Geothermal Data Management Webinar

06 October 2020

Presenters

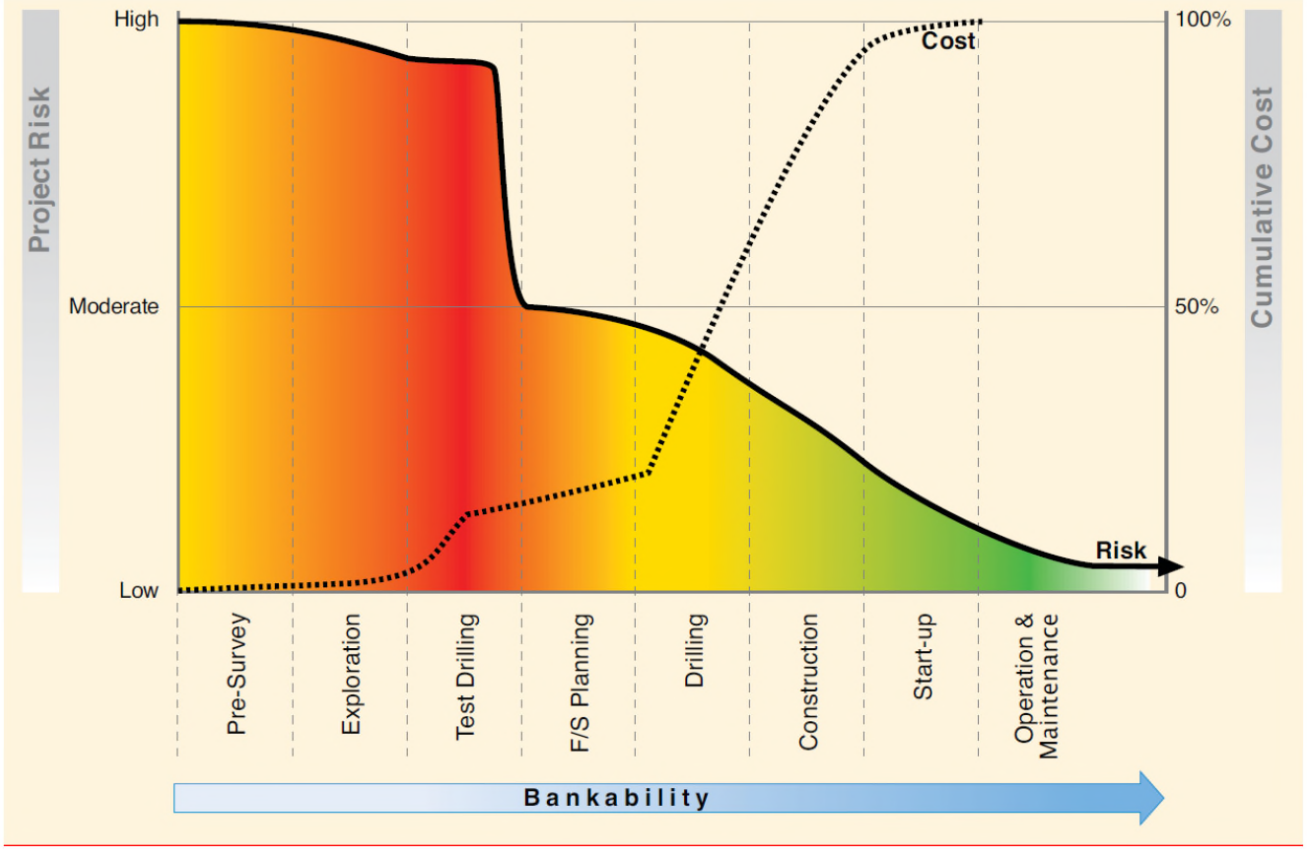
- Jeffrey Benegar, Tetra Tech – Hydrogeologist and Director of Geothermal Services (jeff.benegar@tetratech.com)
- Robert Kennedy, Tetra Tech – Senior Systems Engineer and Geothermal Data Technical Expert (robert.kennedy@tetratech.com)
- If you cannot be here for the whole presentation, here is the conclusion for you: a proper relational database management system (RDBMS) is ***the best practice*** for handling ***your*** valuable geothermal data.

Agenda

- Why data management is important for de-risking geothermal development
- A ***Very*** Brief History of Databases
- Illustration by role-playing of need for proper geothermal relational databases (RDBMS)
- All the types of geothermal data
- Conceptual model of a geothermal RDBMS
- Role of Data Custodians (DC), business rules, linking with GIS, and security
- Best practices for geothermal RDBMS from mature jurisdictions

Why Data Management?

To reduce the risky nature of geothermal development to a minimal level with good data that informs decisions at different stages of development



Source: Gehringer and Loksha, 2012

Why Data Management?

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> Exploration risk is best mitigated…by experienced data interpretation.

(IFC, 2013)

What is a Database?

- Wikipedia – An organized collection of data
- Merriam-Webster – A usually large collection of data organized for especially rapid search and retrieval (as by a computer)
- Connolly & Begg – A collection of related data

Database vs. DBMS (Database Management System)

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- Database – Set of related data we want to do something with
- Database Management System (DBMS) – The software used to manage and control the database, and allow access to it (usually by user level)

Database ≠ “spreadsheet, but better”

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Spreadsheet Pros

- Excel is readily available
- Excel is easy to learn and use
- Excel can be utilized offline

Spreadsheet Cons

- Data ownership
- Data control and security
- Single user access
- Coordination problem
- Metcalfe’s Law problem
- Configuration management and version control

True Database Management System

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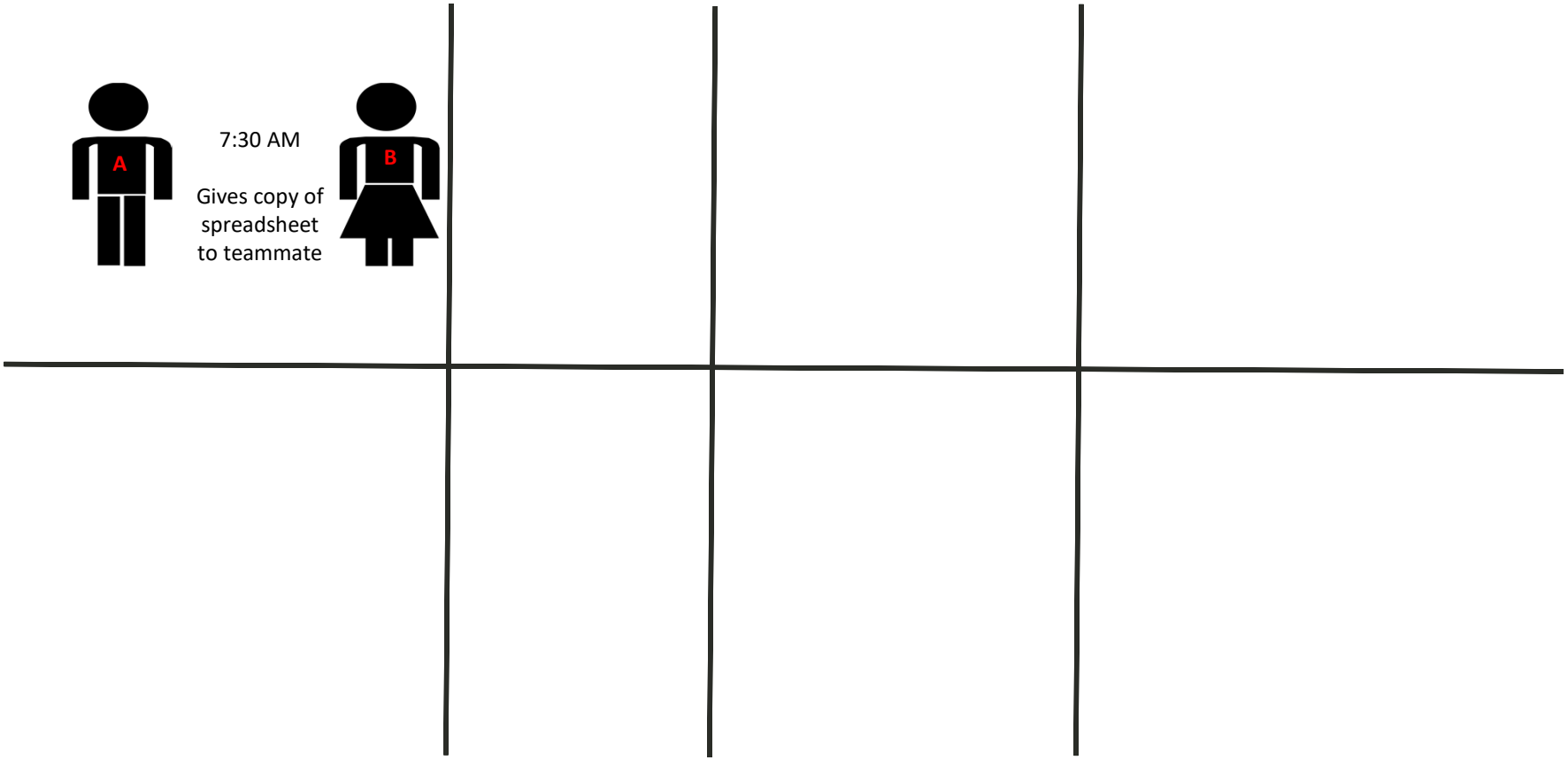
Database Pros

- Data integrity
- Data control and security (multiple levels and groups)
- Simultaneous access
- Data segregation (ability to have multiple databases for distinct uses)
- Reporting and analytics

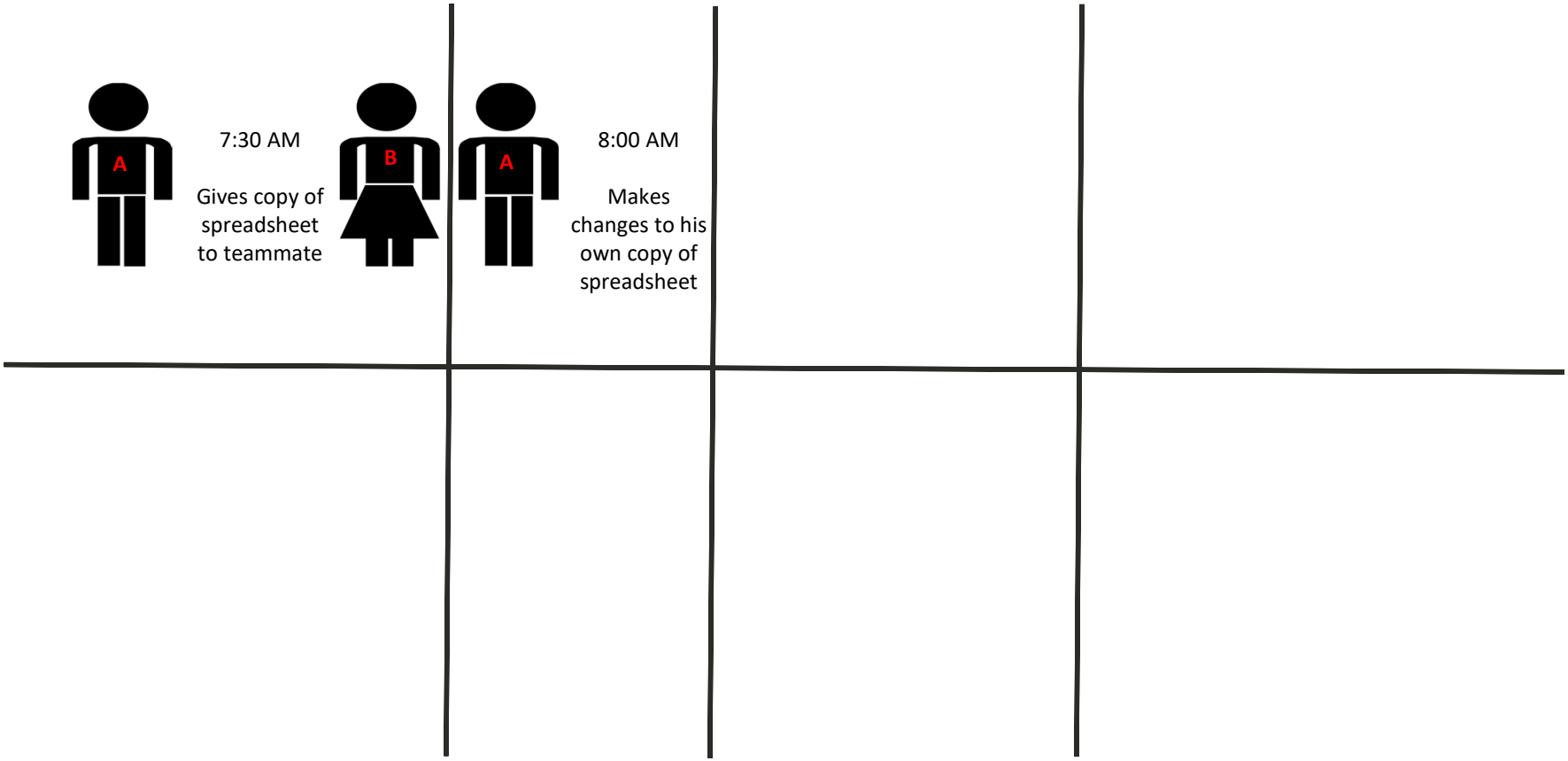
Database Cons

- Offline availability (depends on product)
- Interface programs to access and modify data
- Learning curve
- Requires specialized skillset to develop, maintain and administer (but is an investment in capacity)

File Sharing and Data Consistency Example



File Sharing and Data Consistency Example



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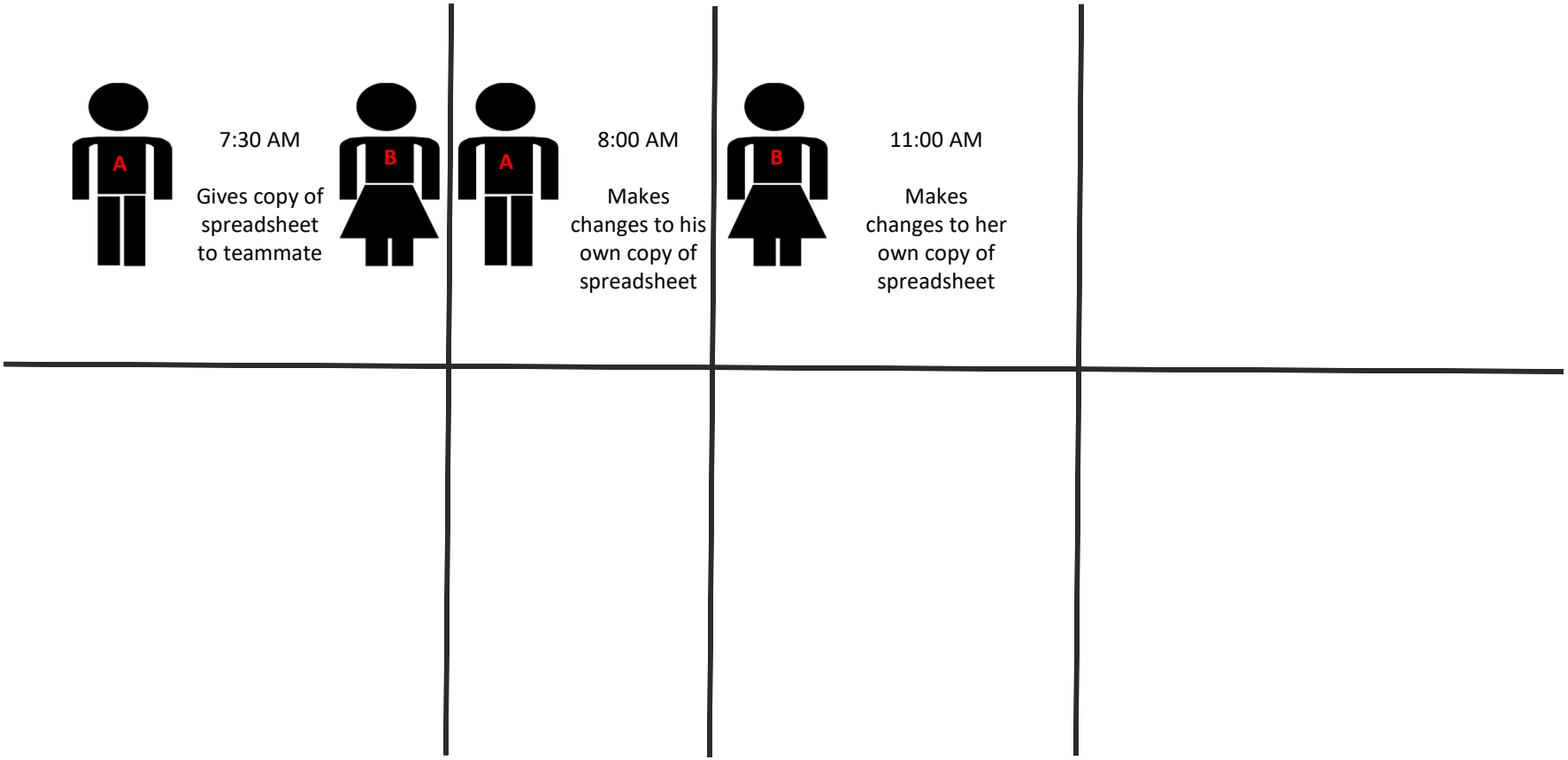
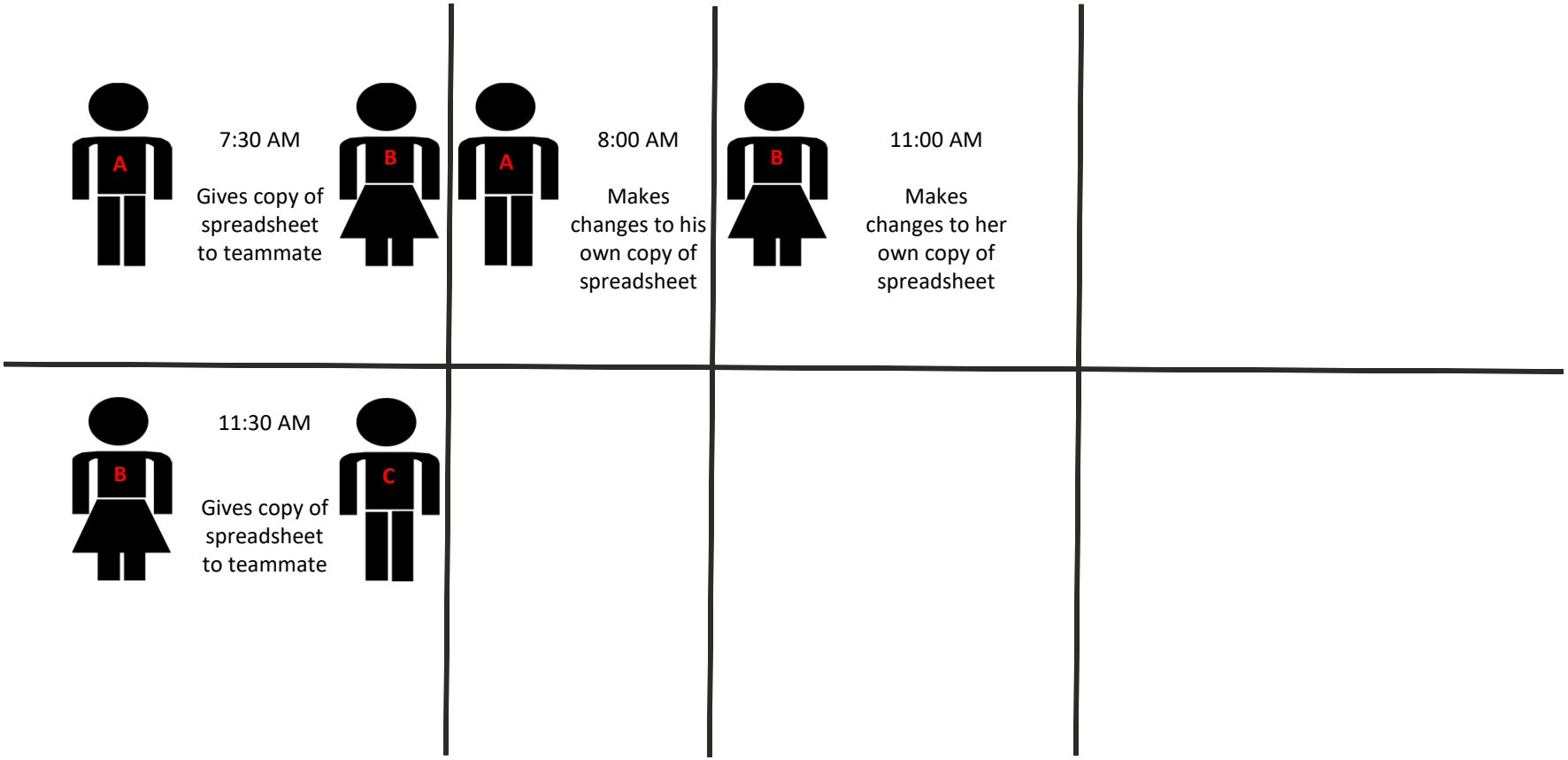


File Sharing and Data Consistency Example



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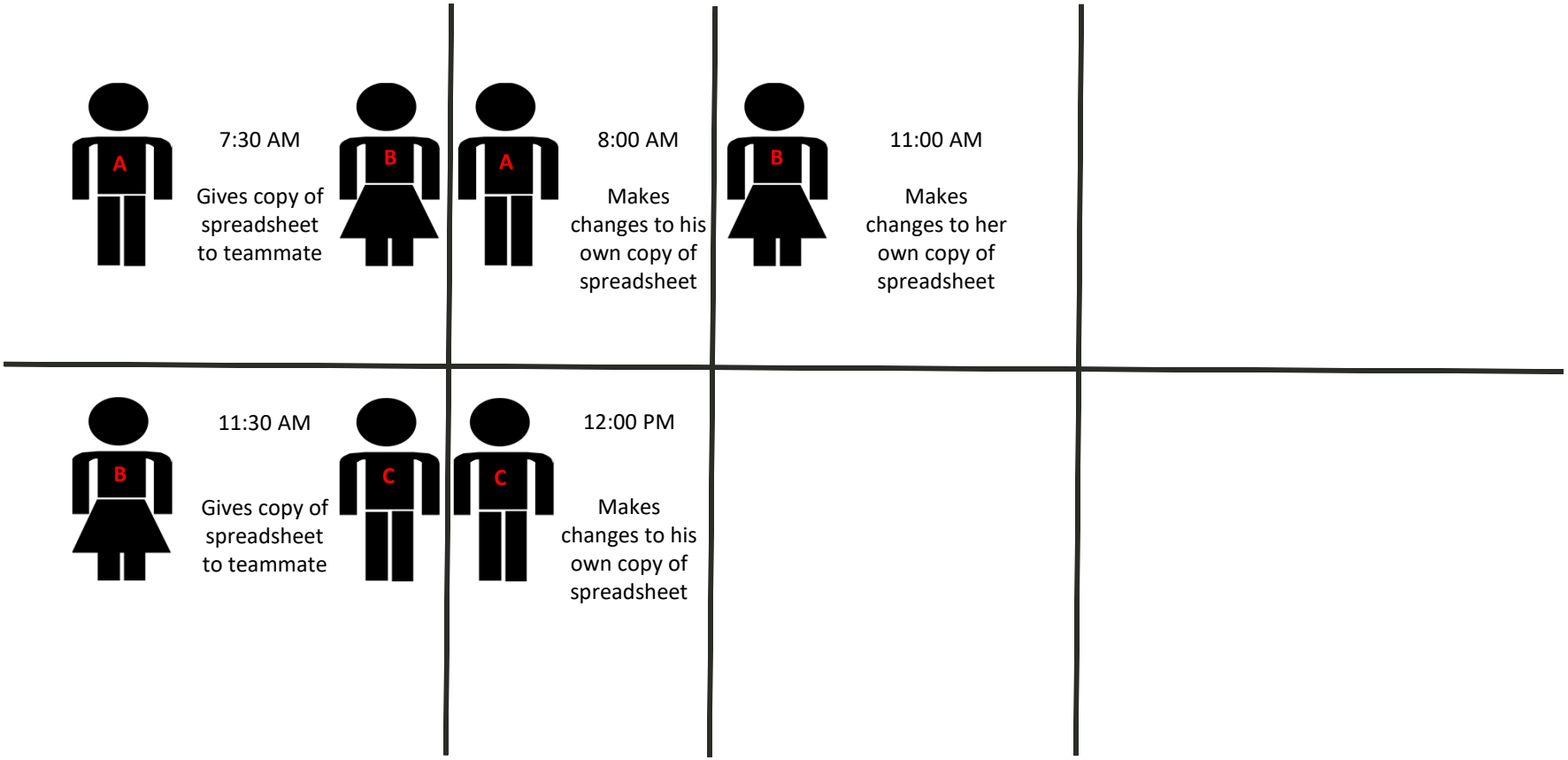

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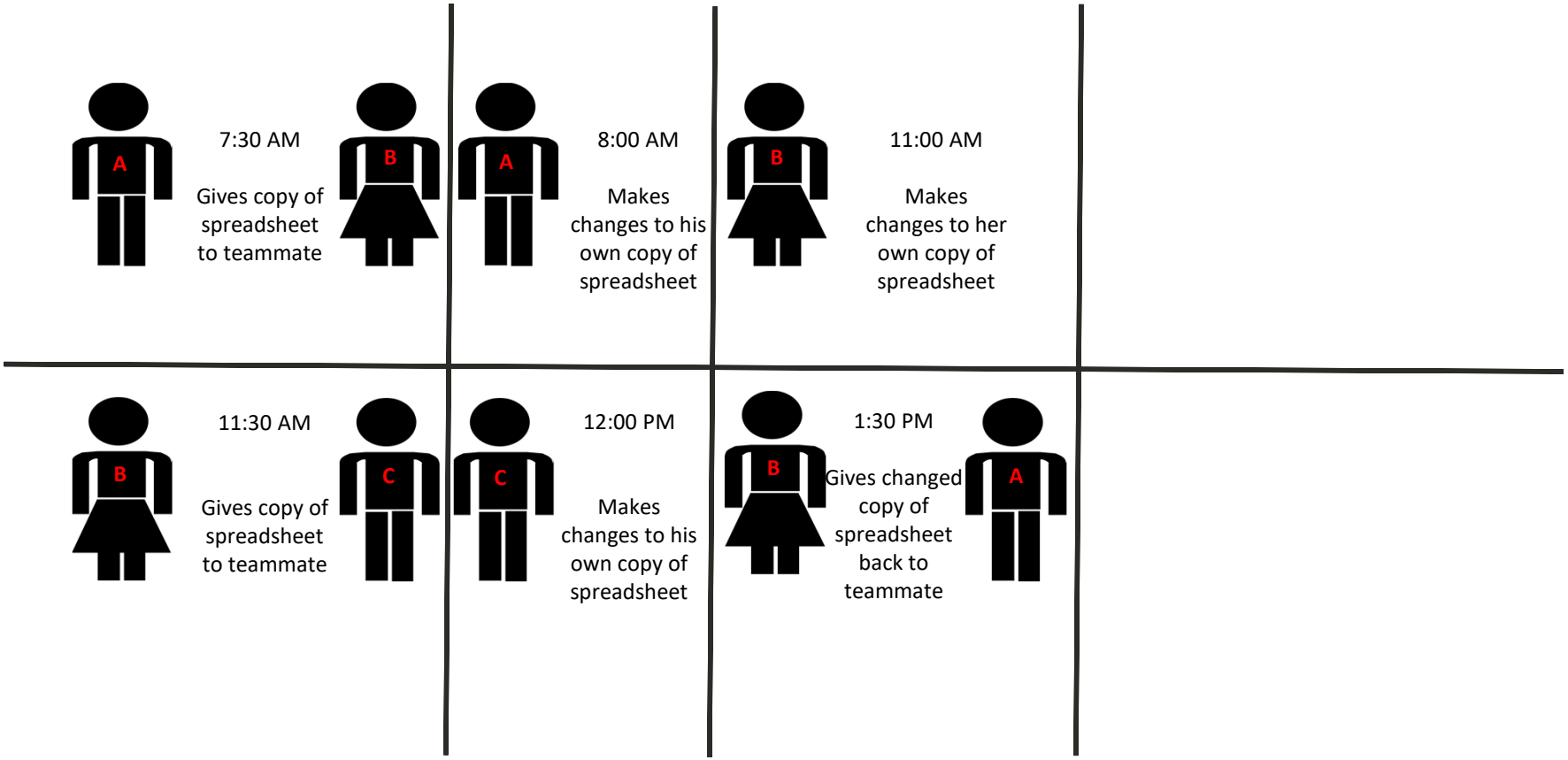

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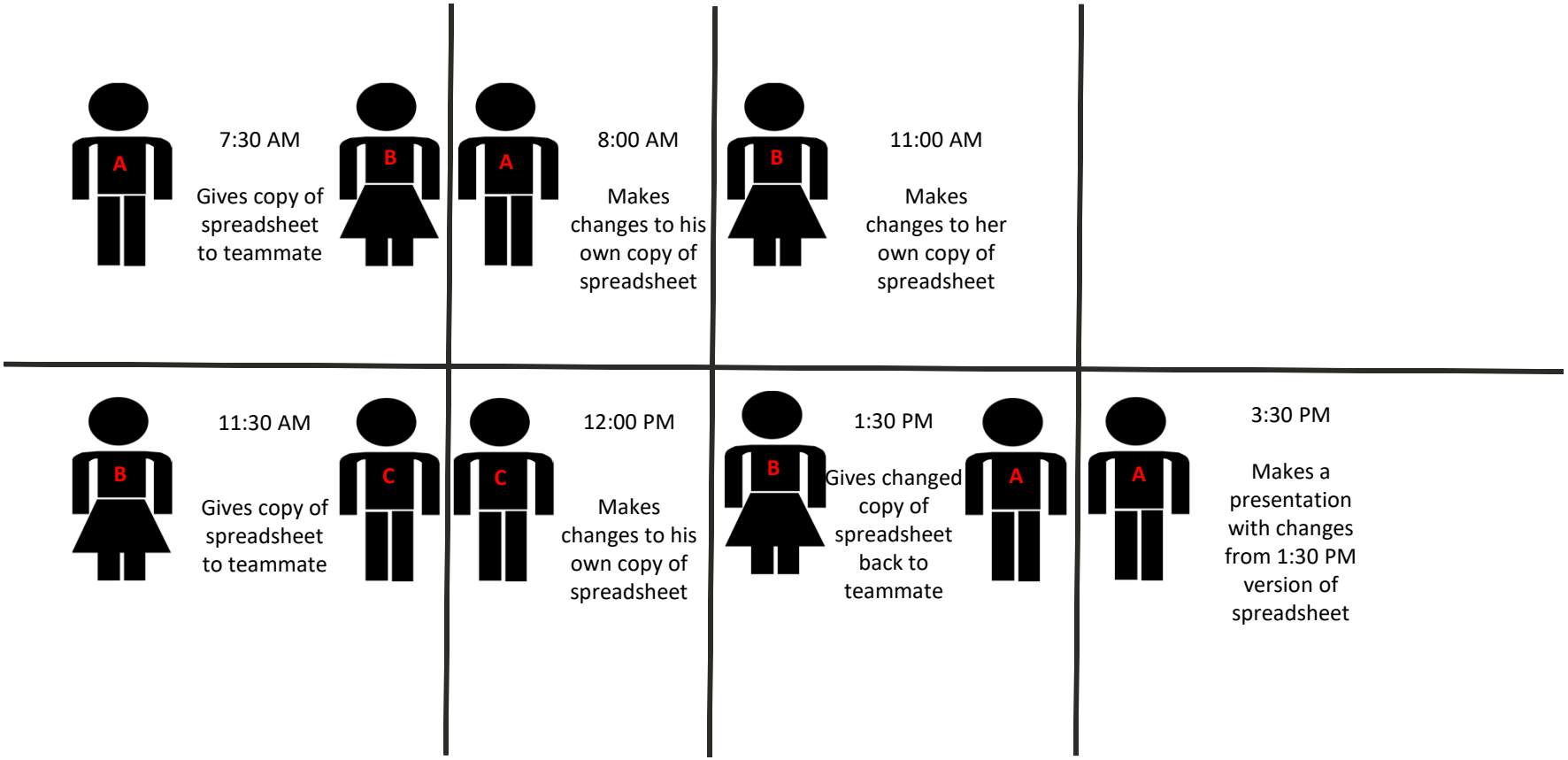

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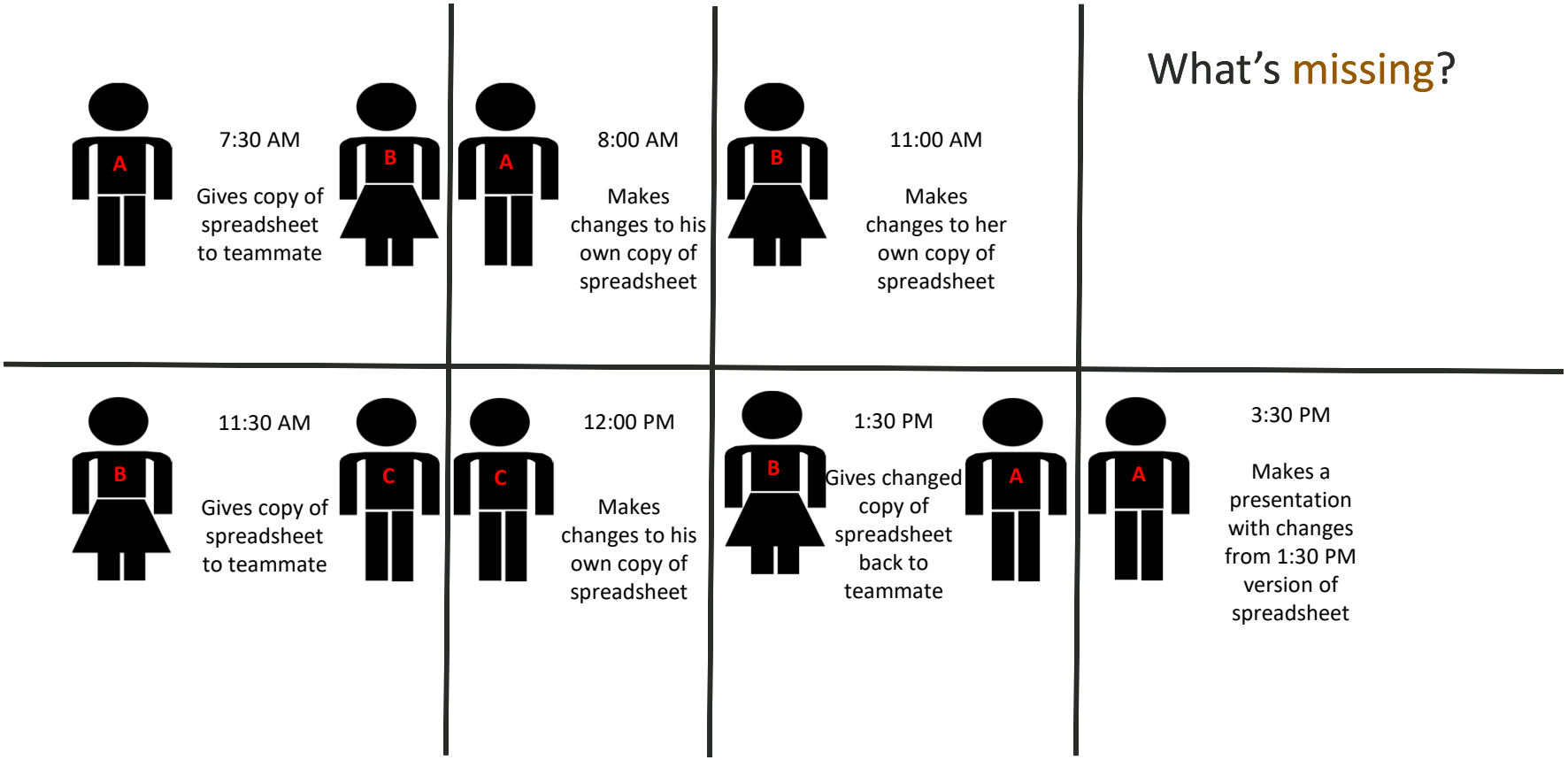
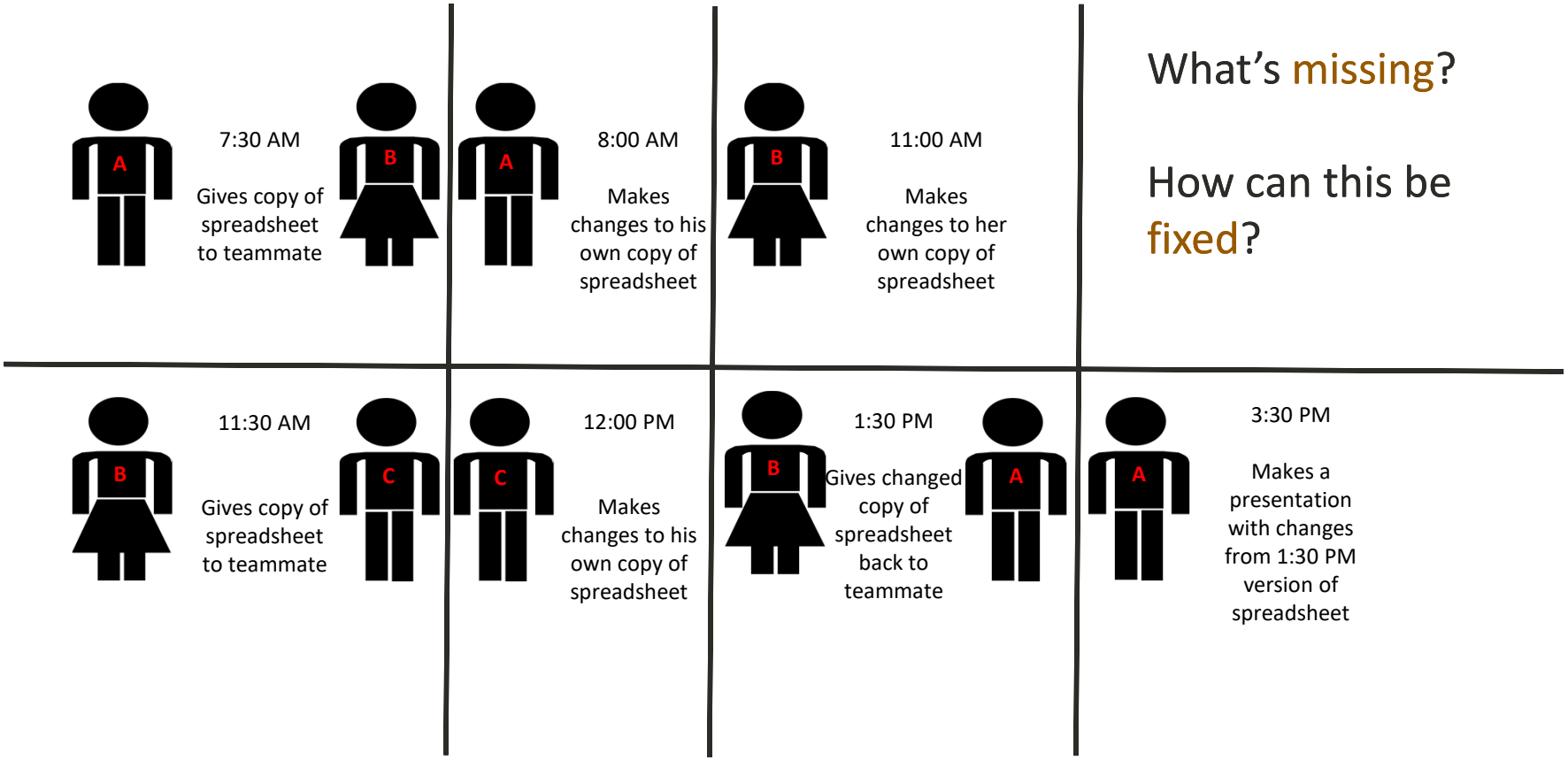
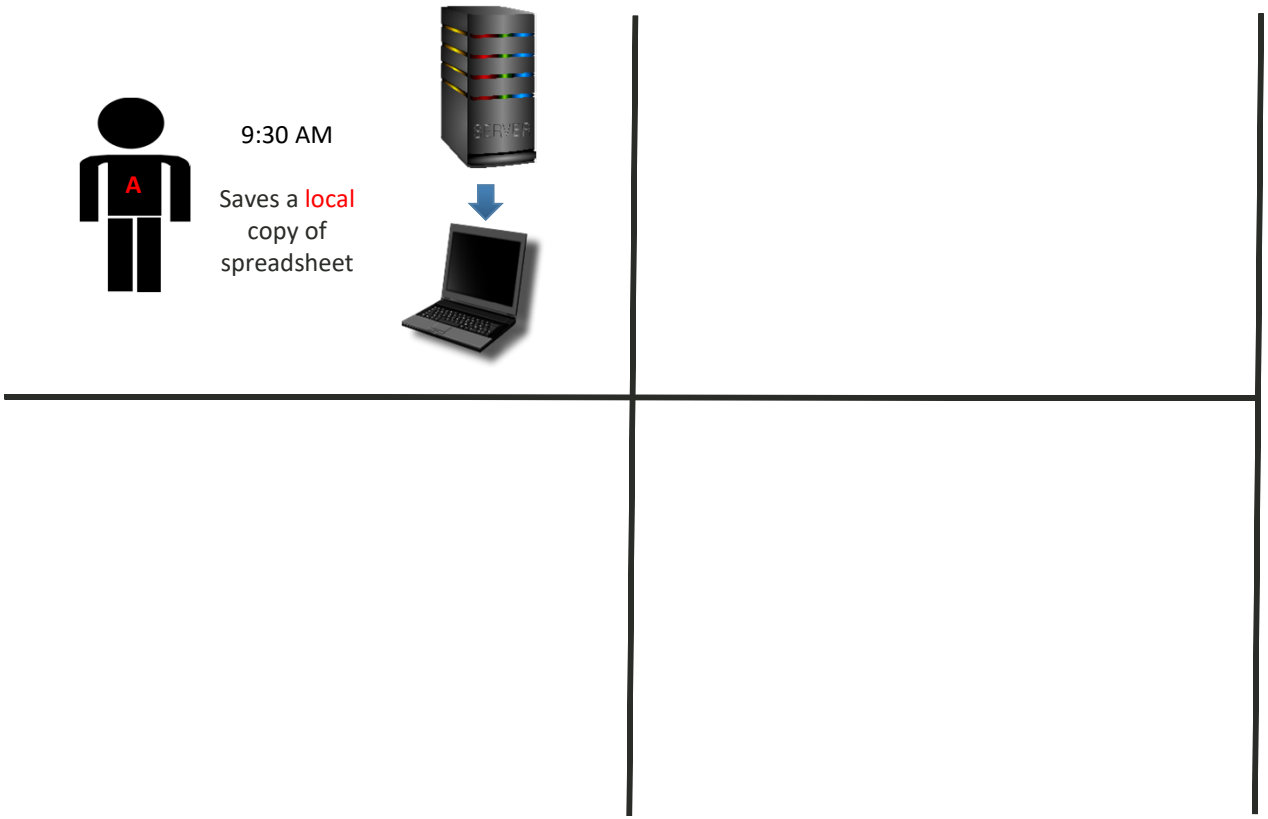


File Sharing and Data Consistency Example



Access, Availability and Control



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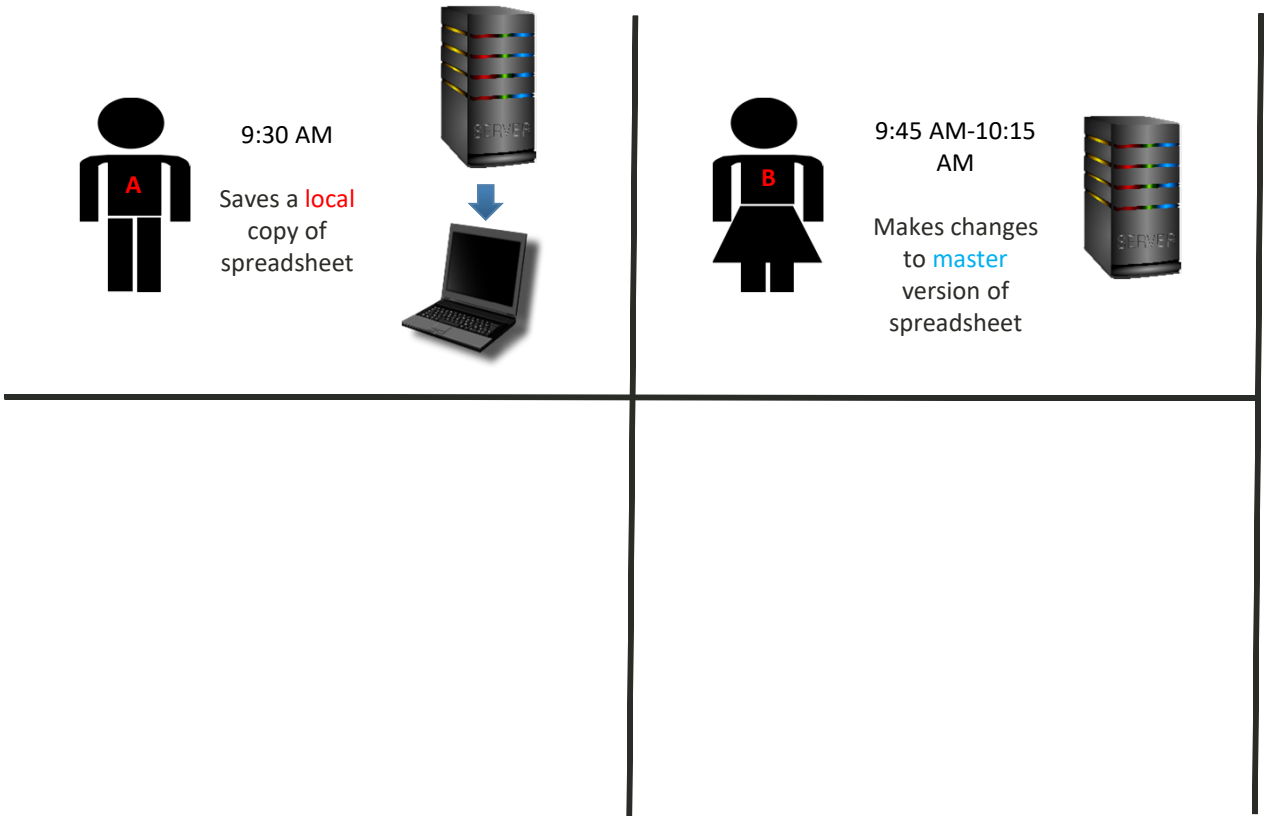

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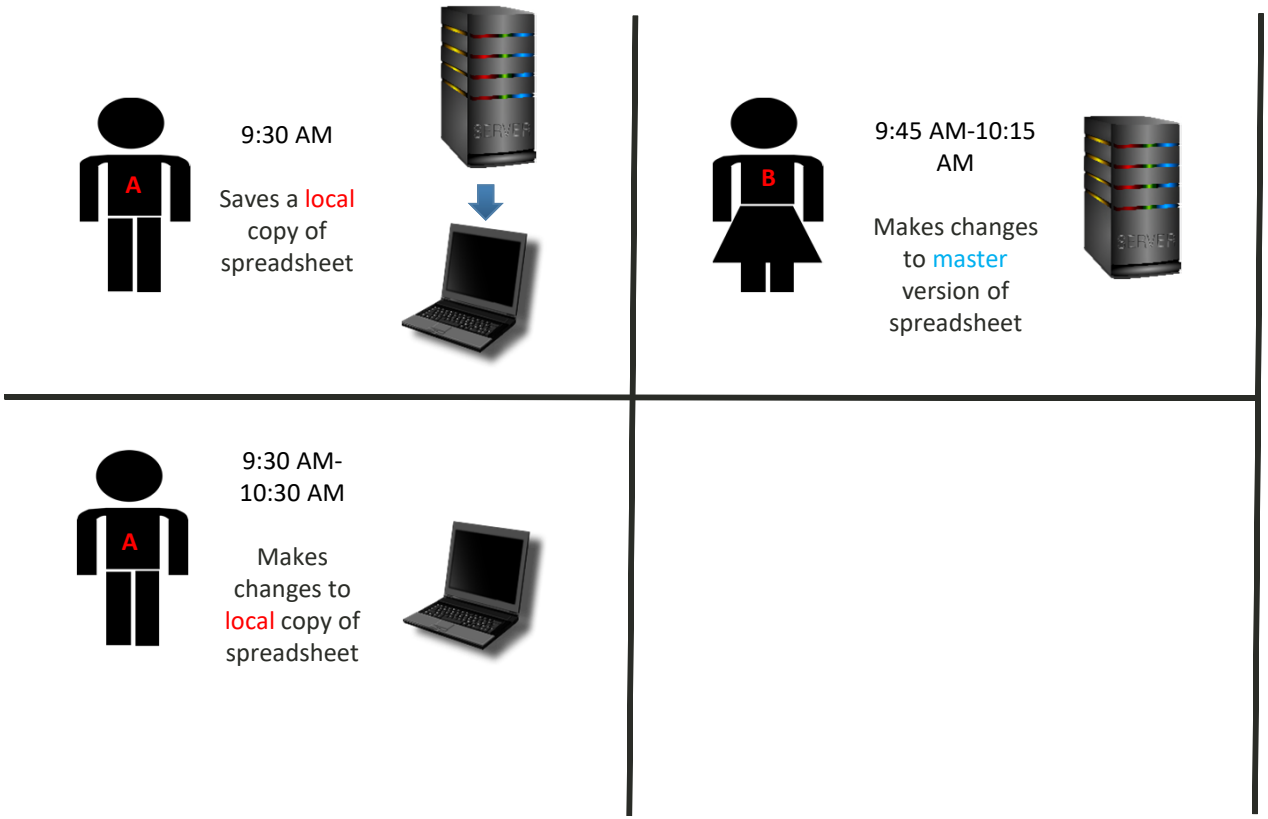

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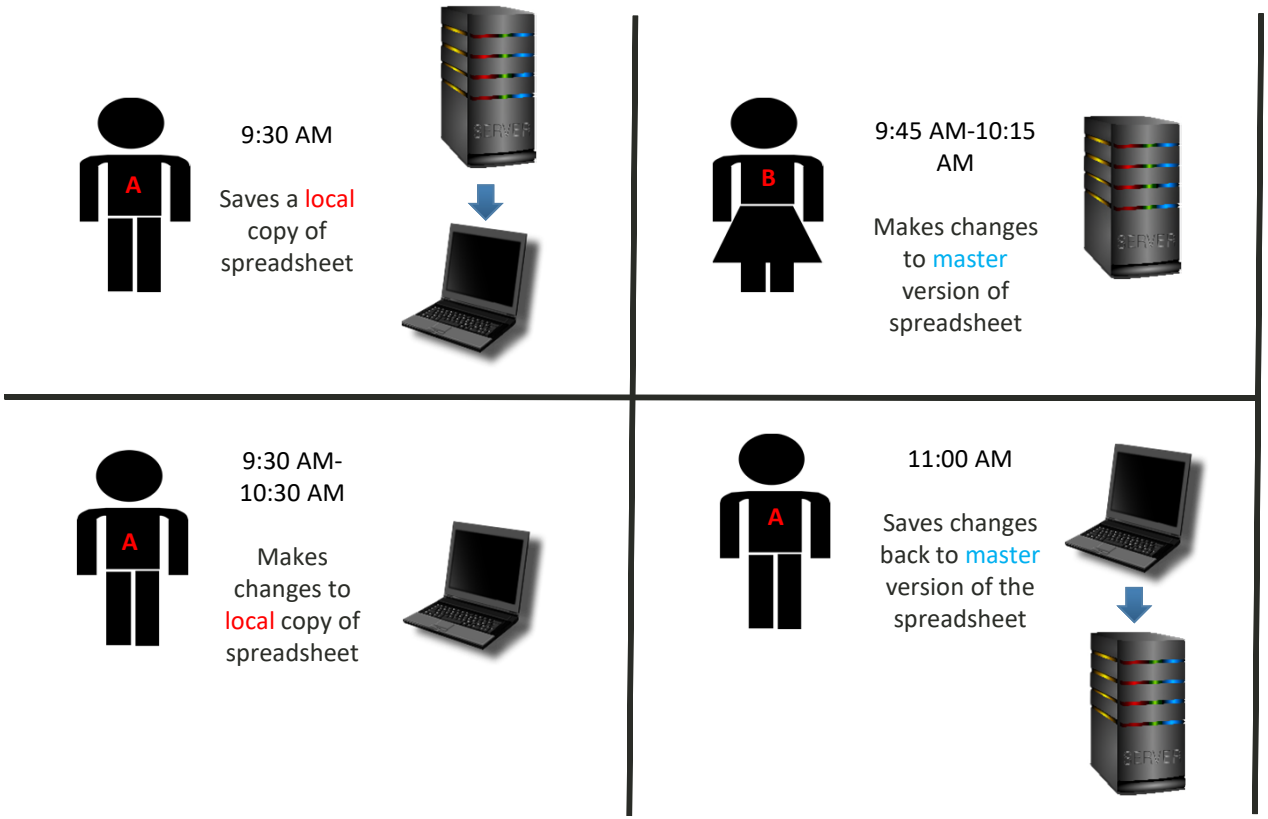

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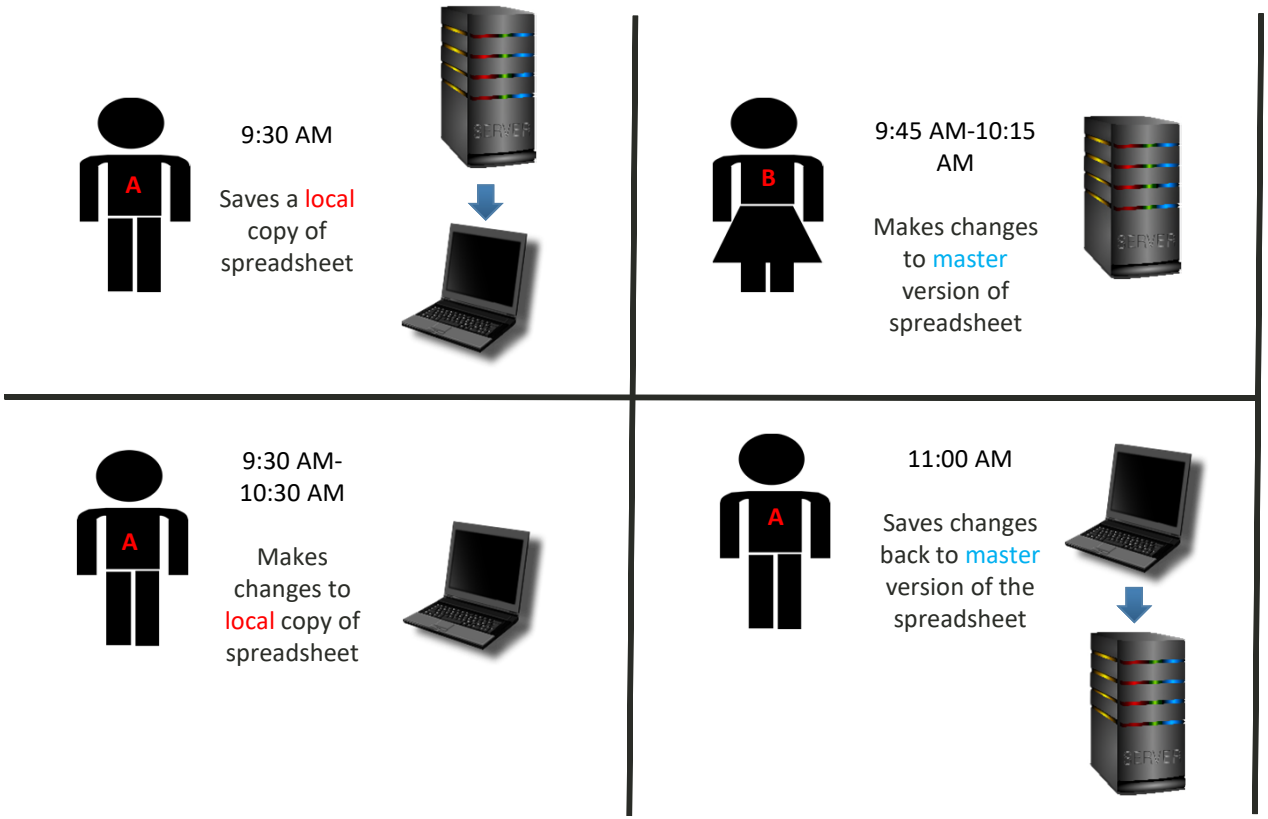
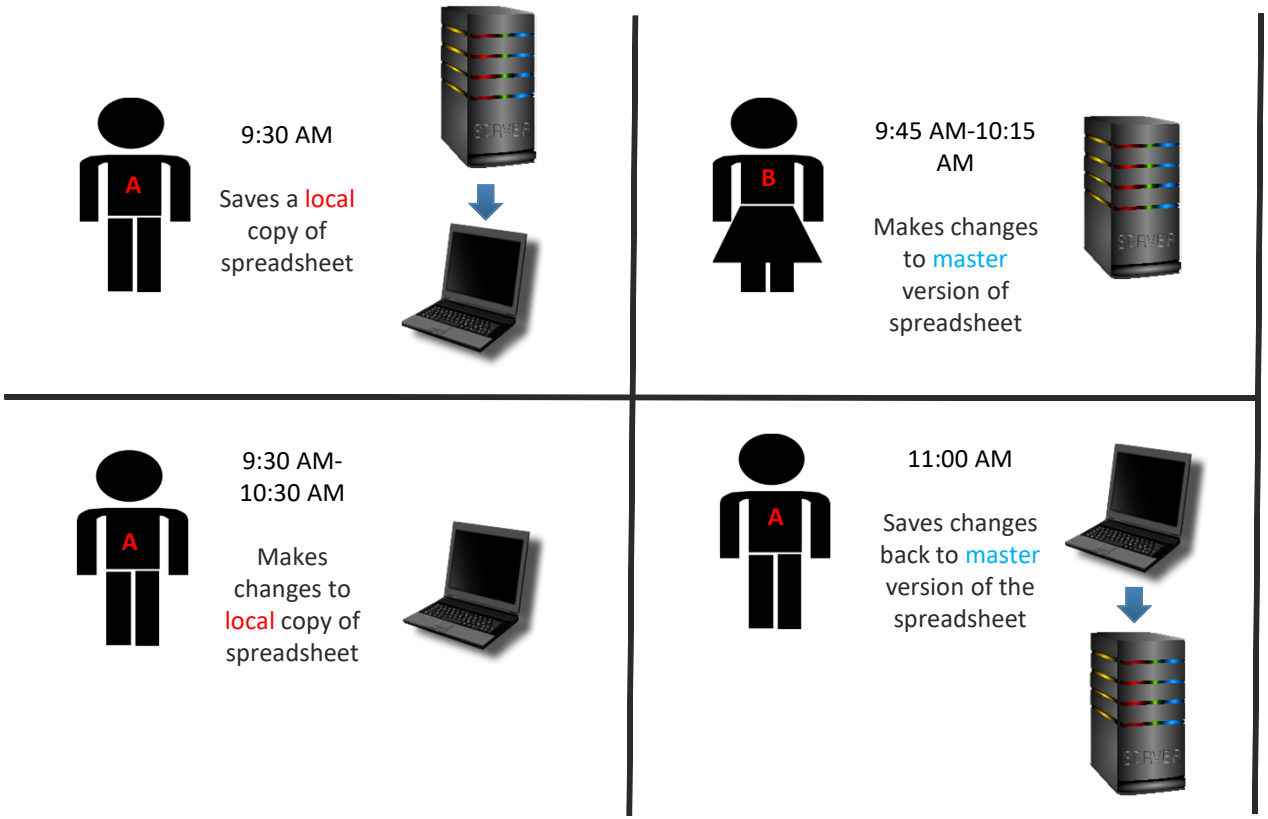


What's missing?

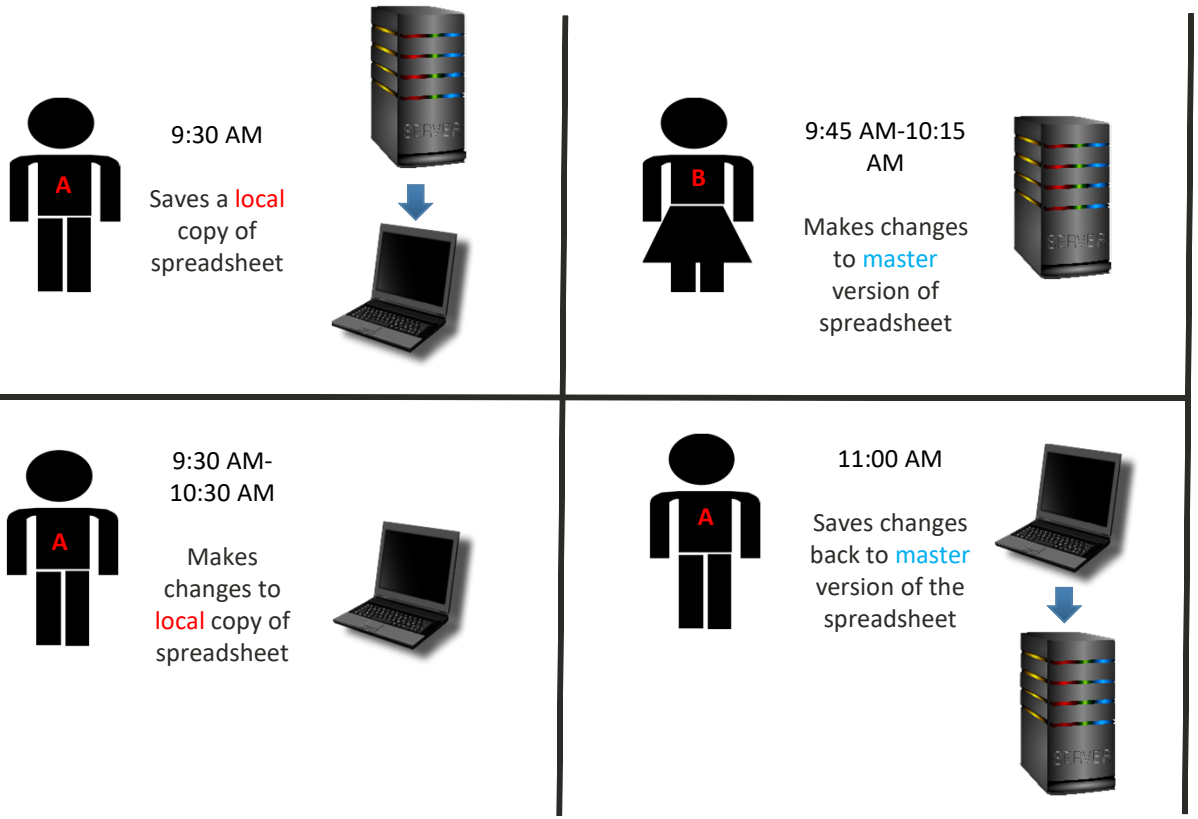
Access, Availability and Control



What's missing?

Why did this happen?

Access, Availability and Control



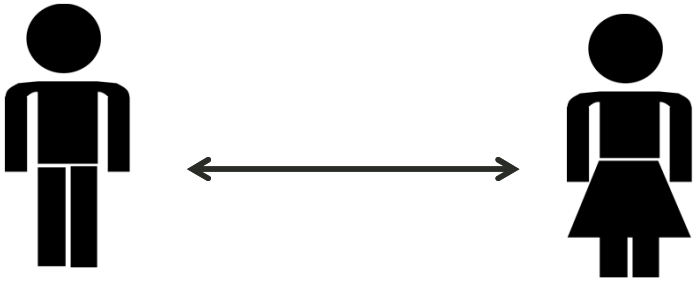
What's missing?

Why did this happen?

How could this be avoided?

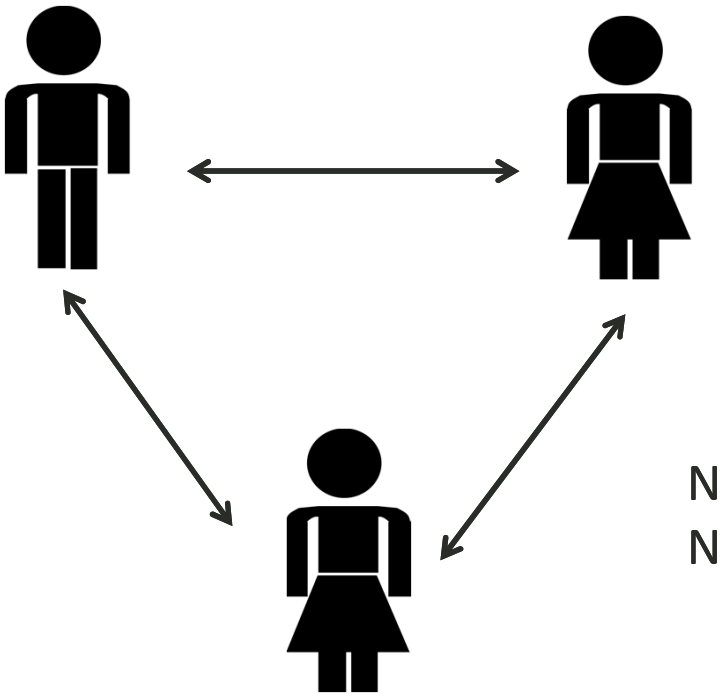
Metcalfe's Law

2 nodes
1 link



Metcalfe's Law (cont'd)

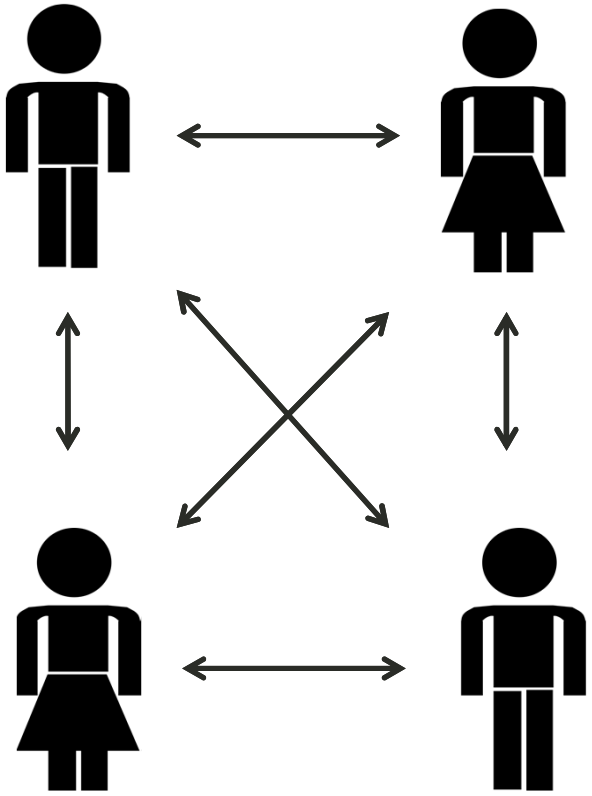
3 nodes
3 links



Number of nodes now +50%
Number of links now +200%!

Metcalfe's Law (cont'd)

4 nodes
6 links



Number of nodes now +100%
Number of links now +600%!

Metcalfe's Law → N^2 problem

The number of possible cross-connections in a network grows as the square of the number of users.

Geothermal Data Types

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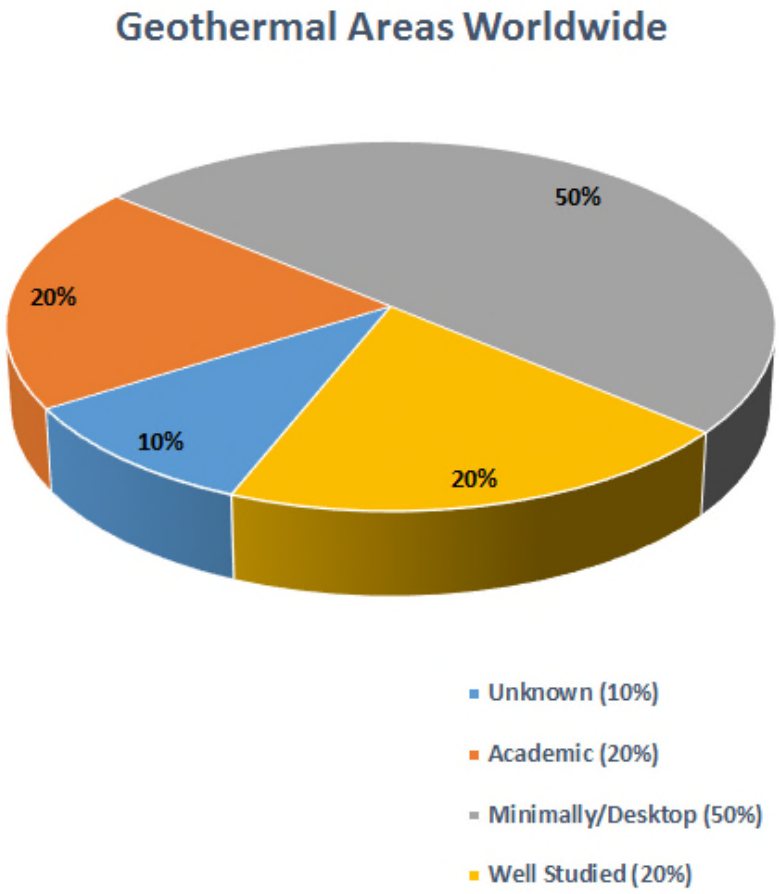
Geothermal data is highly heterogeneous
Data types that an RDBMS needs to include:

- I. Desktop studies (e.g., papers, reports, maps)
- II. Physiography and geomorphology
- III. Geology & Geochemistry & Geophysics
- IV. Imaging and geodesy/geomatics
- V. Wells and boreholes
- VI. Socioeconomic (e.g., environmental, ecological and cultural)

Geothermal Data Types I: Reports

RDBMS needs to index and link keywords in:

- Paper maps
- Journals and periodicals
- Conference proceedings
- Desktop studies (both internal and external)
- Private-sector records in geothermal or oil & gas industries
- Often not machine-readable (cannot be OCR'ed)
- Soft copies may only be available



Geothermal Data Types I: Archives and Libraries

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Data sources:

- 1. Online search of geothermal-related information
- 2. Trade associations: IGA, GRC (note: on-line library)
- 3. Private sector geothermal companies are less secretive and proprietary than O&G sector, mining firms, or national oil companies (NOC)
- 4. Universities
- 5. Government ministries (the Philippines and Kenya are good examples) as sources of “self-knowledge”
- 6. Journals -> usually derivative rather than original material and/or academic. GRC Bulletin is “soft”, but proceedings of GRC Annual Meeting is “hard”.

Geothermal Data Types II: Physiography and Geomorphology

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RDBMS needs to link to data, much of which is georeferenced:

- Alteration zones, e.g., travertines, zeolites
- Surface manifestations, e.g., lineaments, faults, fumaroles, hot springs
- Geological (rock/soil) samples and locations
- Temperatures and locations
- Data is often unstructured (maps, reports) and spans huge ranges of spatial scales

Geothermal Data Types III: Structural Geology and Geochemistry & Geophysics

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RDBMS needs to link to data, much of which is georeferenced:

- Stratigraphy and structural/tectonic stress and strain diagrams
- 2D cross sections and 3D solid block models (geologist interpreted or computer-based modeling, e.g. “Leapfrog”, “GEM”, “MVS”)
- Conceptual models and reservoir models
- Measurements of temperature, pH, conductivity, flow rate, TDS, dissolved gasses, major anions and cations, isotopic markers, soil gas, geothermometers
- Descriptive data (reports, papers, imagery that is not geo-referenced)
- Structured data (models, geo-referenced maps/imagery)

Geothermal Data Types III: Structural Geology and Geochemistry & Geophysics

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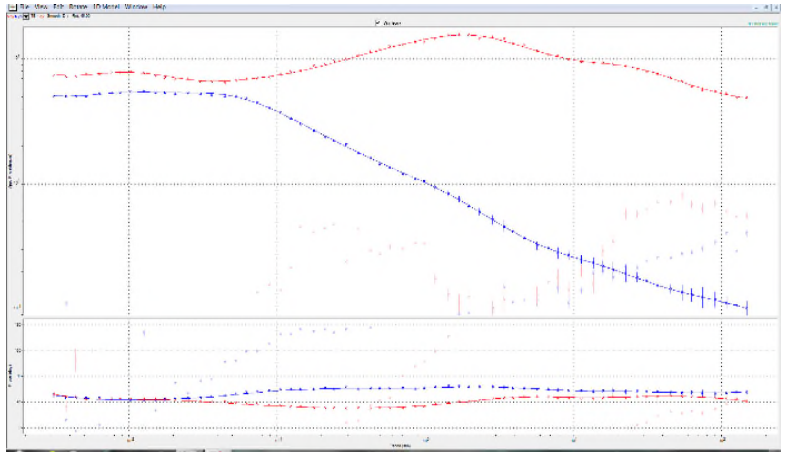
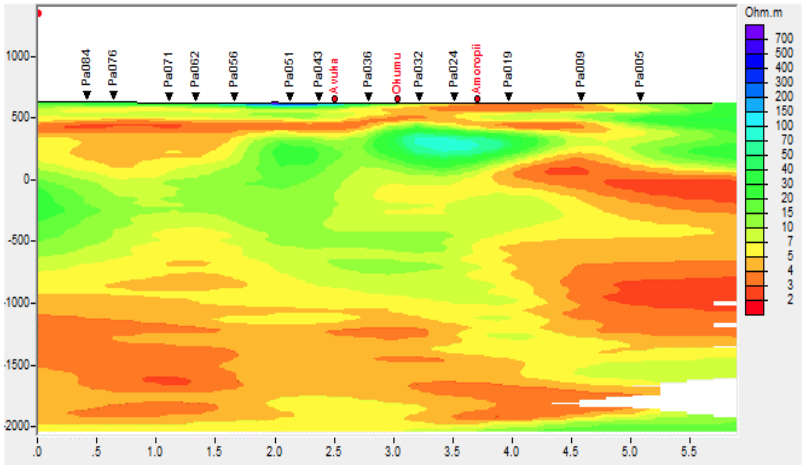
RDBMS needs to link to:

- ➢ Resistivity studies, e.g., MT, TEM, dipole-dipole, pole-dipole, audio MT, TDEM, deep EM
- ➢ Aeromagnetic surveys
- ➢ Gravity surveys
- ➢ Micro-seismic - passive listening with geophones
- ➢ Active seismic tomography from O&G exploration





Geothermal Data Types IV: Imaging, Geodosy, Geodetics and Geomatics

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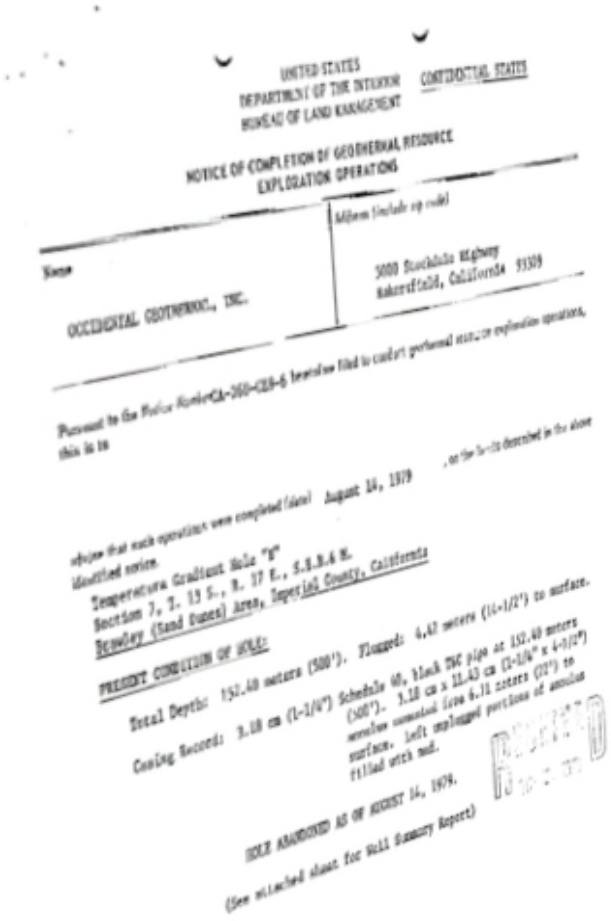
RDBMS needs to link to:

- Overhead panchromatic and multispectral photos
- LIDAR, FLIR, radar, thermal
- GIS and digital elevations models (DEMs)
- Differential GPS for ground motion
- Data is inherently geo-referenced
- Consistent referencing of coordinate datums (e.g. Arc60 vs. WGS84) is key. An example is a 600-m offset due to incorrect specification of datum, resulting in wrong drilling location and wasting millions of dollars

Geothermal Data Types V: Wells and Boreholes



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

CONFIDENTIAL STATUS

NOTICE OF COMPLETION OF GEOTHERMAL RESOURCE EXPLORATION OPERATIONS

Name

OCCIDENTAL GEOTHERMAL, INC.

Address (include zip code)

5000 Stockdale Highway
Bakersfield, California 93309

Pursuant to the Public Law 88-583-CIR-6 heretofore filed to conduct geothermal resource exploration operations, this is to

advise that such operations were completed (date) August 14, 1979 on the lands described in the above identified notice.

Temperature Gradient Hole "F"
Section 7, T. 13 S., R. 17 E., S.B.B.&M.
Brawley (Sand Dunes) Area, Imperial County, California

PRESENT CONDITION OF HOLE:

Total Depth: 152.40 meters (500'). Plugged: 4.42 meters (14-1/2') to surface.

Casing Record: 3.18 cm (1-1/4") Schedule 40, black IPC pipe at 152.40 meters (500'). 3.18 cm x 11.43 cm (1-1/4" x 4-1/2") annulus cemented from 4.11 meters (13') to surface. Left unplugged portions of annulus filled with mud.

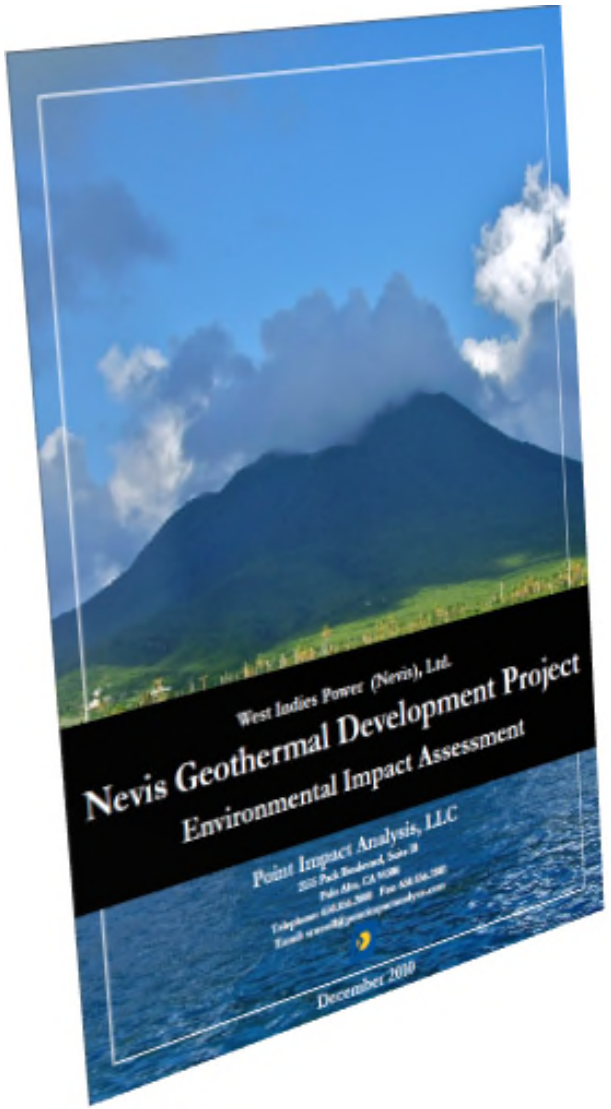
HOLE ABANDONED AS OF AUGUST 14, 1979.

(See attached sheet for Well Summary Report)

RDBMS needs to link to:

- Drilling logs & construction diagrams from active or abandoned water wells, O&G wells and geothermal wells
- Thermal gradient holes, slimholes
- Full-size geothermal wells for exploration, production, and injection (including P&A wells)
- Data often old, unstructured, not originally geo-referenced, fragmentary, inconsistent, non-machine readable, hand-written or poorly typed paper records

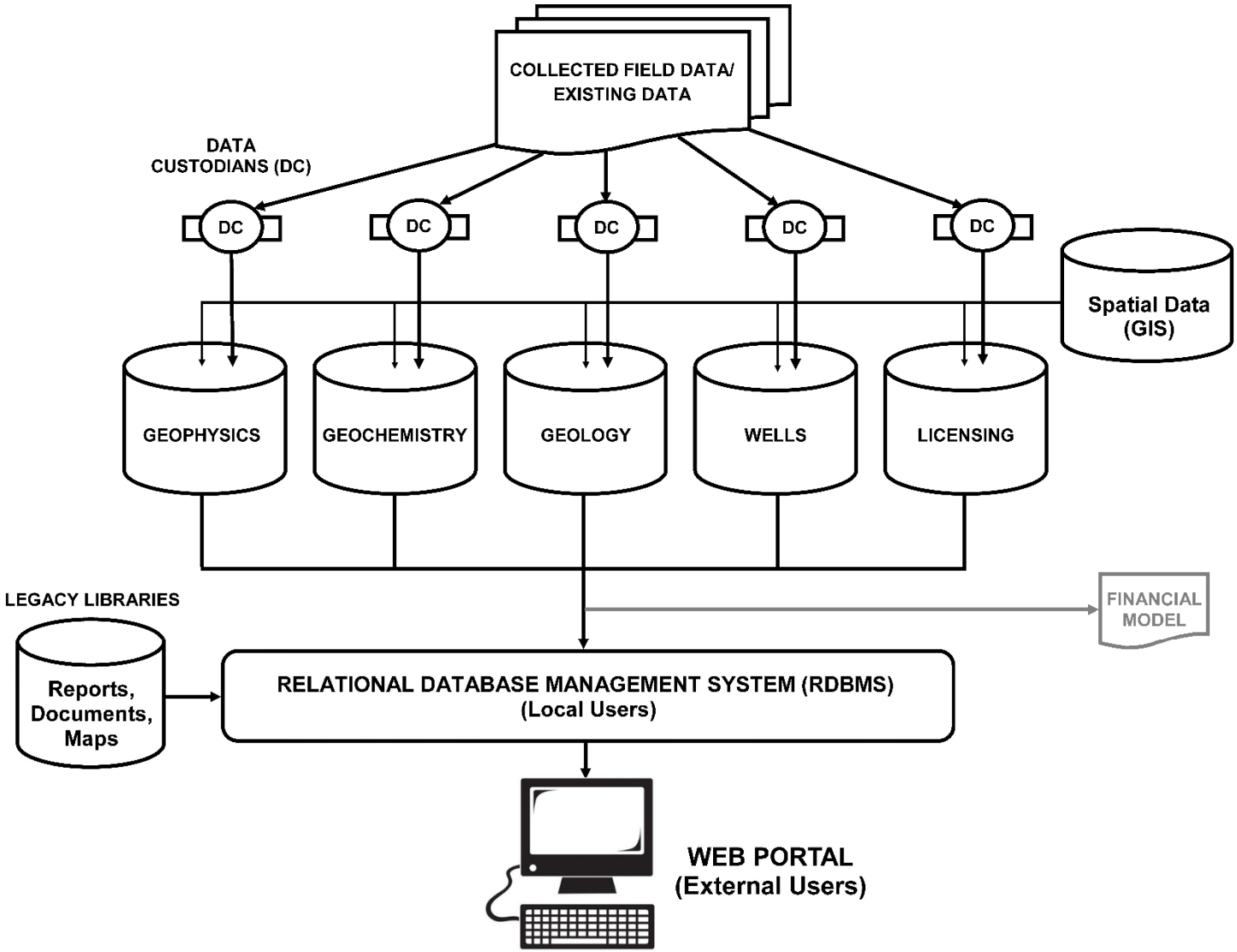
Geothermal Data Types VI: Socioeconomic



RDBMS needs to link to:

Environmental, ecological, and cultural data, assessment and management of environmental and social impacts and issues
Many jurisdictions face issues with geothermal resources located in/near national parks (e.g., Japan, Indonesia), limited or restricted access -> importance of ESIAs
Sociological and economic data gathered in the course of World Bank funded project, or a project that requires impact assessment to WB standards

General Model for a Geothermal RDBMS



Roles and Missions of Data Custodians (DCs)

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- Responsible for identifying data sets within his/her area of expertise for storage in the database. The "point" person for a subject matter area (e.g., geochemistry, geology, geophysics).
- Knows the scope and extent of data (raw, legacy and ongoing data collection activities)
- Responsible for the quality of the data (i.e., data cleaning)
- Maintenance, disposition and long-term preservation of records and data
- Ideally should be 2-person team (Principal and Deputy)
  - Primary role of deputy is QA/QC of data
  - Roles can be reversed when deputy provides data/fills in when principal not available

Importance of Business Rules

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Design of an RDBMS for an enterprise is driven by business rules. Business rules are operating rules that govern an enterprise, to which the design of an RDBMS must conform:

- Enterprise's mission, authority, and limits thereof
- Policies (e.g., confidentiality)
- Procedures (reporting, data standards, chain of command)
- Example situation:
  - In most countries of East Africa, the primary document instantiating a geothermal concession is the exploration license
  - Geo-referenced boundaries and dates in the license are primary data elements, from which all others flow, and to which all other data elements can be traced back to

Linking with GIS

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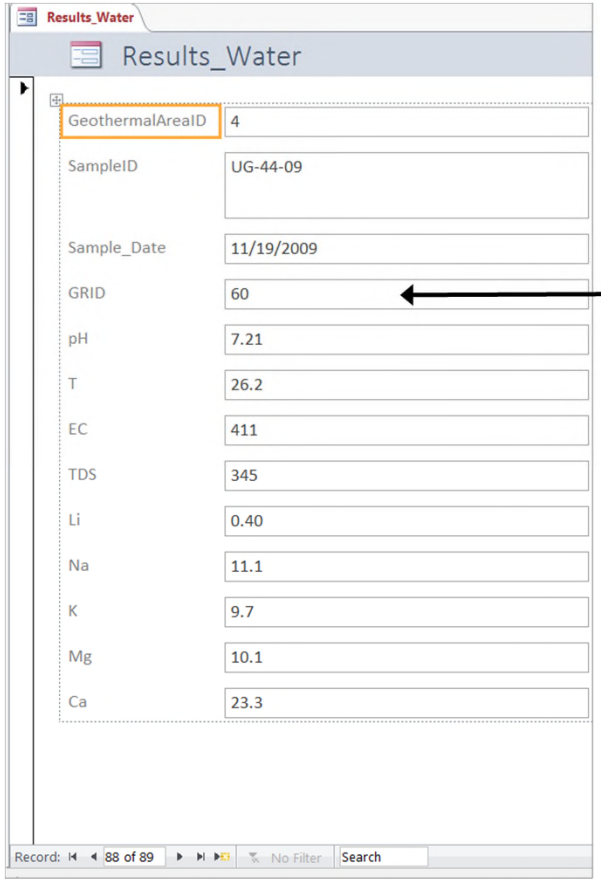
Much geoscience data is spatial in nature. It makes more sense for this type of data to be stored in GIS. A well-designed data management system will link geospatial data in GIS with corresponding data records in the RDBMS.

Geospatial means data that has a geographic component to it. There are various types:

- A specific location (e.g., a single wellbore location)
- A series of specific locations (e.g., a fault or lineament)
- An area (e.g., the boundaries of a licensed geothermal area)
- A volume (e.g., a geothermal reservoir)

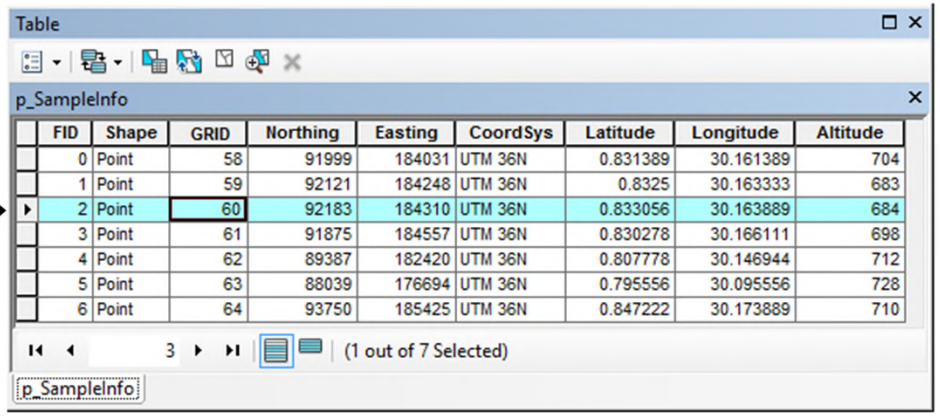
Linking with GIS (cont'd)

A unique identifier for every record is used within the RDBMS and links to corresponding data in GIS. In this example, the unique identifier is the data element "GRID" (Geographic Reference ID)



Geochemistry results table (MS Access)

Join/Relate



FID	Shape	GRID	Northing	Easting	CoordSys	Latitude	Longitude	Altitude
0	Point	58	91999	184031	UTM 36N	0.831389	30.161389	704
1	Point	59	92121	184248	UTM 36N	0.8325	30.163333	683
2	Point	60	92183	184310	UTM 36N	0.833056	30.163889	684
3	Point	61	91875	184557	UTM 36N	0.830278	30.166111	698
4	Point	62	89387	182420	UTM 36N	0.807778	30.146944	712
5	Point	63	88039	176694	UTM 36N	0.795556	30.095556	728
6	Point	64	93750	185425	UTM 36N	0.847222	30.173889	710

Sample location table (ArcGIS)

→ This obviates the need for duplicate data. Rather, geospatial data and their attributes can logically be stored and used in GIS and can be referenced via joins/relates back to their corresponding data elements in the RDBMS.

Security

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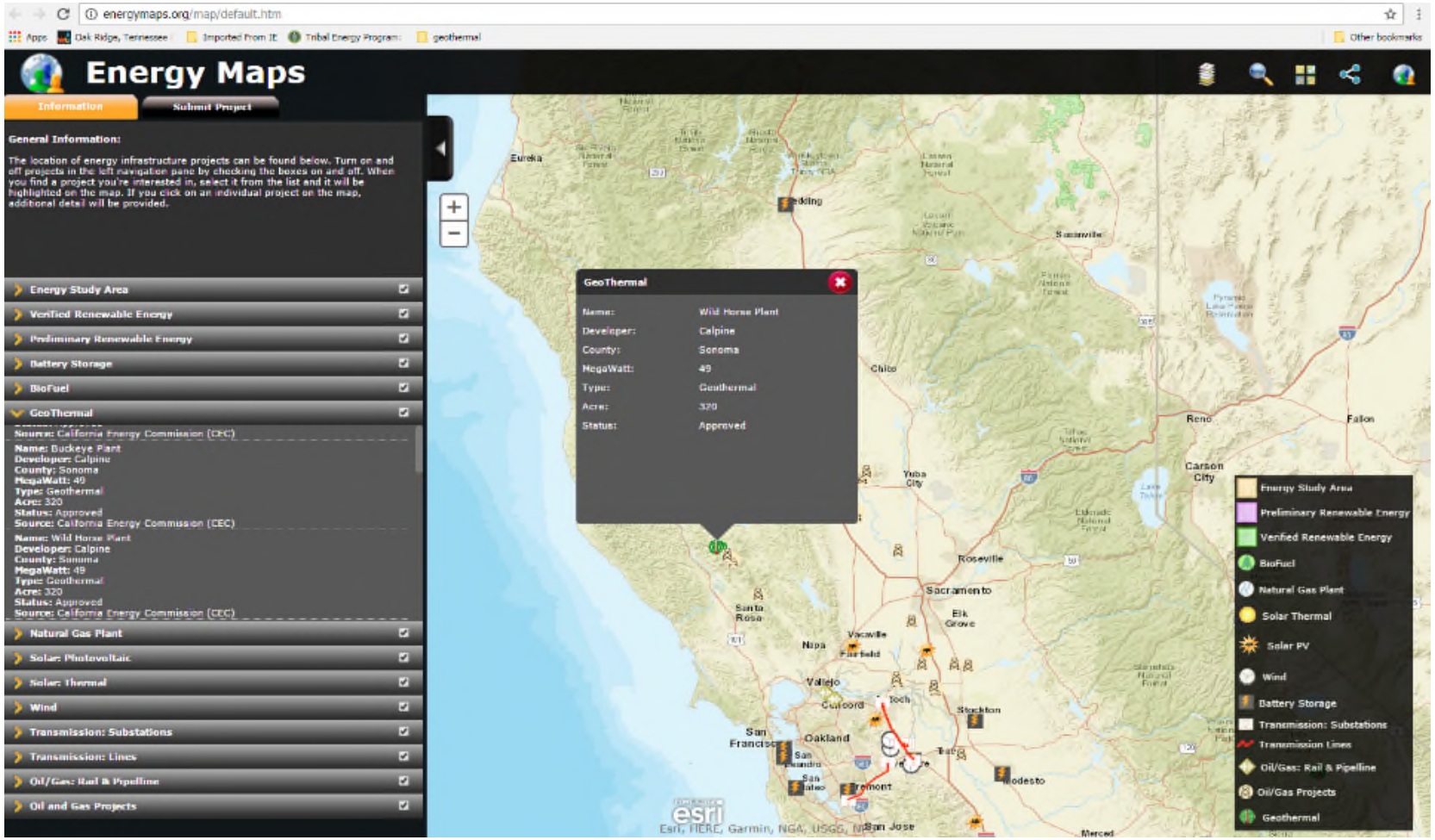
In general, security considerations dominate the choice of particular software selected by an enterprise. In an enterprise, the risk to proprietary and/or valuable data is great. In general, a good security plan should:

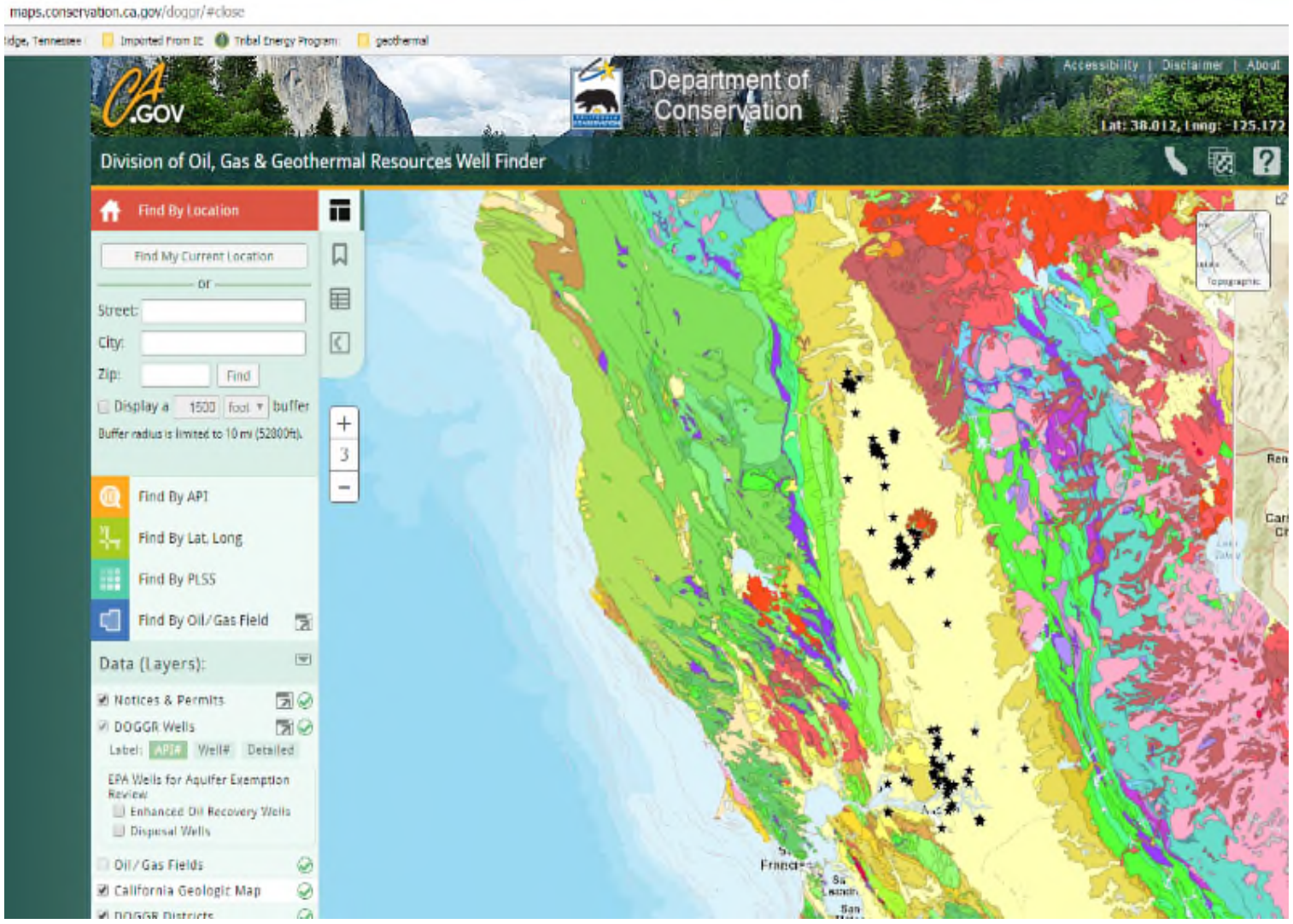
- Protect the databases and the servers on which they reside
- Administer and protect the rights of internal database users
- Guarantee confidentiality of users
- Protect high-value data/information
- Prevent unauthorized access, use, disclosure, modification, and/or destruction of information
- Prevent disruption in services or access

Example: California Geothermal RDBMS



California has a mature geothermal industry; the largest producer of geothermal energy in the world. Their geothermal data is available online, viewable by the public yet allows highly diverse data to be collected, managed, displayed and downloaded.

Example: California Geothermal RDBMS (cont'd)



Same, but now displayed with geologic map overlay.

Example: California Geothermal RDBMS (cont'd)

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Department of Conservation

Division of Oil, Gas & Geothermal Resources

Online Geothermal Well Data Query for State of California, Department of Conservation, Division of Oil, Gas, and Geothermal Resources.

Geothermal Home Page | Help with Well Record Program | Help with Production & Injection Data

Back

Geothermal Well List

SEARCH CRITERIA: District: 3 / County: Napa / Operator: Calistoga (private) well

(Click API# to view details.) Total Number of Pages: 5 - Total Number of Wells: 87 Export to Excel

1 2 3 4 5

District	API#	LeaseName	Well#	WellType	WellStatus	OperatorName	OpCode	Field	CountyName	MineralRights	Confidential	Section	Township	Range	BM
3	05590049	Shade Factory	1	CLT	ACTV	Calistoga (private) well	CLSTG	CALIS	Napa	P	N	26	9N	7W	MD
3	05590050	Donshick	1	NLT	UNKN	Calistoga (private) well	CLSTG	CALIS	Napa	P	N	6	8N	6W	MD
3	05590051	Wilkinson	1	CLT	ACTV	Calistoga (private) well	CLSTG	CALIS	Napa	P	N	36	9N	7W	MD
3	05590052	Dober	1	NLT	ACTV	Calistoga (private) well	CLSTG	CALIS	Napa	P	N	36	9N	7W	MD
3	05590054	Cirio's	1	NLT	ACTV	Calistoga (private) well	CLSTG	CALIS	Napa	P	N	6	8N	6W	MD
3	05590055	Greenwood Ave	1428	NLT	ACTV	Calistoga (private) well	CLSTG	CALIS	Napa	P	N	35	9N	7W	MD
3	05590056	Calistoga Spa	1	CLT	ACTV	Calistoga (private) well	CLSTG	CALIS	Napa	P	N	31	9N	6W	MD
3	05590057	Calistoga Spa	2	CLT	ACTV	Calistoga (private) well	CLSTG	CALIS	Napa	P	N	31	9N	6W	MD
3	05590058	Little Village	1	CLT	ACTV	Calistoga (private) well	CLSTG	CALIS	Napa	P	N	36	9N	7W	MD
3	05590062	Tubbs Lane	1239A	NLT	IDLE	Calistoga (private) well	CLSTG	CALIS	Napa	P	N	26	9N	7W	MD
3	05590063	Michael Way	1717	NLT	ACTV	Calistoga (private) well	CLSTG	CALIS	Napa	P	N	36	9N	7W	MD
3	05590064	Greenwood Ave	2281	NLT	ACTV	Calistoga (private) well	CLSTG	CALIS	Napa	P	N	25	9N	7W	MD
3	05590065	Geyser	2	NLT	IDLE	Calistoga (private) well	CLSTG	CALIS	Napa	P	N	26	9N	7W	MD
3	05590070	Godward	1	NLT	IDLE	Calistoga (private) well	CLSTG	CALIS	Napa	P	N	26	9N	7W	MD
3	05590071	Geyser	1	NLT	ACTV	Calistoga (private) well	CLSTG	CALIS	Napa	P	N	26	9N	7W	MD
3	05590085	View Road	40	NLT	ACTV	Calistoga (private) well	CLSTG	CALIS	Napa	P	N	36	9N	7W	MD
3	05590086	Foothill Blvd	200	NLT	ACTV	Calistoga (private) well	CLSTG	CALIS	Napa	P	N	1	8N	7W	MD
3	05590087	Oak St	1755	NLT	IDLE	Calistoga (private) well	CLSTG	CALIS	Napa	P	N	36	9N	7W	MD
3	05590088	Oak St	1758	NLT	ACTV	Calistoga (private) well	CLSTG	CALIS	Napa	P	N	36	9N	7W	MD
3	05590089	Silverado Trail	4377	NLT	ACTV	Calistoga (private) well	CLSTG	[N/A]	Napa	P	N	4	8N	6W	MD

1 2 3 4 5

Last edited on March 29, 2011

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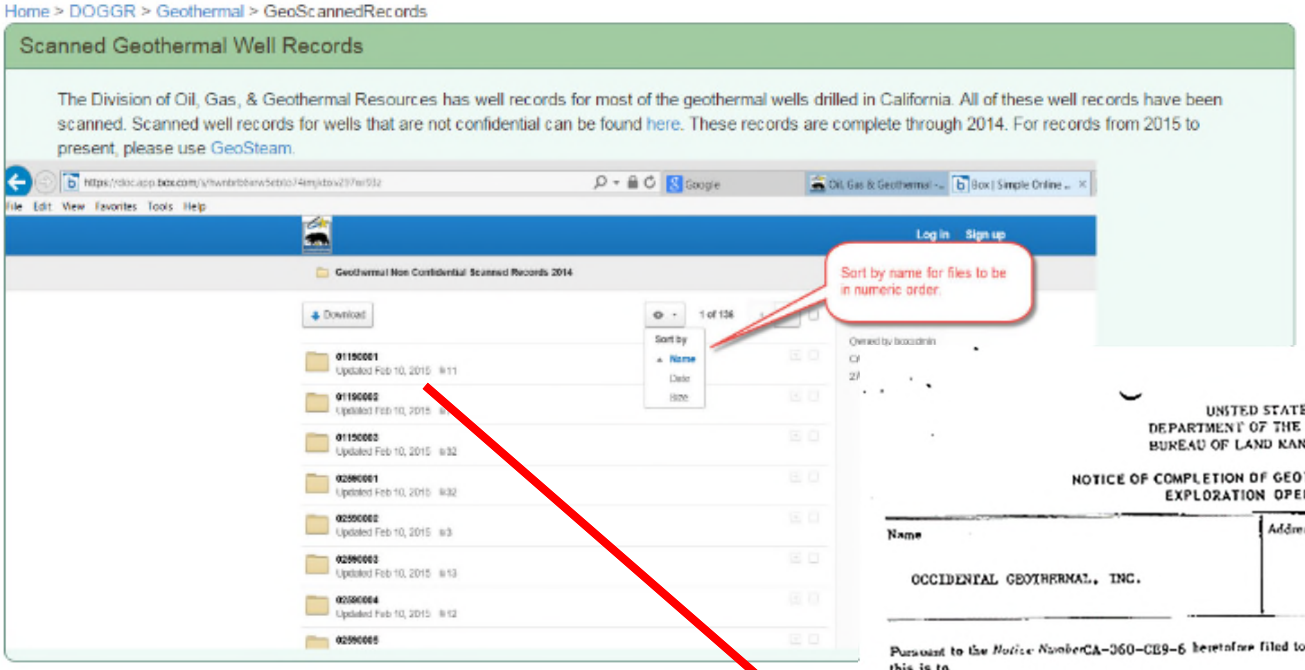
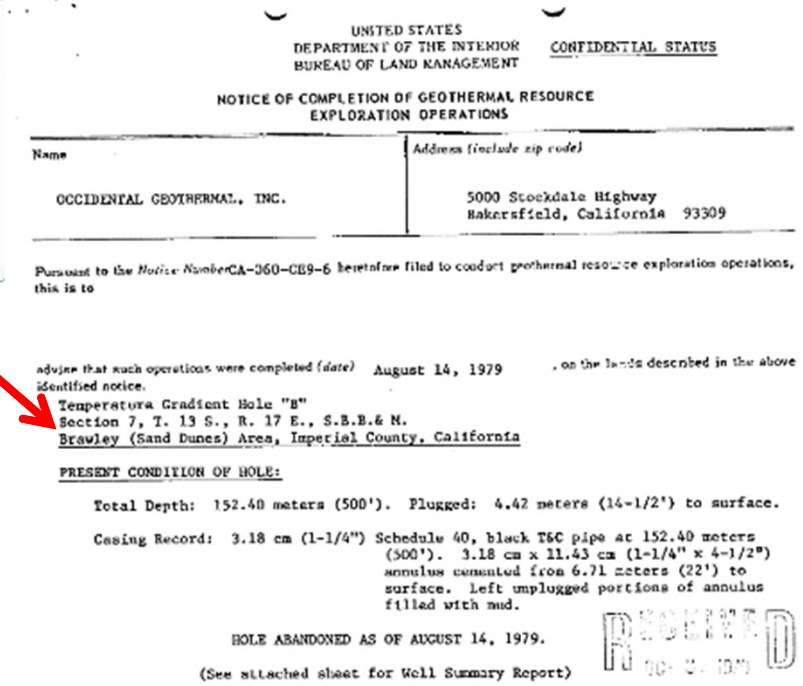
An RDBMS can access digital and GIS data (in this example, geo-referenced wells).

Example: California Geothermal RDBMS (cont'd)





UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

CONFIDENTIAL STATUS

NOTICE OF COMPLETION OF GEOTHERMAL RESOURCE EXPLORATION OPERATIONS

Name	Address (include zip code)
OCCIDENTAL GEOTHERMAL, INC.	5000 Stockdale Highway Bakersfield, California 93309

Pursuant to the Notice Number CA-060-CE9-6 heretofore filed to conduct geothermal resource exploration operations, this is to

advise that such operations were completed (date) August 14, 1979 on the lands described in the above identified notice.

Temperature Gradient Hole "B"
Section 7, T. 13 S., R. 17 E., S.B.B.& M.
Brawley (Sand Dunes) Area, Imperial County, California

PRESENT CONDITION OF HOLE:

Total Depth: 152.40 meters (500'). Plugged: 4.42 meters (14-1/2') to surface.

Casing Record: 3.18 cm (1-1/4") Schedule 40, black T&C pipe at 152.40 meters (500'). 3.18 cm x 11.43 cm (1-1/4" x 4-1/2") annulus cemented from 6.71 meters (22') to surface. Left unplugged portions of annulus filled with mud.

HOLE ABANDONED AS OF AUGUST 14, 1979.

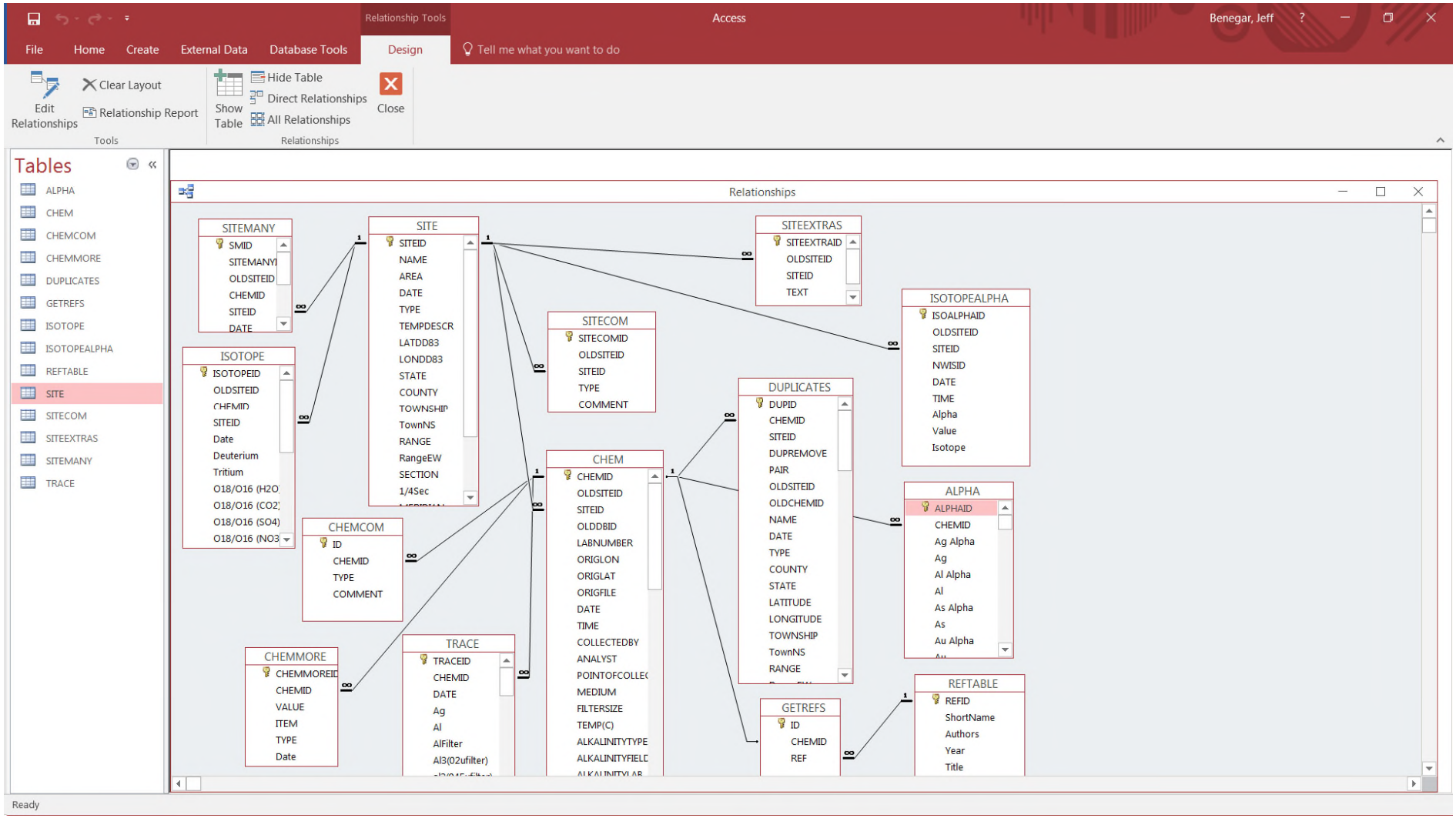
(See attached sheet for Well Summary Report)

RECEIVED

Clicking on link instantly brings up decades-old paper records

Example: old, scanned paper records

Example: Nevada Geothermal RDBMS



Statewide database for geothermal geochemistry data (MS Access format)

Best Practices for Data Management

TETRA TECH

Mature geothermal jurisdictions (USA, Iceland, New Zealand, Italy, for example) all share commonalities such as:

#1 – Setting up a DBMS is the best practice to securely manage exploration data and risk

Also:

- Data should be in digital format as much as practically possible
- Collect data in raw, processed and interpreted formats for long-term use/analysis/interpretation
- Data submission procedures clearly defined as part of regulatory framework/requirements
- Use existing commercial software on local servers or the cloud
- QC procedures for data completeness and accuracy

Questions?

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Mwebale nnyo,
bannyabo ne bassebo!

Asenteni sana!

THANK YOU!