Toward an Integrated Surface and Subsurface Water Ontology

Boyan Brodaric, Torsten Hahmann
[1]Geological Survey of Canada
[2]University of Toronto

Ressources naturelles Canada
Natural Resources Canada

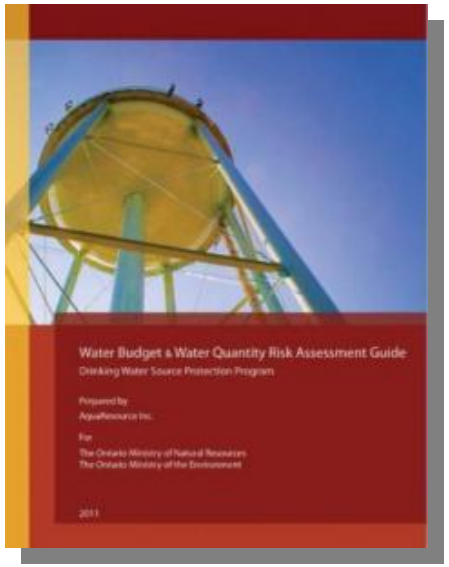
Canada

Scientific and societal drivers

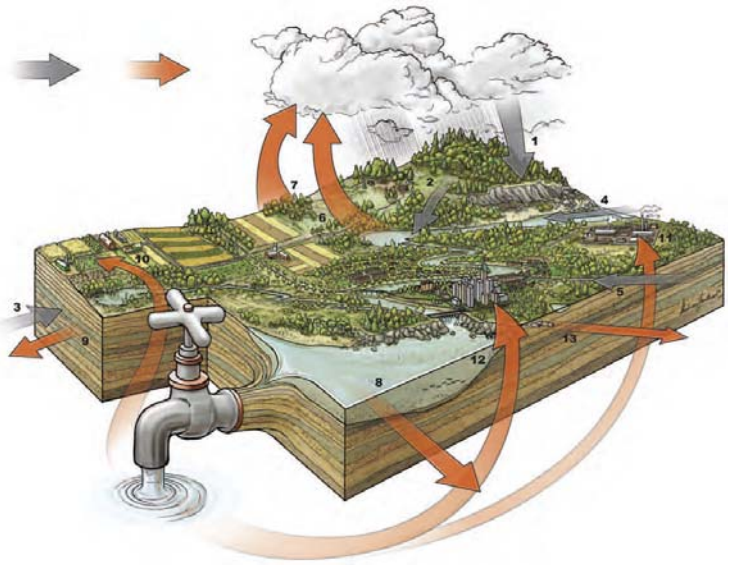
- **Integrating surface water and groundwater**

  water budgets: reporting units are ‘surface water basin’ + ‘groundwater body’

increase in regulations to develop water budgets



~25% of Canadian rely on groundwater (StatsCan 2010)



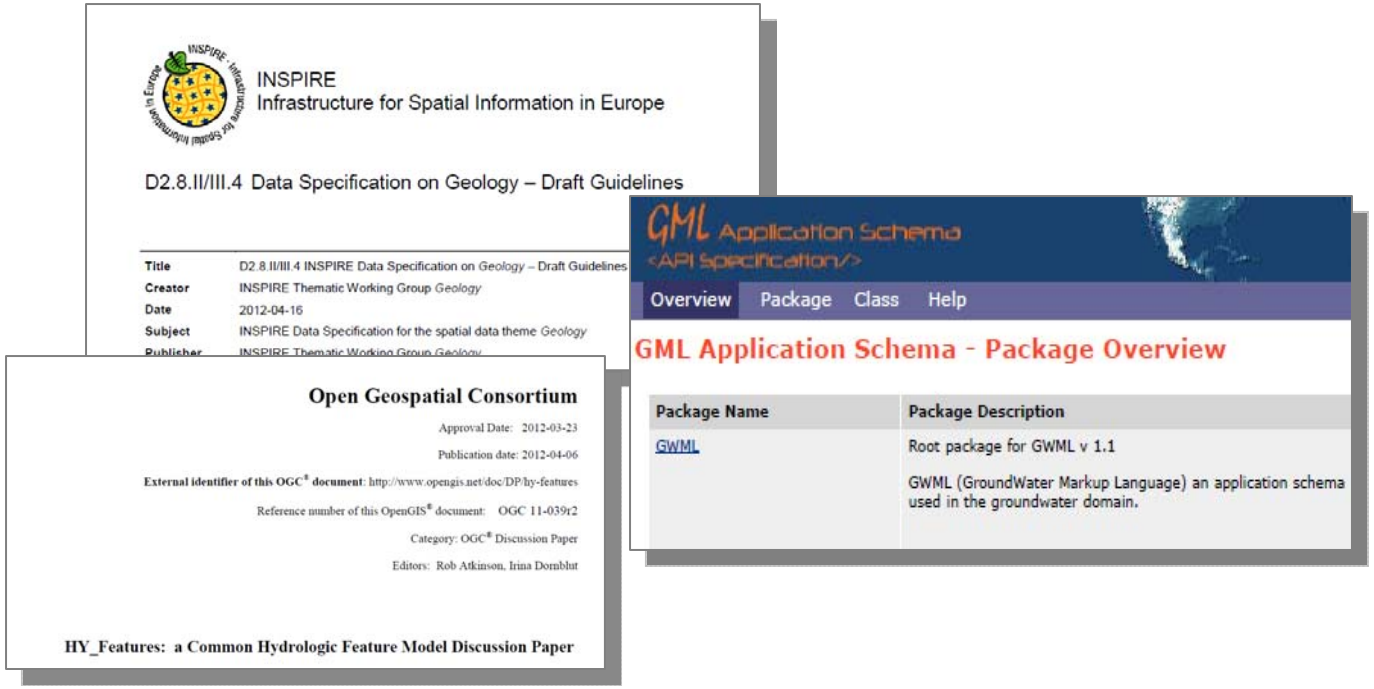
(Gauthier, 2009, Conservation Ontario)

Technologic drivers

- **SDI: a promising approach to deliver data for water budgeting**

  numerous distributed, heterogeneous data sources

  emerging, competing water data standards, e.g. ‘groundwater body’



Semantic heterogeneity

- **what's a 'groundwater body'**

specific amount of **matter** or the **object** composed of the matter?

- e.g. water body of the Ogallala aquifer is a timeless object but its water matter (slowly) changes over time
- water quality issue: the matter travels, object is fixed
- water quantity issue: the matter disappears (dry river), object persists

fills a **void**?

- water quantity and quality issue: size and connection of voids constrains quantity and flow

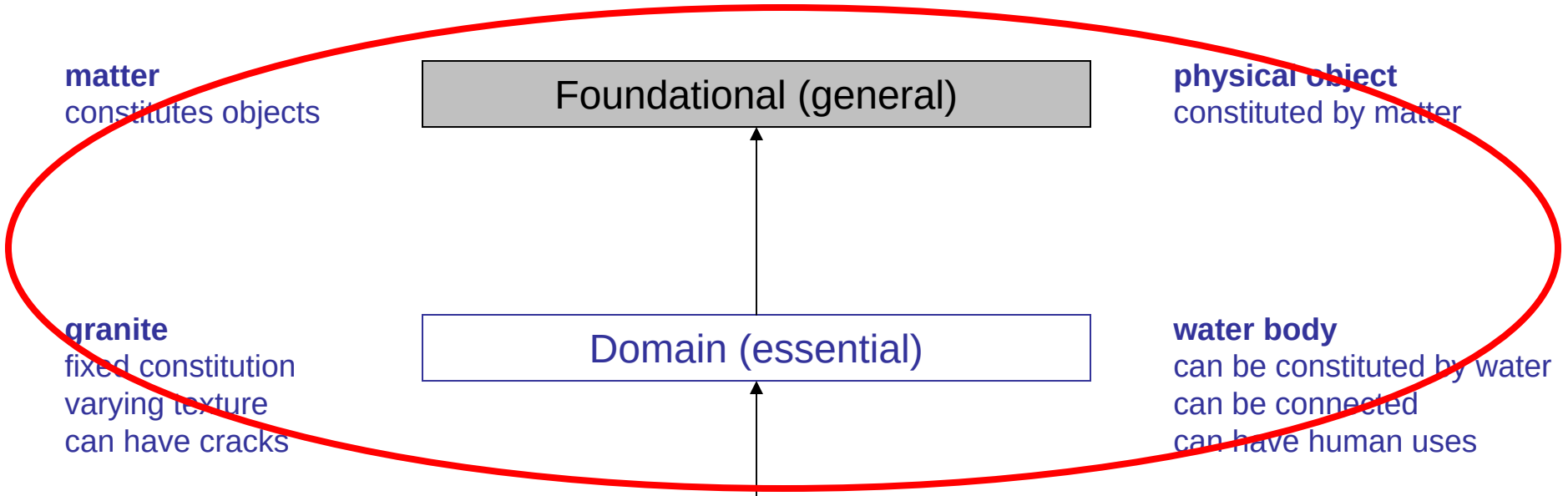
INSPIRE
object or matter?
no voids

GWML
object
object fills voids

- **use reference concepts for disambiguation**

Types of reference ontologies

- **science ontologies:** non-contextual focus



matter
constitutes objects

granite
fixed constitution
varying texture
can have cracks

countertop granite
larger crystals
non-porous (no cracks)

(after Guarino, 1998)

physical object
constituted by matter

water body
can be constituted by water
can be connected
can have human uses

(Duce & Janowicz, 2010)

Spanish River
can be dry (no water)
may not connect
not navigable

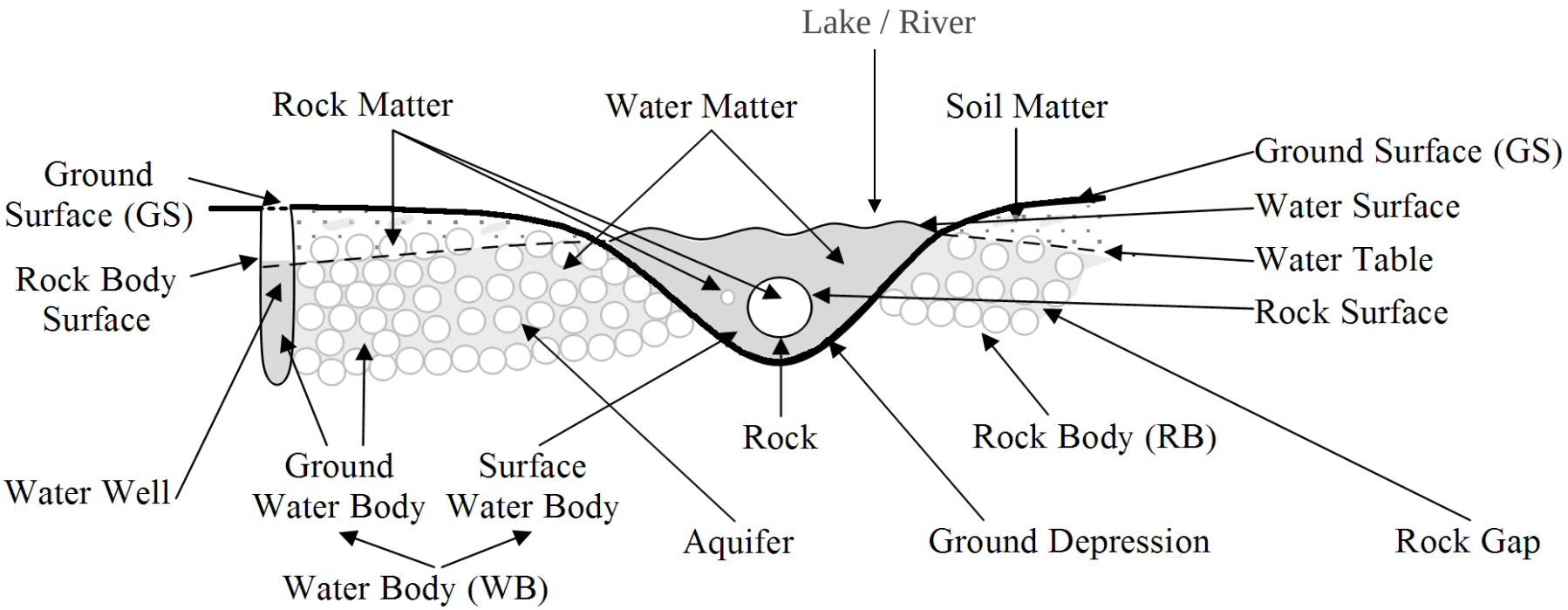
German River
has water
connected
navigable

Inland Water Ontologies… many

- **Surface Water Features**
  - lake vs pond, river vs stream? UK Ordinance Survey
  (Santos et al. 2005; Hart et al. 2007)
- **Measured Properties**
  - stream flow, level, arsenic, evapotranspiration: CUAHSI
  (Bermudez & Piasecki, 2003; Beran & Piasecki, 2009; Privesetev et al.)
- **Events and Processes**
  - floods, flow: ‘water falls but waterfall doesn’t’ (Galton & Mizoguchi, 2009)
- **Hydrogeology**
  - aquifer, groundwater body, well: SWEET
  (Tripathi & Babaie, 2008; Brodaric & Probst 2009)
- **Schema: Surface and Subsurface**
  - OGC WaterML, GWML, HydroFeatures; INSPIRE GE

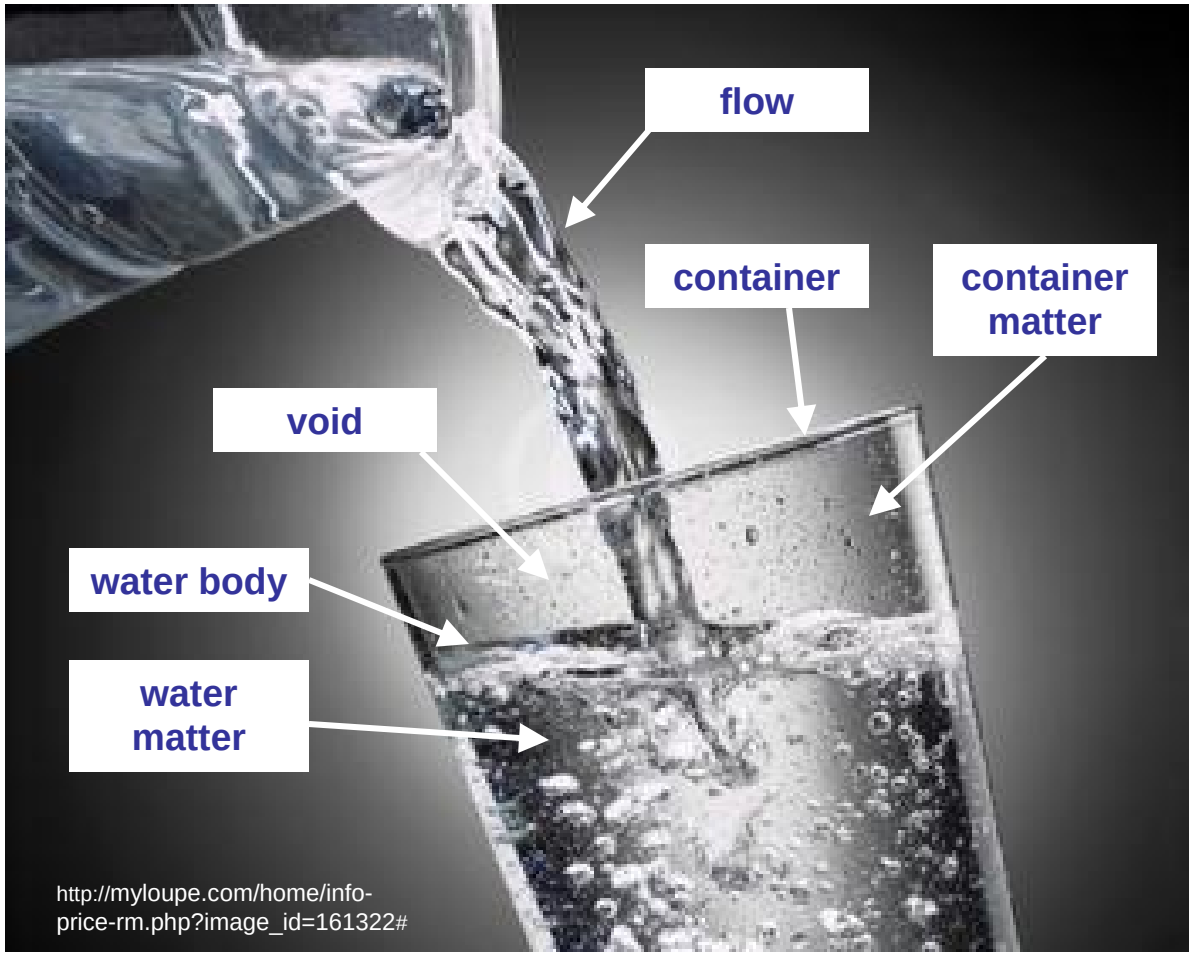
Elements of essential hydro ontology

- **contrast concepts:** different natural situations for gw & sw
- **boundary concepts:** bridge between gw & sw, e.g. flow
- **common concepts:** shared container concepts for gw & sw



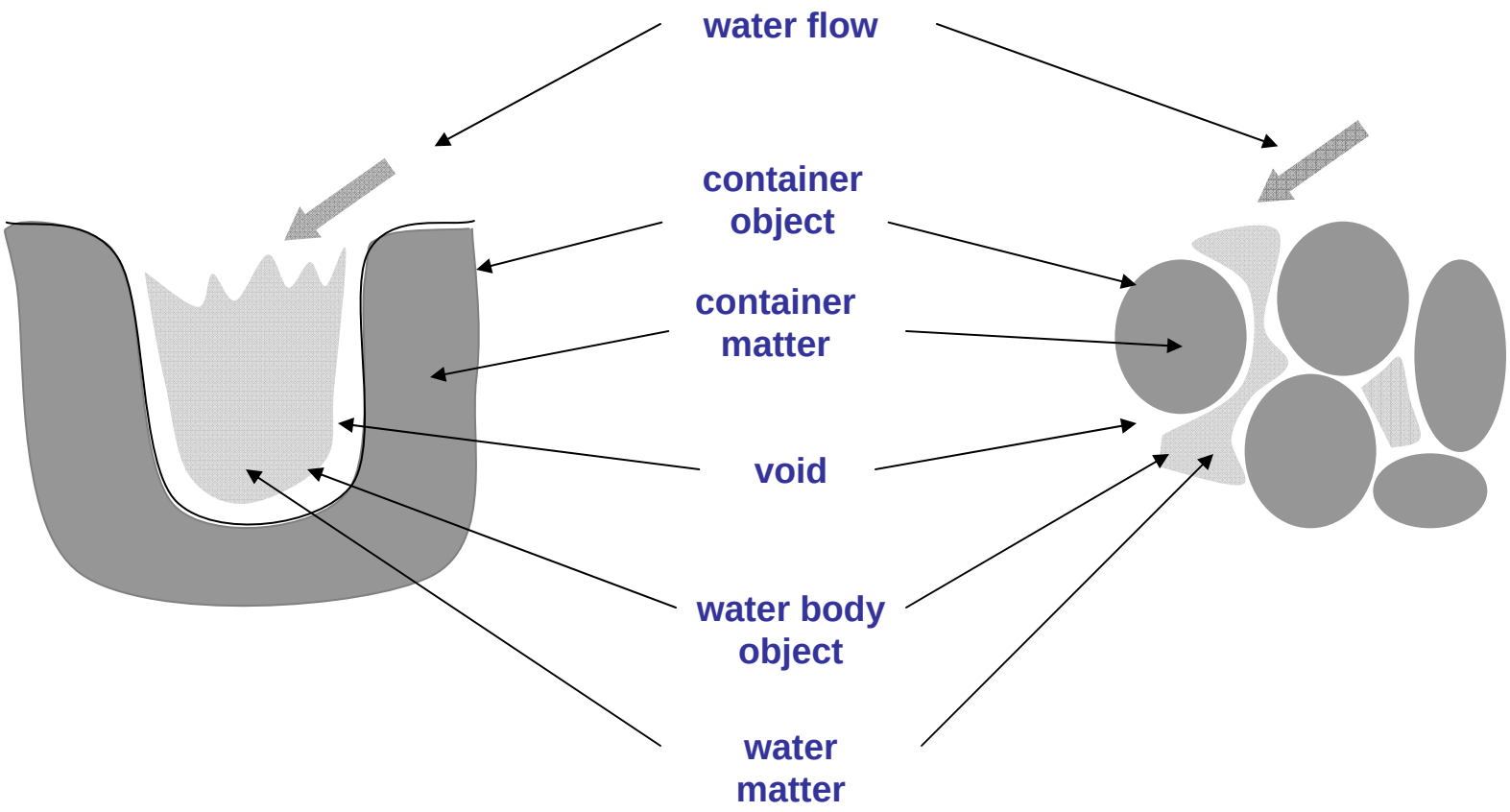
Essential common concepts

- **container schema for water**

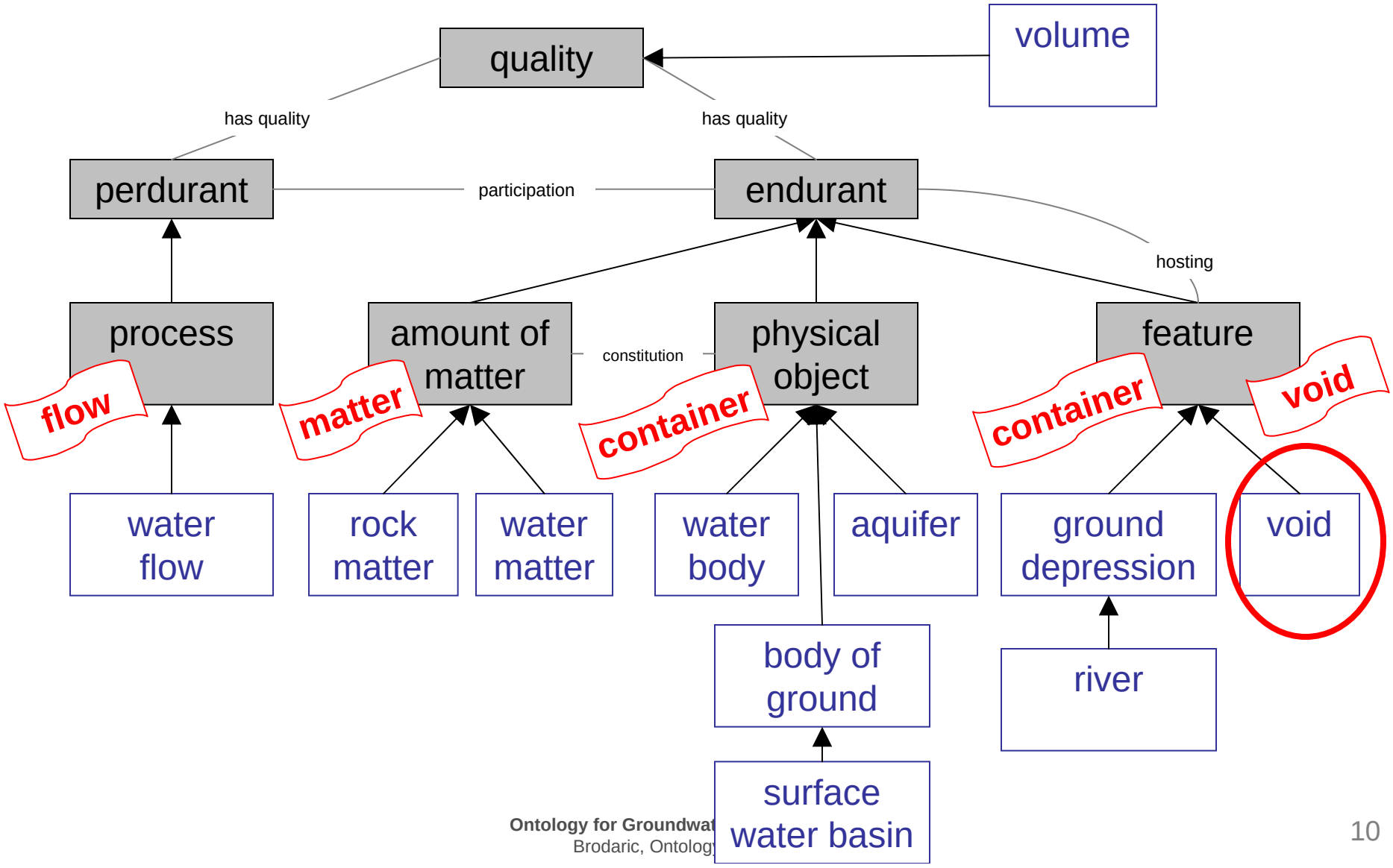


Essential common concepts

- **applied to surface water and groundwater**



DOLCE: boundary, shared, contrast concepts



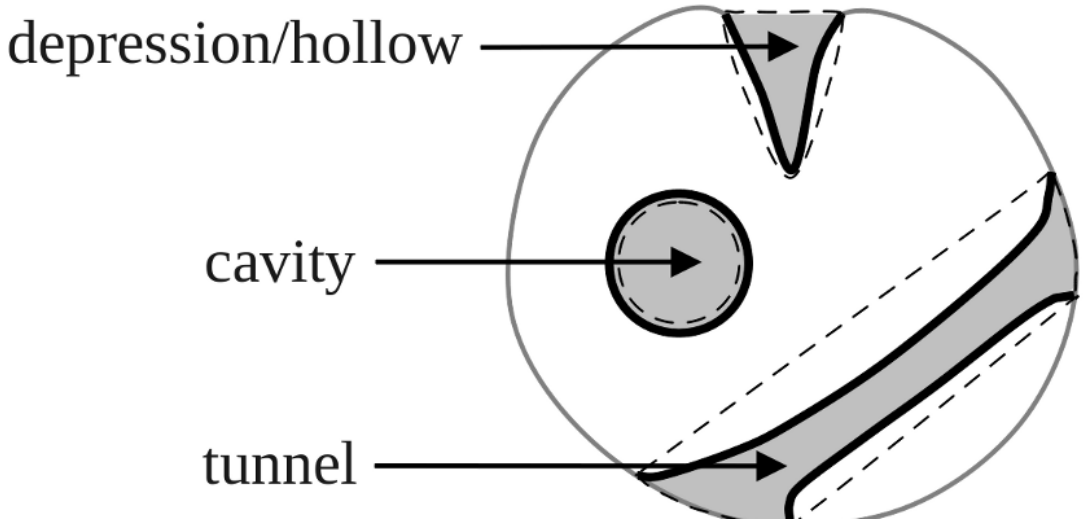
Voids

- **holes** (Casati & Varzi, 1994)

  depressions, cavities, tunnels

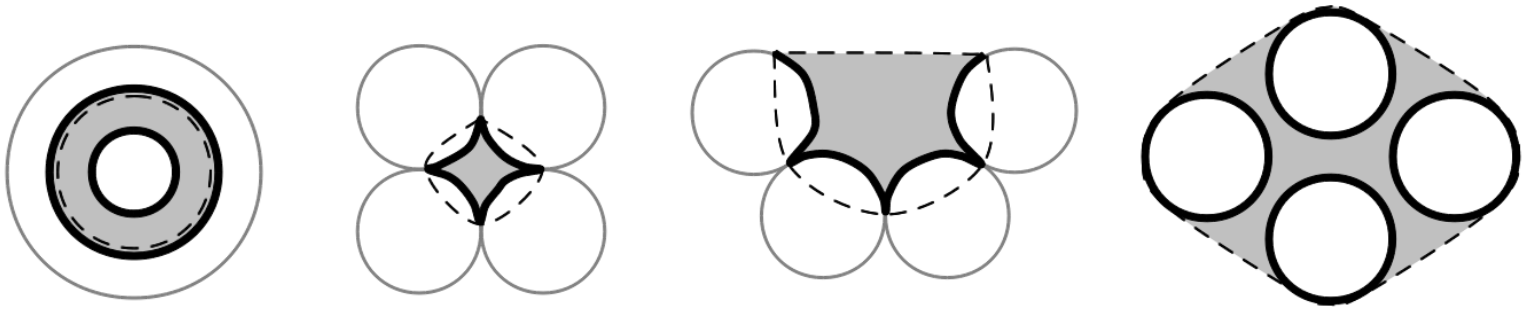
  formal logical theory (FOL)

  no gaps: suitable for surface water but not groundwater



Voids

- **gaps** (Hahmann & Brodaric, 2012)
  depressions, cavities, tunnels
  formal logical theory (FOL)
  suitable for ontology of pores in rocks

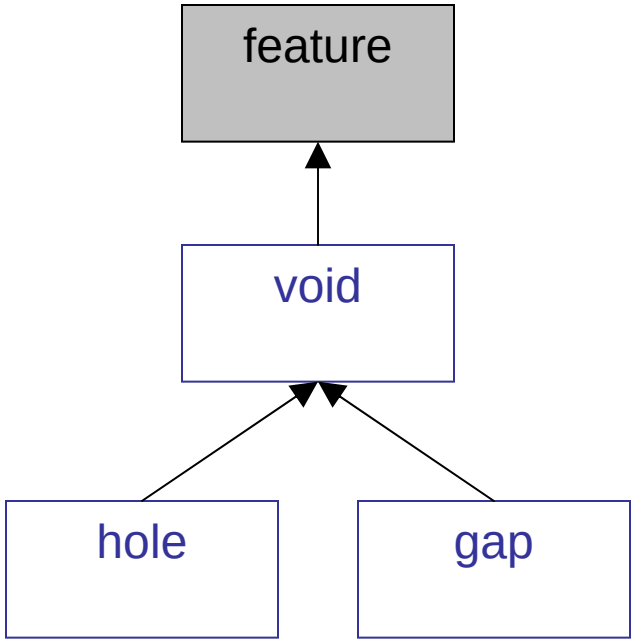


cavity depression tunnel

Voids

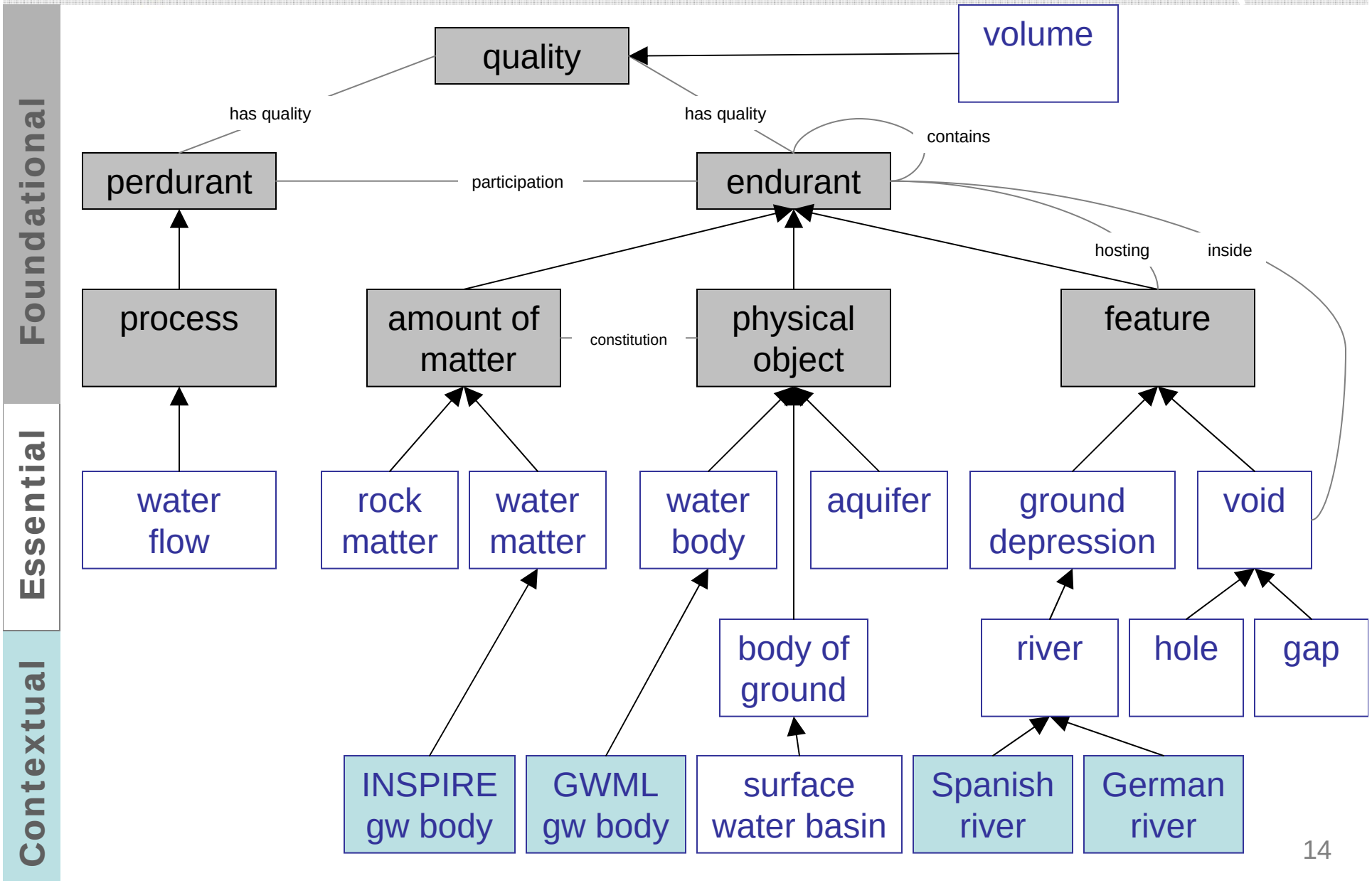
- **voids: generalize holes and gaps**

  need containment relations with voids ('*inside a hole*')



(V9) $hosts\text{-}h(x,y) \equiv hosts\text{-}v(x,y) \wedge ICon(x)$ (non-scattered host of a void)
(Hole-D) $Hole(y) \equiv \exists x[hosts\text{-}h(x,y)]$ (hole has a non-scattered host)
(V10) $hosts\text{-}g(x,y) \equiv hosts\text{-}v(x,y) \wedge \neg ICon(x)$ (scattered host of a void)
(Gap-D) $Gap(y) \equiv \exists x[hosts\text{-}g(x,y)]$ (gap has a scattered host)
(V-T2) $V_S(x) \leftrightarrow Gap(x) \vee Hole(x)$ (gap and hole exhaustive classes of simple voids)

Tiered hydro ontology



Conclusions

- **progress on reference hydro ontology that integrates surface and groundwater entities**
- **includes expanded ontology of voids and some topological relations**
- **foundational and essential domain ontologies can help:**

  - disambiguate conceptual differences in emerging SDI standards
  - inform SDI data standards design

Thank you!