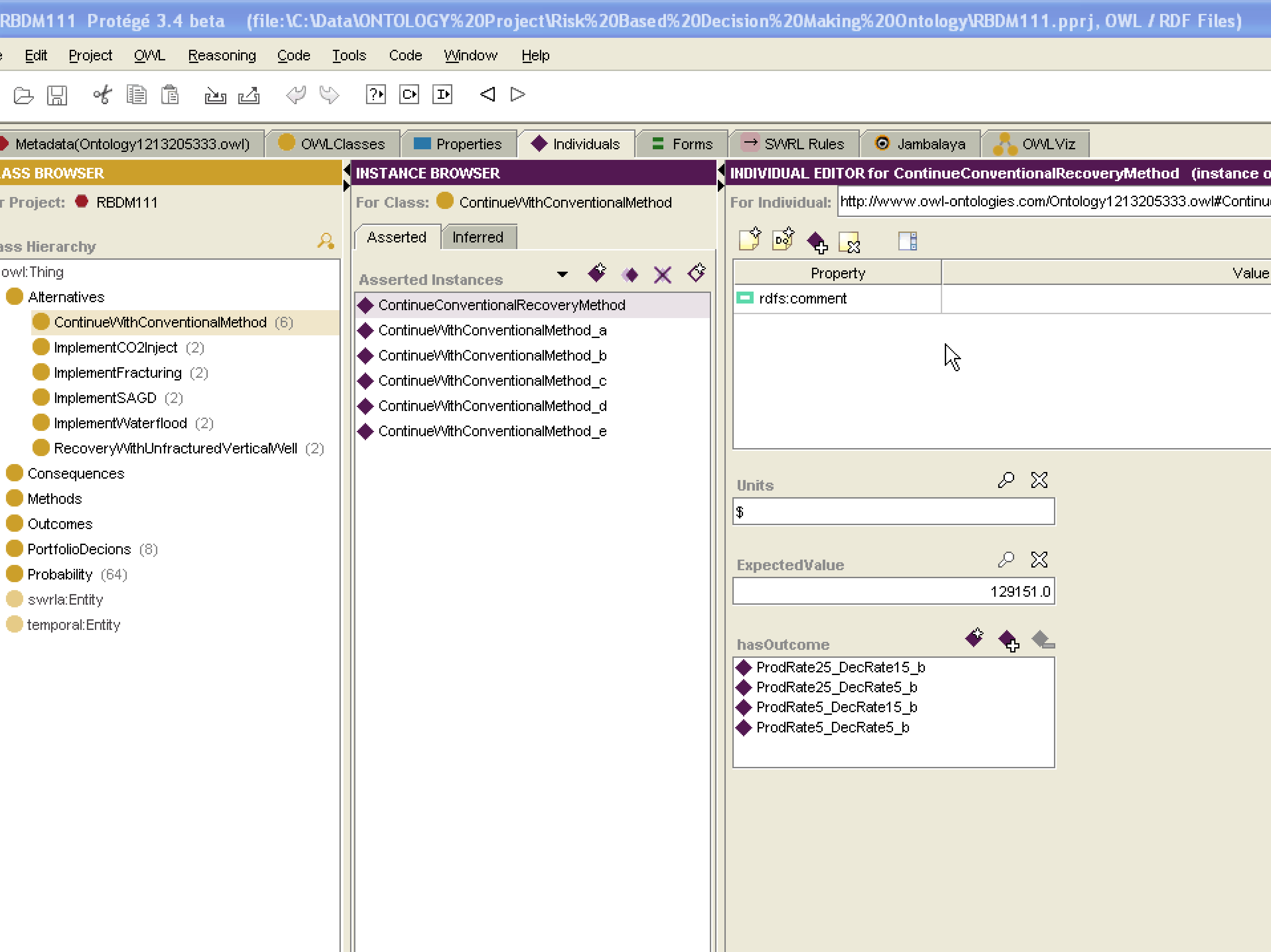
Allowed values


RBDM111 Protégé 3.4 beta (file:\C:\Data\ONTOLOGY%20Project\Risk%20Based%20Decision%20Making%20Ontology\RBDM111.pprj, OWL / RDF Files)
Edit Project OWL Reasoning Code Tools Code Window Help
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r Project: RBDM111
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owl:Thing
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ImplementSAGD (2)
ImplementWaterflood (2)
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For Class: ContinueWithConventionalMethod
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ContinueWithConventionalMethod_a
ContinueWithConventionalMethod_b
ContinueWithConventionalMethod_c
ContinueWithConventionalMethod_d
ContinueWithConventionalMethod_e
INDIVIDUAL EDITOR for ContinueConventionalRecoveryMethod (instance o
For Individual: http://www.owl-ontologies.com/Ontology1213205333.owl#Continu
Property
Value
rdfs:comment
Units
$
ExpectedValue
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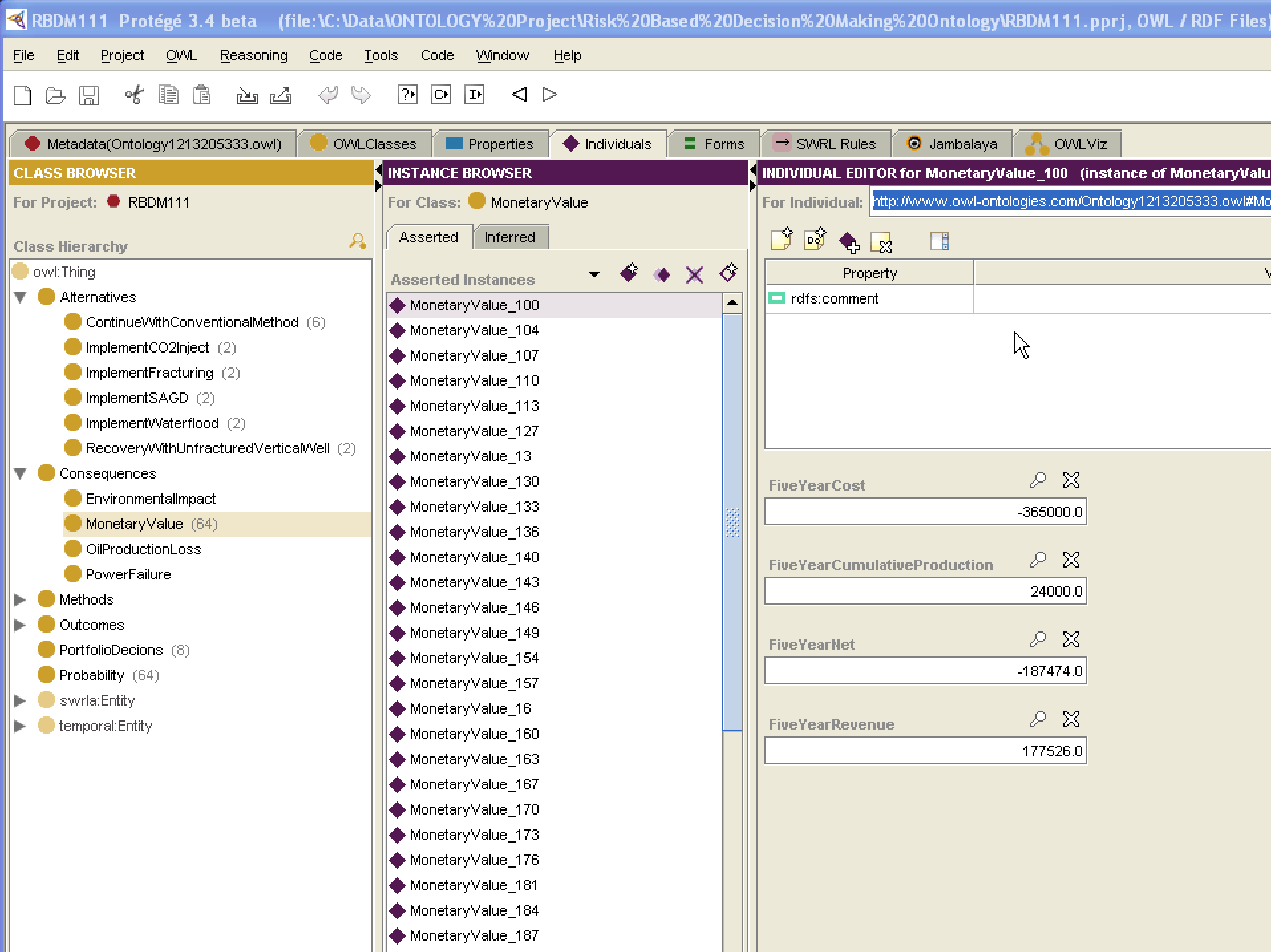
hasOutcome
ProdRate25_DecRate15_b
ProdRate25_DecRate5_b
ProdRate5_DecRate15_b
ProdRate5_DecRate5_b



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ImplementFracturing (2)
ImplementSAGD (2)
ImplementWaterflood (2)
RecoveryWithUnfracturedVerticalWell (2)
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MonetaryValue (64)
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Probability (64)
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temporal:Entity
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For Class: MonetaryValue
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MonetaryValue_104
MonetaryValue_107
MonetaryValue_110
MonetaryValue_113
MonetaryValue_127
MonetaryValue_13
MonetaryValue_130
MonetaryValue_133
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MonetaryValue_140
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MonetaryValue_149
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MonetaryValue_157
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MonetaryValue_160
MonetaryValue_163
MonetaryValue_167
MonetaryValue_170
MonetaryValue_173
MonetaryValue_176
MonetaryValue_181
MonetaryValue_184
MonetaryValue_187
INDIVIDUAL EDITOR for MonetaryValue_100 (instance of MonetaryValu
For Individual: http://www.owl-ontologies.com/Ontology1213205333.owl#Mo
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FiveYearCumulativeProduction
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FiveYearNet
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FiveYearRevenue
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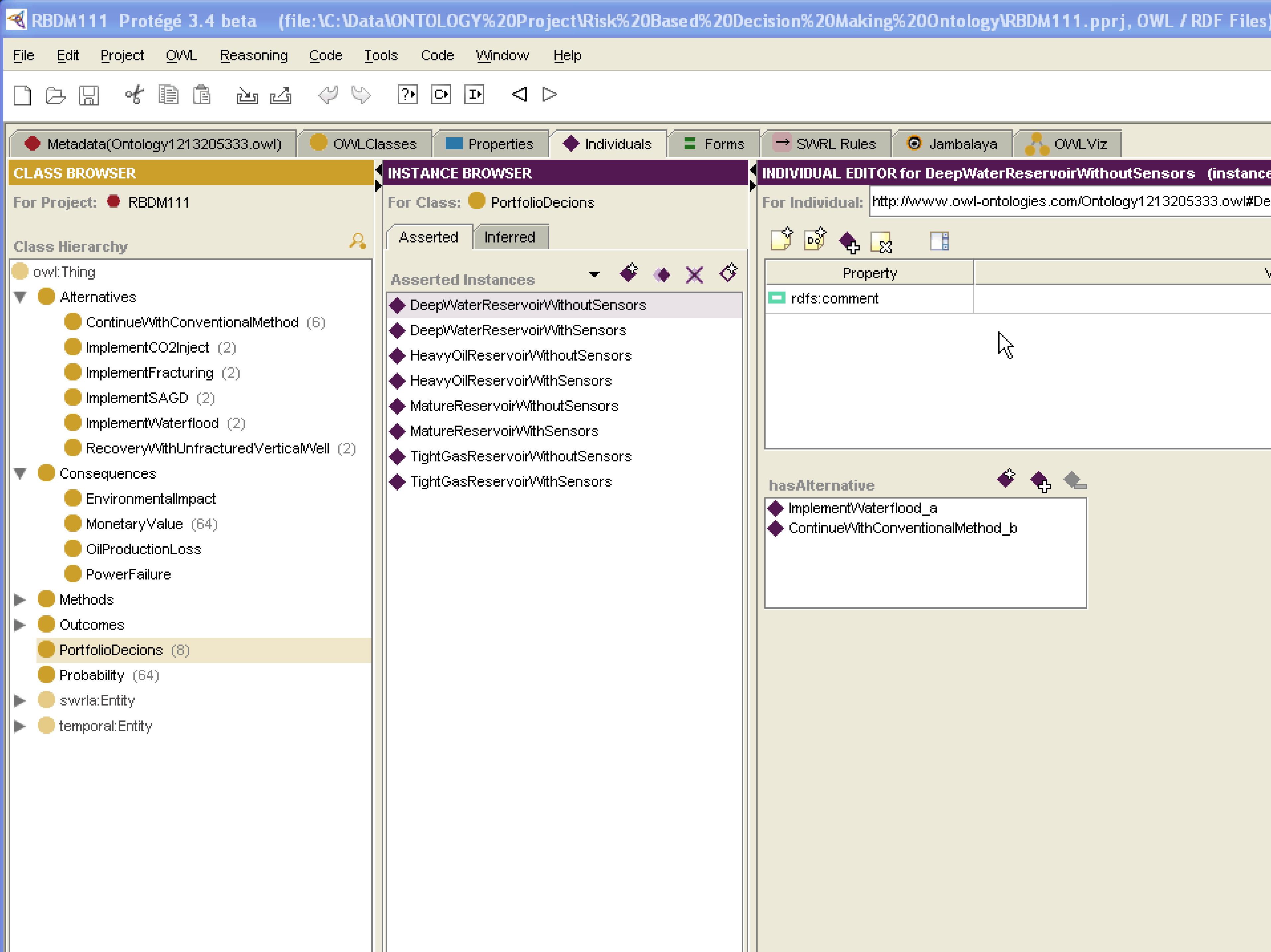
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For Project: RBDM111
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ImplementFracturing (2)
ImplementSAGD (2)
ImplementWaterflood (2)
RecoveryWithUnfracturedVerticalWell (2)
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DeepWaterReservoirWithSensors
HeavyOilReservoirWithoutSensors
HeavyOilReservoirWithSensors
MatureReservoirWithoutSensors
MatureReservoirWithSensors
TightGasReservoirWithoutSensors
TightGasReservoirWithSensors
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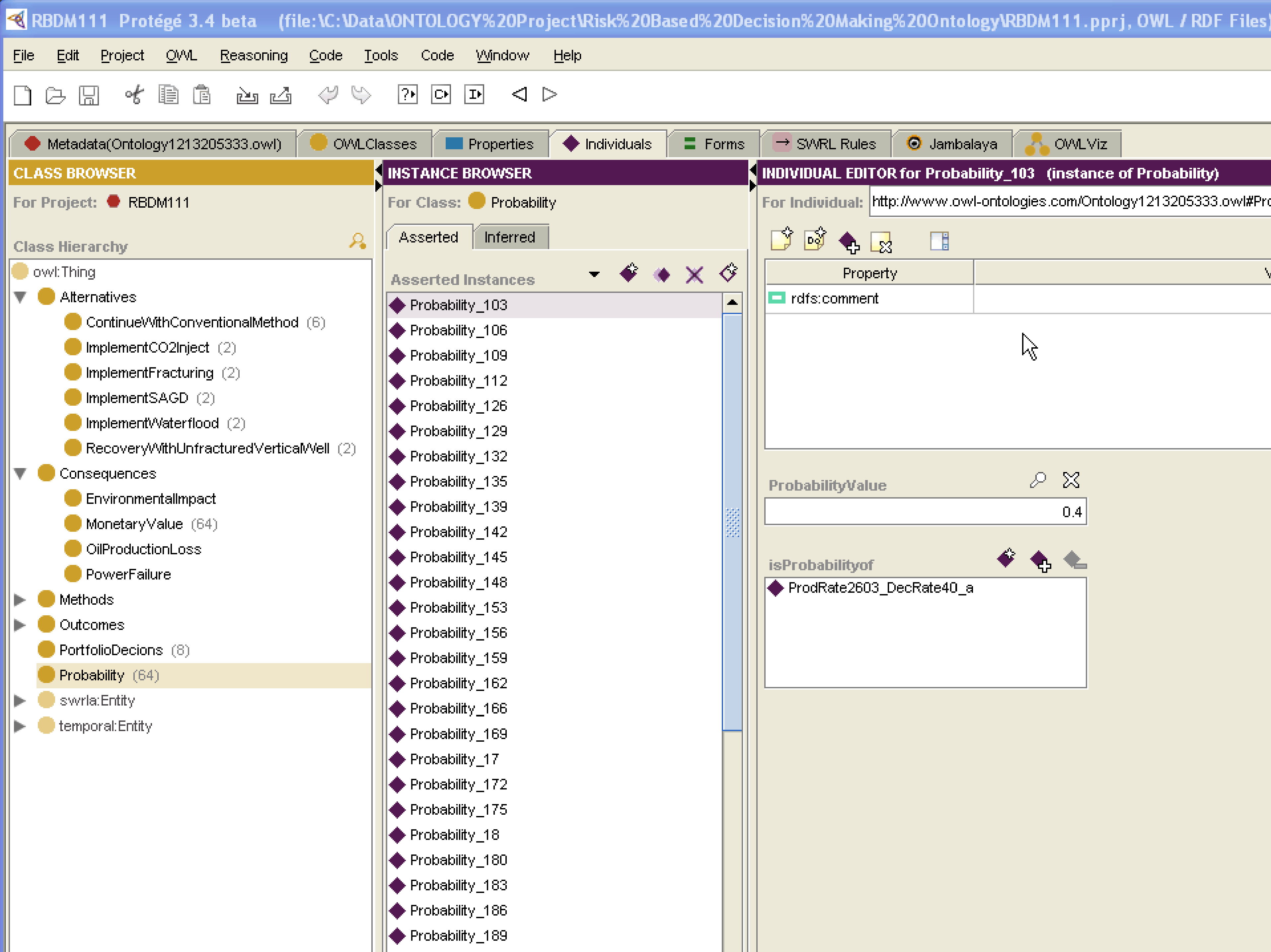
rdfs:comment
hasAlternative
ImplementWaterflood_a
ContinueWithConventionalMethod_b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Probability_109
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Probability_126
Probability_129
Probability_132
Probability_135
Probability_139
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Probability_162
Probability_166
Probability_169
Probability_17
Probability_172
Probability_175
Probability_18
Probability_180
Probability_183
Probability_186
Probability_189
INDIVIDUAL EDITOR for Probability_103 (instance of Probability)
For Individual: http://www.owl-ontologies.com/Ontology1213205333.owl#Pro
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isProbabilityof
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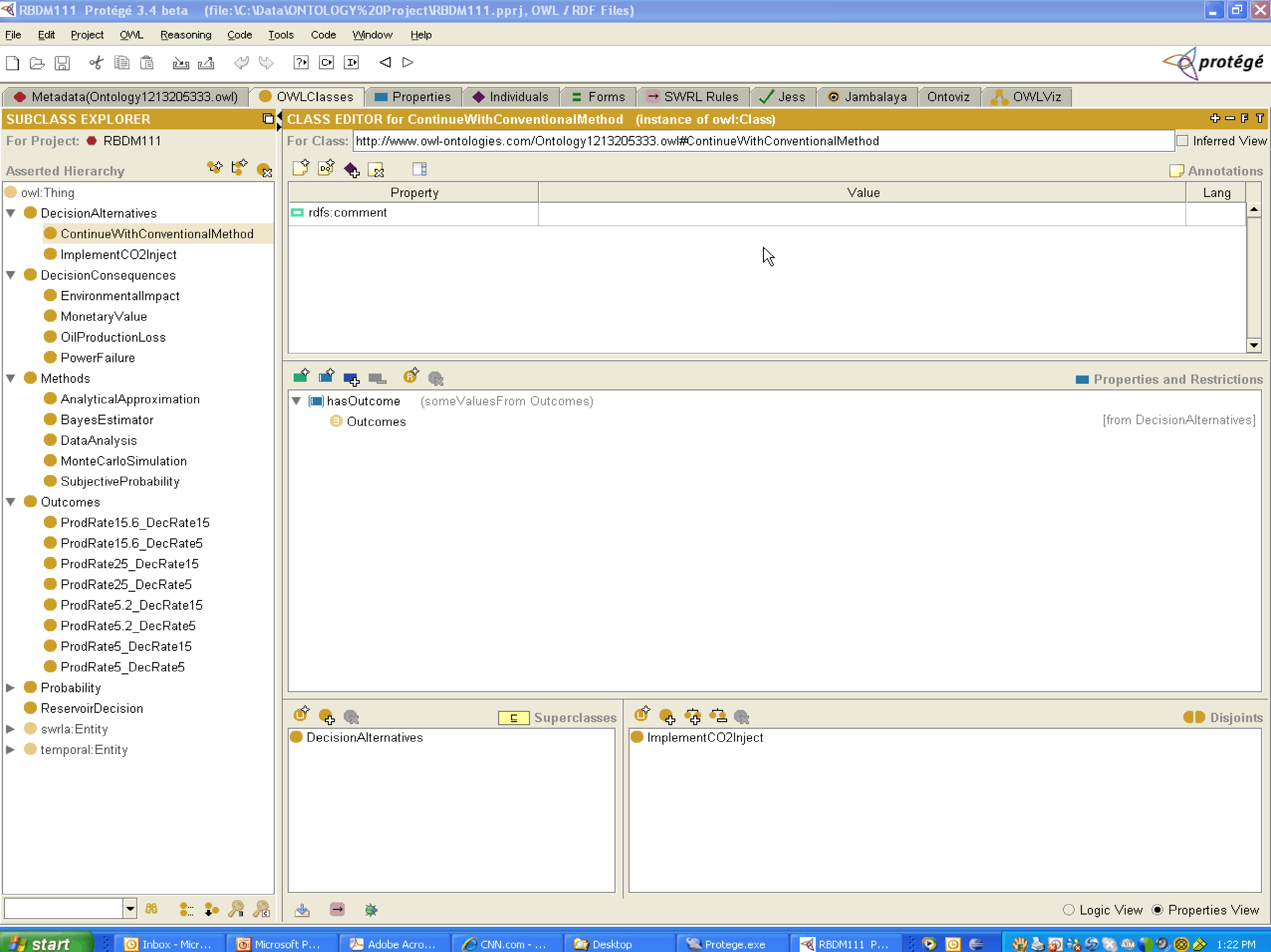
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ProdRate5.2_DecRate15
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swrla:Entity
temporal:Entity
CLASS EDITOR for ContinueWithConventionalMethod (instance of owl:Class)
For Class: http://www.owl-ontologies.com/Ontology1213205333.owl#ContinueWithConventionalMethod
Inferred View
Annotations
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rdfs:comment
Properties and Restrictions
hasOutcome (someValuesFrom Outcomes)
Outcomes
[from DecisionAlternatives]
Superclasses
DecisionAlternatives
Disjoints
ImplementCO2Inject
Logic View
Properties View
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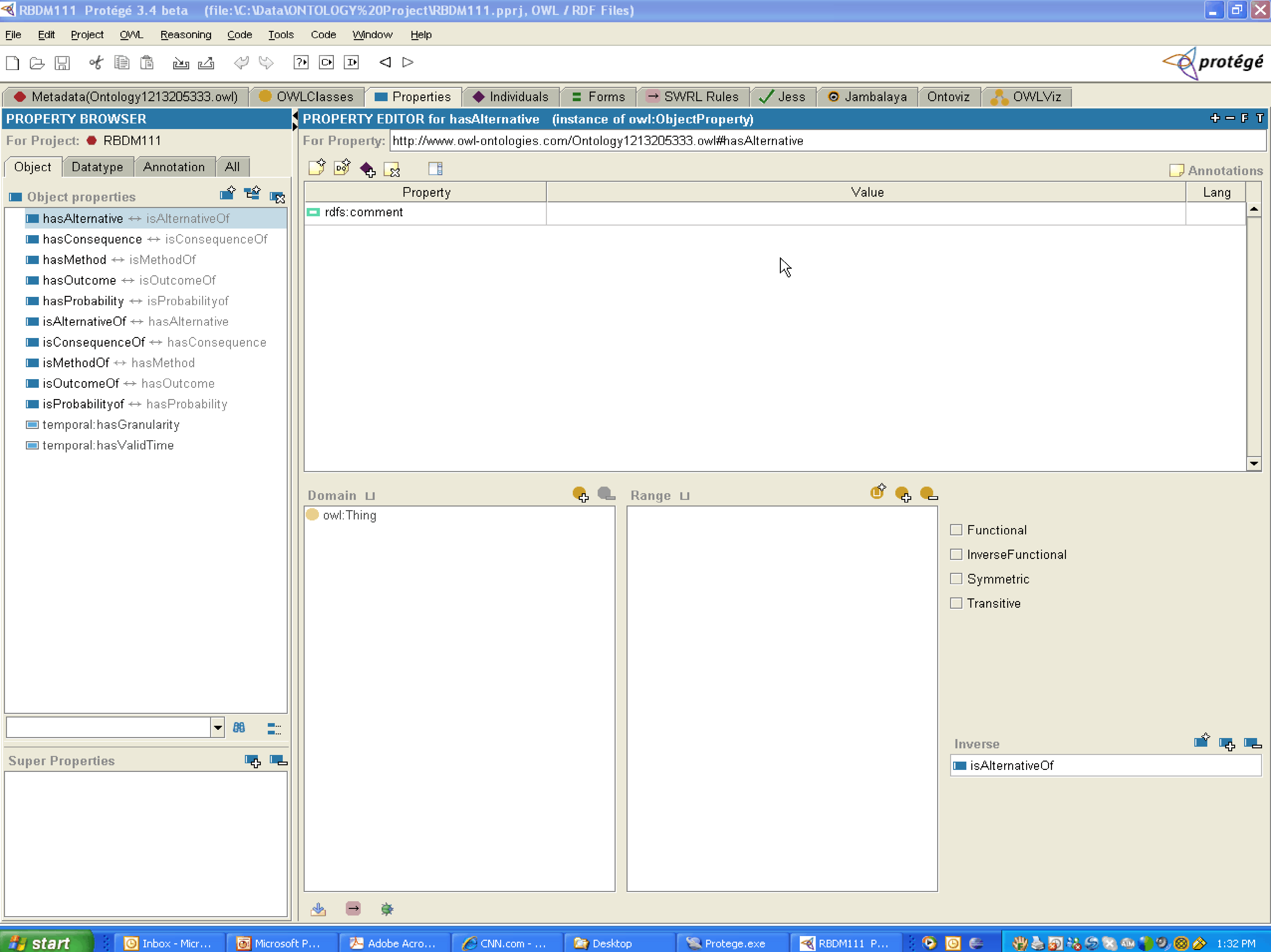
CNN.com - ...
Desktop
Protege.exe
RBDM111 P...
1:22 PM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Object properties
hasAlternative ↔ isAlternativeOf
hasConsequence ↔ isConsequenceOf
hasMethod ↔ isMethodOf
hasOutcome ↔ isOutcomeOf
hasProbability ↔ isProbabilityof
isAlternativeOf ↔ hasAlternative
isConsequenceOf ↔ hasConsequence
isMethodOf ↔ hasMethod
isOutcomeOf ↔ hasOutcome
isProbabilityof ↔ hasProbability
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temporal:hasValidTime
Super Properties
PROPERTY EDITOR for hasAlternative (instance of owl:ObjectProperty)
For Property: http://www.owl-ontologies.com/Ontology1213205333.owl#hasAlternative
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Symmetric
Transitive
Inverse
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Microsoft P...
Adobe Acro...
CNN.com - ...
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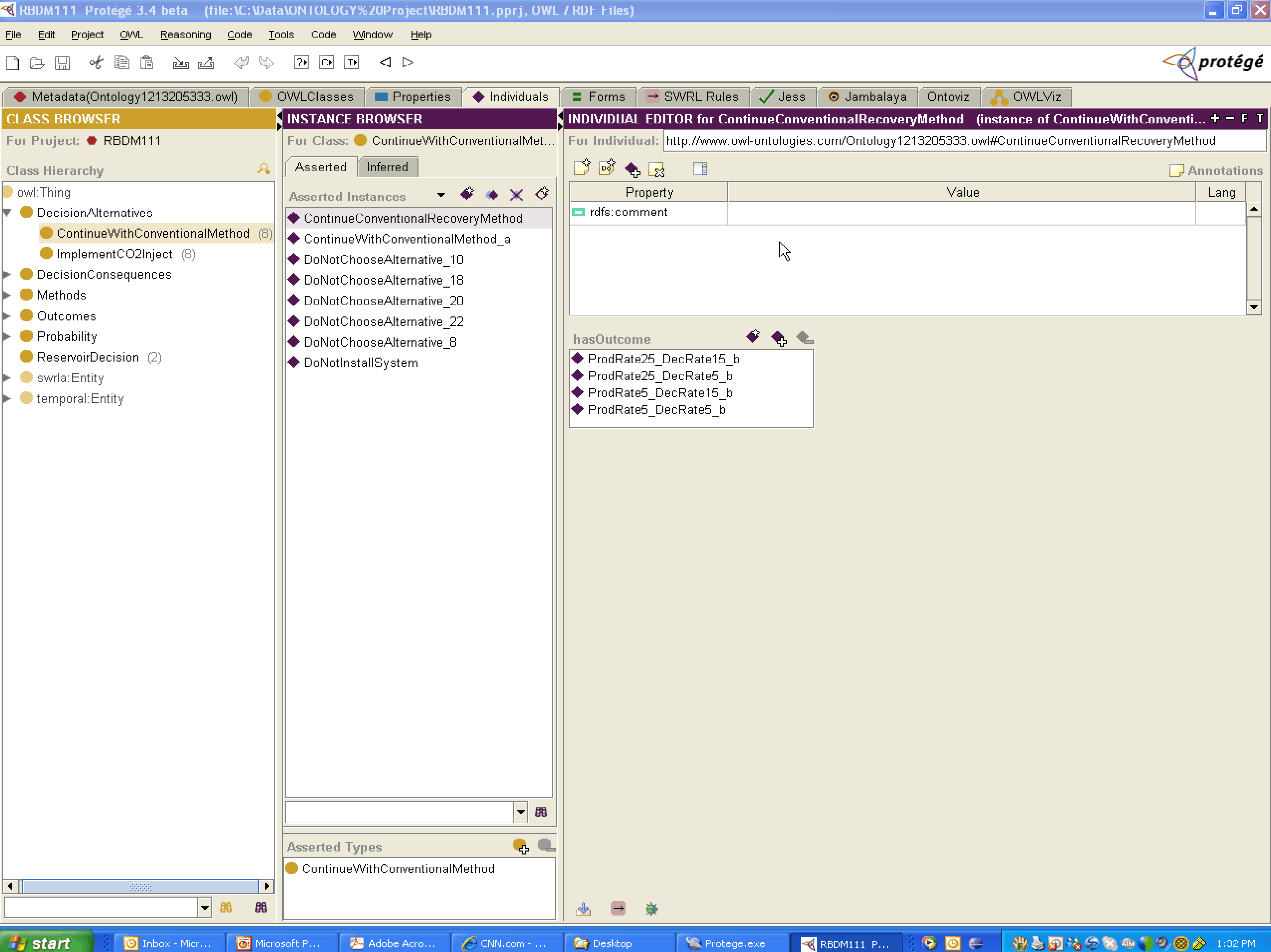
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ProdRate5_DecRate15_b
ProdRate5_DecRate5_b
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Adobe Acro...
CNN.com - ...
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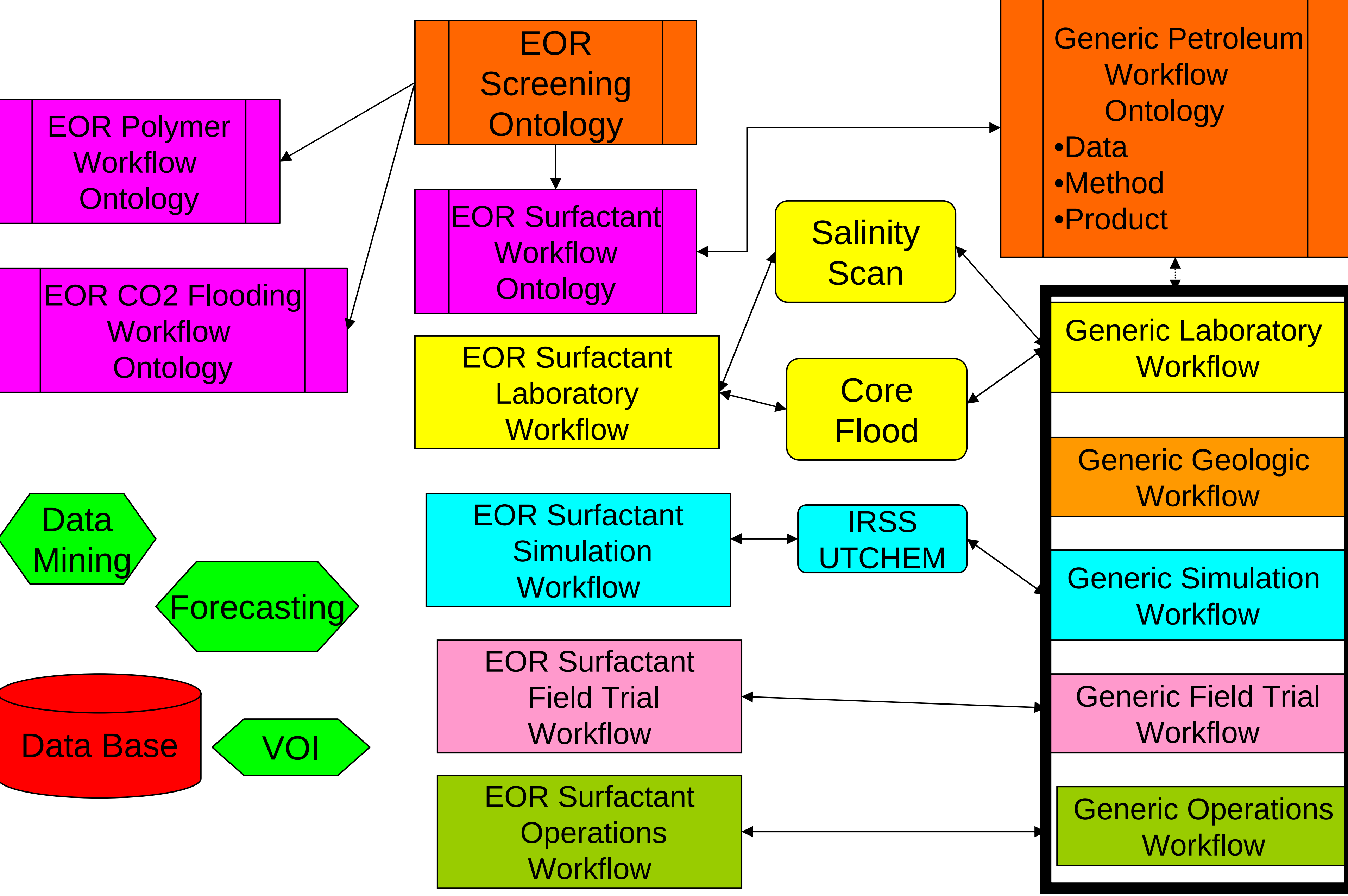
1:32 PM

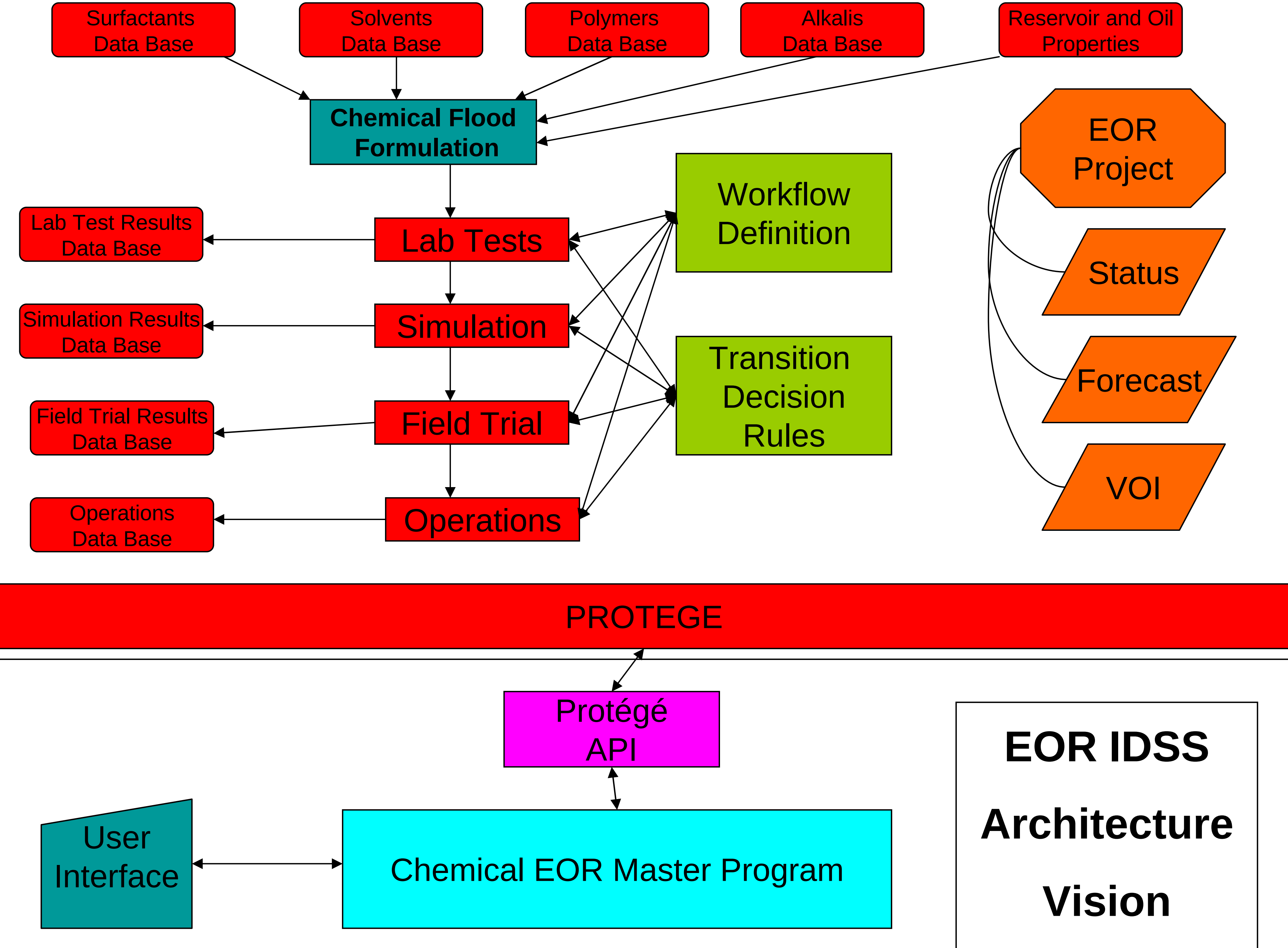
Risk Management Ontology Pilot – Summary

- General Risk Management Concepts
- Specific Application
- Captured all numbers and meanings from published SPE paper
- Now available to software agents

Some Tentative Visions



A Vision for an Ontology-Based EOR Intelligent Decision Support System


Surfactants Data Base
Solvents Data Base
Polymers Data Base
Alkalis Data Base
Reservoir and Oil Properties
Chemical Flood Formulation
Lab Test Results Data Base
Lab Tests
Simulation Results Data Base
Simulation
Field Trial Results Data Base
Field Trial
Operations Data Base
Operations
Workflow Definition
Transition Decision Rules
EOR Project
Status
Forecast
VOI
PROTEGE
Protégé API
User Interface
Chemical EOR Master Program
EOR IDSS
Architecture
Vision

Possible Queries for Decision Support System

- What EOR Methods should be considered for this reservoir?
- How do we calculate the oil recovery vs. time when this EOR Project is implemented?
- What is the total porosity/permeability of the reservoir and what is their uncertainty?
- If chemical flooding, what chemicals should be considered as candidates for surfactants, co-surfactants, alkali, polymers, co-solvents for this particular chemical flooding project?
- What is a rough estimate of the net present value (NPV) of this EOR Project?
- How much uncertainty is associated with the prediction of performance in the field?
- Given that chemicals are available and the NPV is acceptable, what is the chemical EOR formulation that we should simulate?
- How do we calculate the value of doing more lab work before going into production with this EOR method?
- Should we do a pilot test in the field?
- How do we decide whether to skip a step in the process to accelerate production?

Next Steps

- Use Lessons from Pilots to Design the Ontology – Based EOR Decision Support System.
- Prepare Software Development Plan including Knowledge Capture and Ontology Development

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