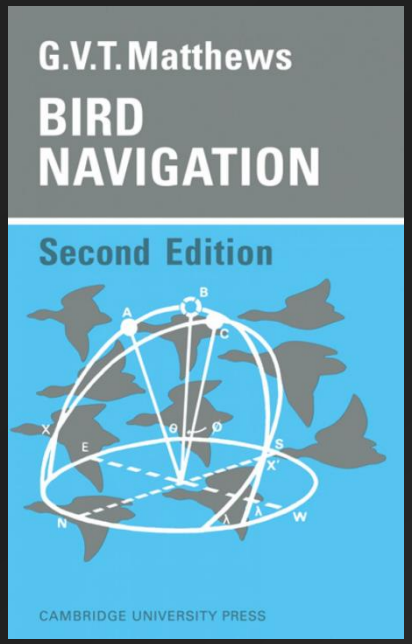
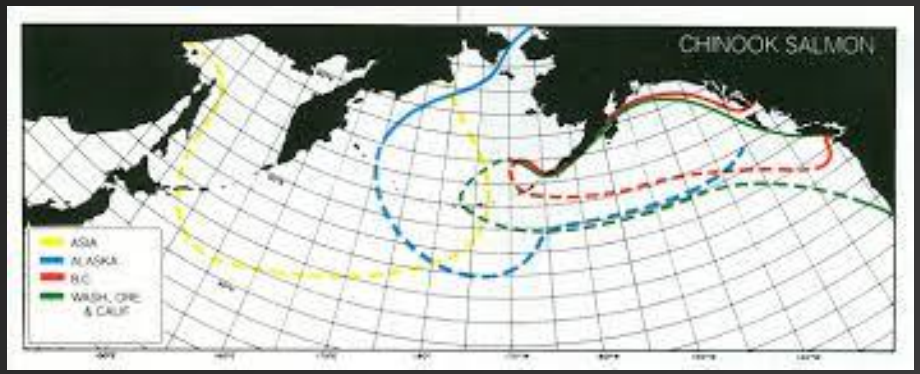
Fundamentals of Geographic Information Systems

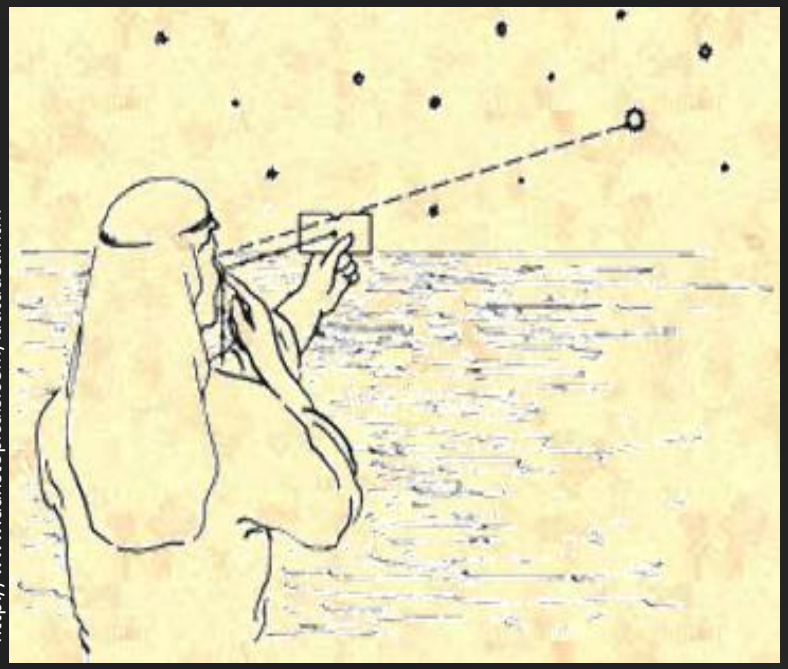
Instructor: Paul Cote
Assistant Instructor: Sam Jones

Geography and Survival of Species

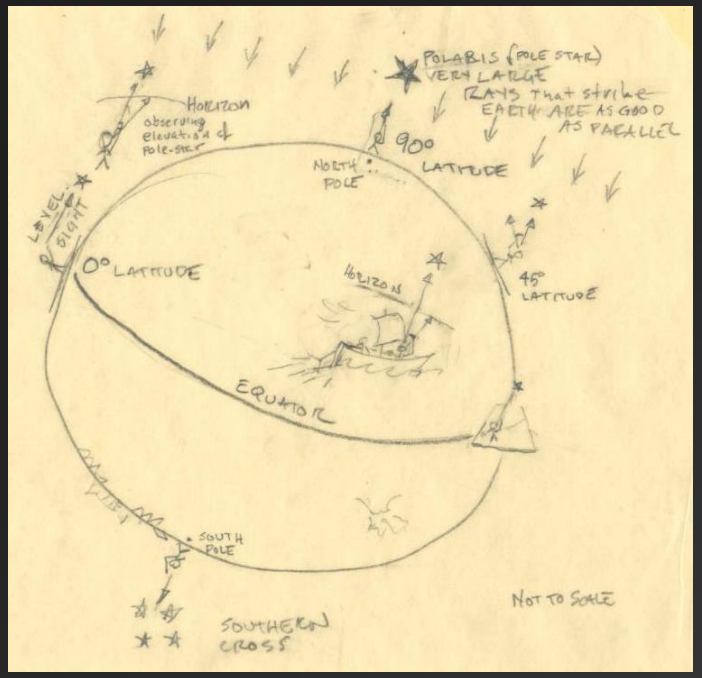




Geography:
Conceiving a World of Relationships



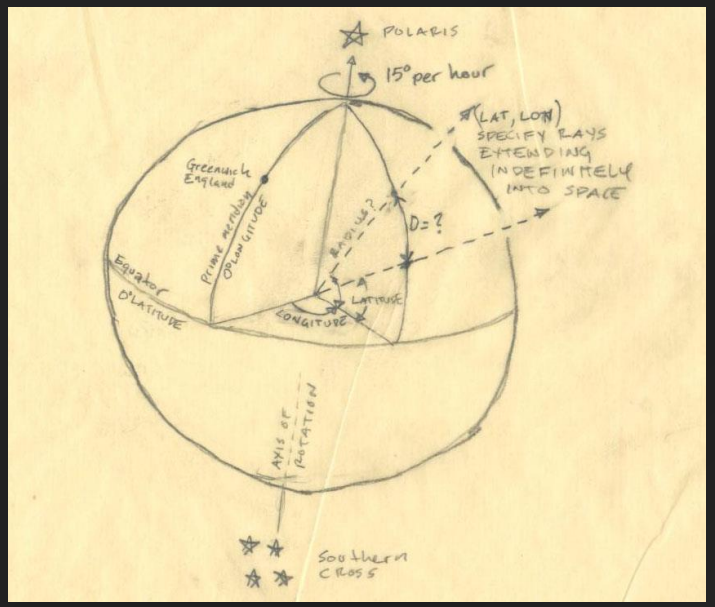
http://www.danstopicals.com/latitudea.htm

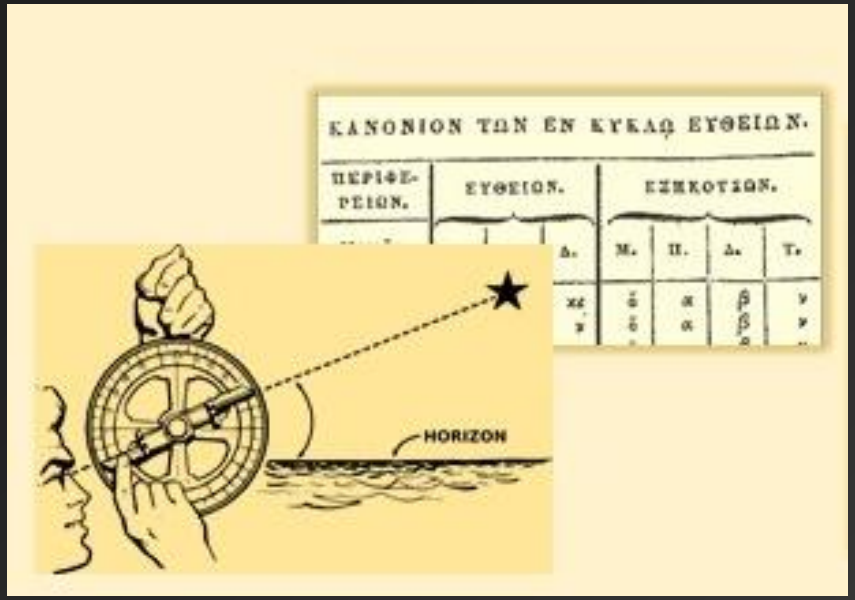


~ 1200BC: Astronomy and Navigation

Geography:

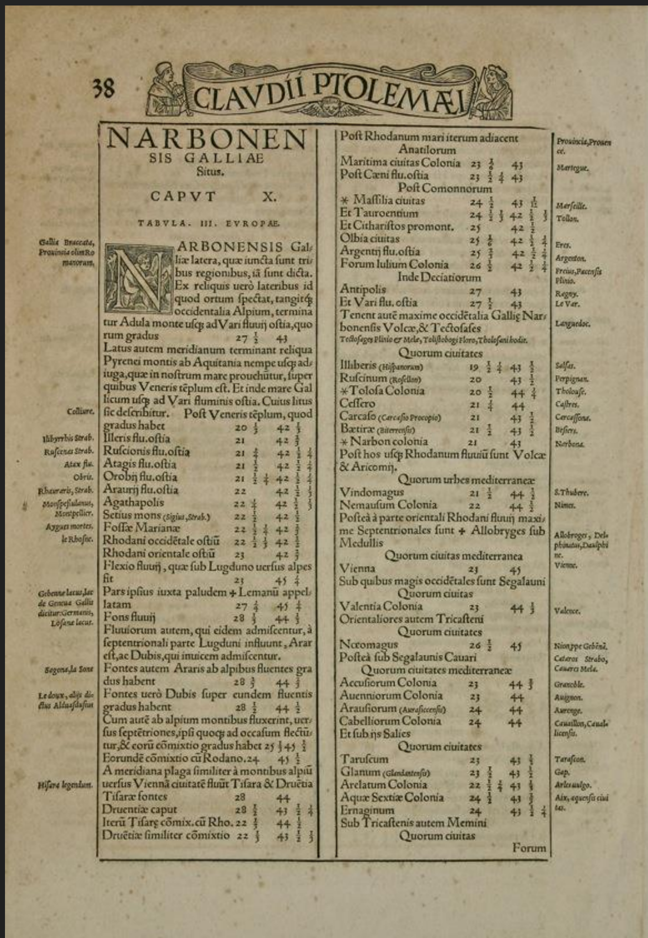
A Common Coding Scheme for Observations





~ 250 BC: Hipparchus: Latitude and Longitude

Geography:
Collaborative Observation and Understanding



38 CLAVDII PTOLEMAEI

NARBONENSIS GALLIAE Situs.

CAPVT X.

TABVLA. III. EVROPAE.

NARBONENSIS Galliae latera, quae iuncta sunt tribus regionibus, iã sunt dicta. Ex reliquis uerò lateribus id quod ortum spectat, tangitq; occidentalia Alpium, terminatur Adula monte usq; ad Vari fluuij ostia, quorum gradus 27 ½ 43

Latus autem meridianum terminant reliqua Pyrenei montis ab Aquitania nempe usq; ad iuga, quae in nostrum mare prouehũtur, super quibus Veneris tẽplum est. Et inde mare Gallicum usq; ad Vari fluminis ostia. Cuius litus sic describitur. Post Veneris tẽplum, quod gradus habet 20 ⅓ 42 ⅓

Illeris flu. ostia 21 42 ⅔
Ruscionis flu. ostia 21 ¾ 42 ½ ¼
Atagis flu. ostia 21 ½ 42 ½ ¼
Orobij flu. ostia 21 ½ ¼ 42 ½ ¼
Araurij flu. ostia 22 42 ½ ⅓
Agathapolis 22 ¼ 42 ½ ⅓
Setius mons (Sigius, Strab.) 22 ½ 42 ½
Fossae Marianae 22 ½ ¼ 42 ⅔
Rhodani occidẽtale ostiũ 22 ½ ⅓ 42 ½
Rhodani orientale ostiũ 23 42 ⅔

Flexio fluuij, quae sub Lugduno uersus alpes fit 23 45 ¼
Pars ipsius iuxta paludem + Lemanũ appellatam 27 ¼ 45 ¼
Fons fluuij 28 ⅓ 44 ⅓

Fluuiorum autem, qui eidem admiscentur, à septentrionali parte Lugduni influunt, Arar est, ac Dubis, qui inuicem admiscentur.

Fontes autem Araris ab alpibus fluentes gradus habent 28 ⅔ 44 ⅔
Fontes uerò Dubis super eundem fluentis gradus habent 28 ½ 44 ½

Cum autẽ ab alpium montibus fluxerint, uersus septẽtriones, ipsi quoq; ad occasum flectũtur, & eorũ cõmixtio gradus habet 25 ⅓ 45 ½
Eorundẽ cõmixtio cũ Rodano. 24 45 ½

A meridiana plaga similiter à montibus alpiũ uersus Viennã ciuitatẽ fluũt Tisara & Druẽtia

Tisarae fontes 28 44
Druentiae caput 28 ½ 43 ½ ¼
Iterũ Tisarę cõmix. cũ Rho. 22 ⅓ 44 ½
Druẽtiae similiter cõmixtio 22 ⅓ 43 ½ ⅓

Post Rhodanum mari iterum adiacent

Anatiliorum

Maritima ciuitas Colonia 23 ⅙ 43
Post Caeni flu. ostia 23 ½ ¼ 43

Post Comonnorum

* Massilia ciuitas 24 ½ 43 1/12
Et Tauroentium 24 ½ ⅓ 42 ½ ⅓
Et Citharistos promont. 25 42 ½
Olbia ciuitas 25 ⅙ 42 ½ ¼
Argentij flu. ostia 25 ⅔ 42 ½ ¼
Forum Iulium Colonia 26 ½ 42 ½ ¼

Inde Deciatiorum

Antipolis 27 43
Et Vari flu. ostia 27 ½ 43

Tenent autẽ maxime occidẽtalia Gallię Narbonensis Volcae, & Tectosases

Tectosages Plinio & Melae, Tolistobogi Floro, Tholosani hodie.

Quorum ciuitates

Illiberis (Hispanorum) 19 ½ ¼ 43 ½
Ruscinum (Rosellon) 20 43 ½
* Tolosa Colonia 20 ½ 44 ¼
Cessero 21 ¼ 44
Carcaso (Carcasio Procopio) 21 43 ½
Baetirae (Biterrensis) 21 ½ 43 ½
* Narbon colonia 21 43

Post hos usq; Rhodanum fluuiũ sunt Volcae & Aricomij.

Quorum urbes mediterraneae

Vindomagus 21 ½ 44 ½
Nemausum Colonia 22 44 ½

Posteà à parte orientali Rhodani fluuij maxime Septentrionales sunt + Allobryges sub Medullis

Quorum ciuitas mediterranea

Vienna 23 45

Sub quibus magis occidẽtales sunt Segalauni

Quorum ciuitas

Valentia Colonia 23 44 ⅓

Orientaliores autem Tricasteni

Quorum ciuitates

Noeomagus 26 ½ 45

Posteà sub Segalaunis Cauari

Quorum ciuitates mediterraneae

Accusiorum Colonia 23 44 ⅔
Auenniorum Colonia 23 44
Arausiorum (Aurasicensis) 24 44
Cabelliorum Colonia 24 44

Et sub ijs Salies

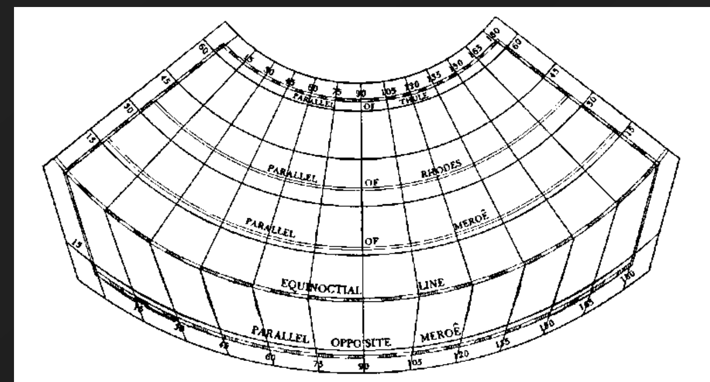
Quorum ciuitates

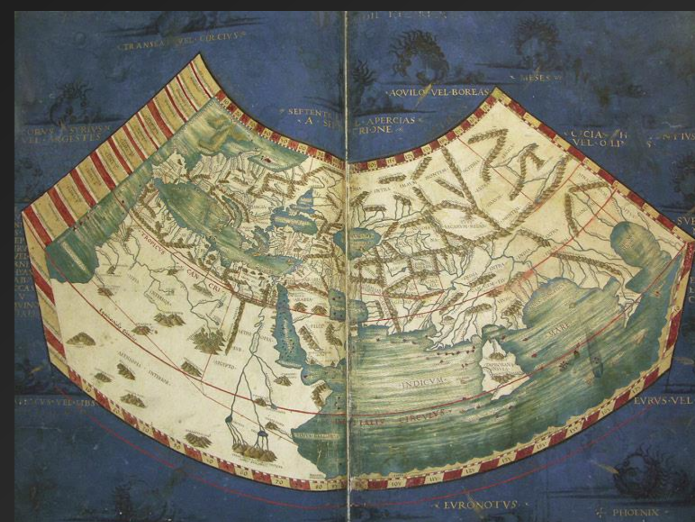
Taruscum 23 43 ⅓
Glanum (Glandatensis) 23 ½ 43 ½
Arelatum Colonia 22 ½ ¼ 43 ⅓
Aquae Sextiae Colonia 24 ½ 43 ⅓
Ernaginum 24 43 ½ ¼

Sub Tricastenis autem Memini

Quorum ciuitas

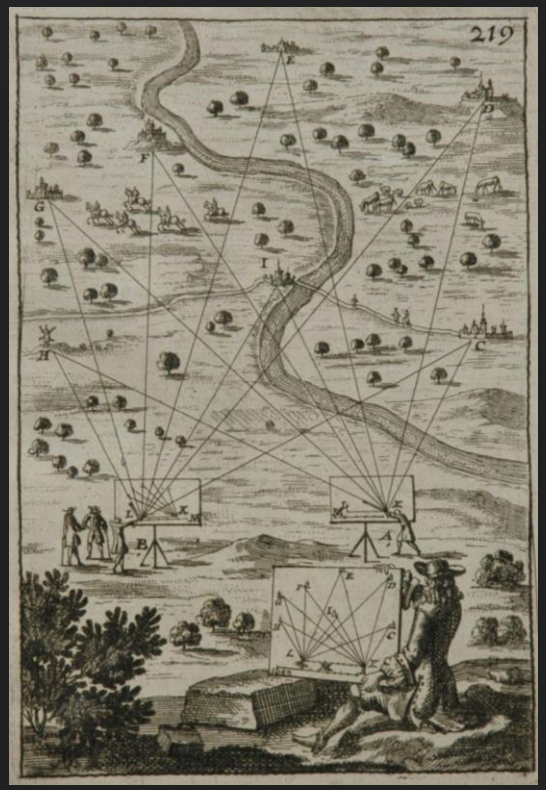
Forum

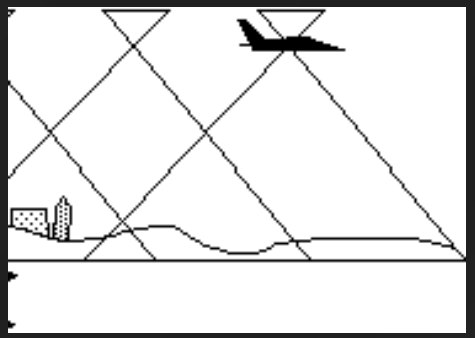


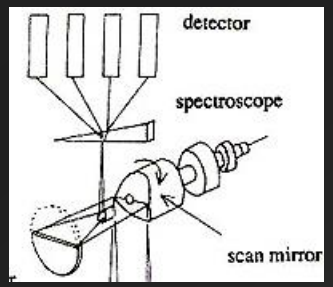


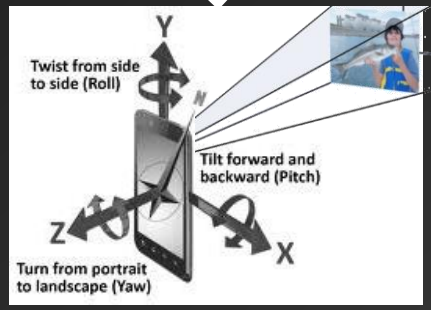
150 AD: Claudius Ptolemaeus: Gazetteer and Map Projections

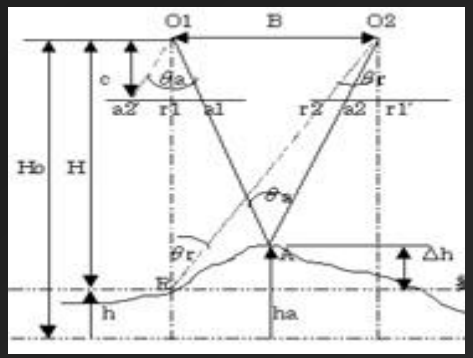
2300 Years of Refinement of Observation and Transformation of References

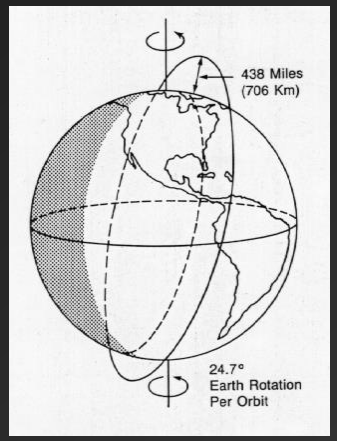








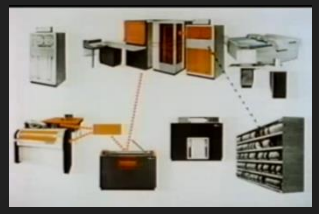


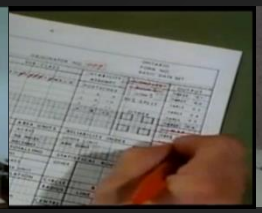


Allain Manesson Mallet: La Geometrie Pratique

400 Years of Precise Topographic Data

Geography:
First GIS: ca 1961

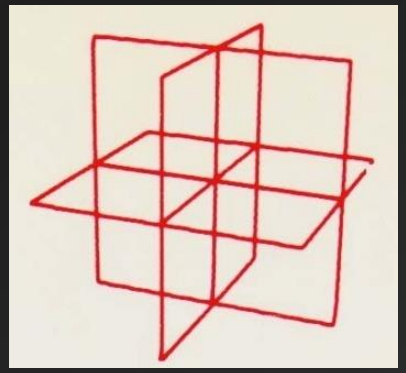




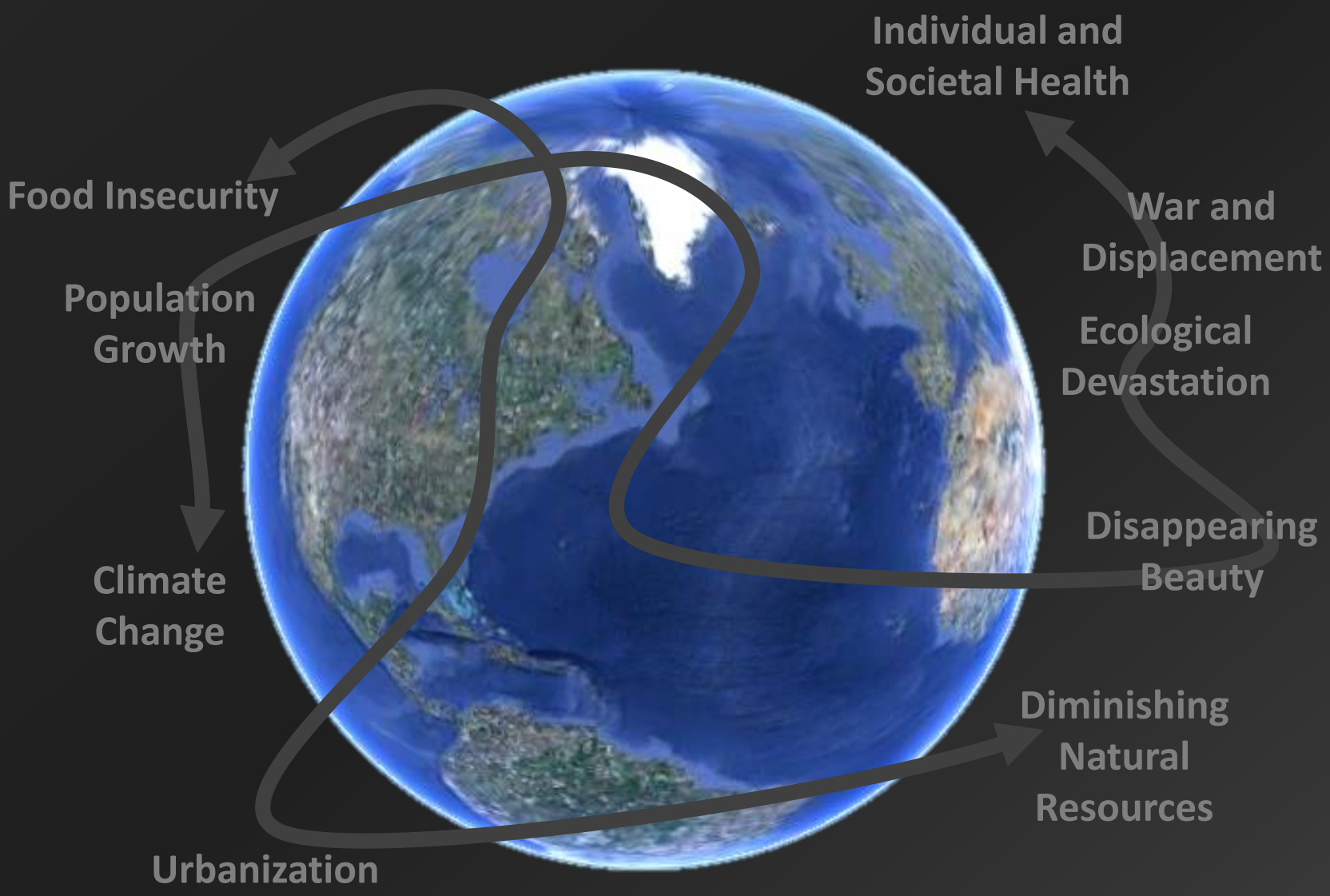
[Watch Video: Data for Decision on You Tube]

Roger Tomlinson and the Canada Land Inventory

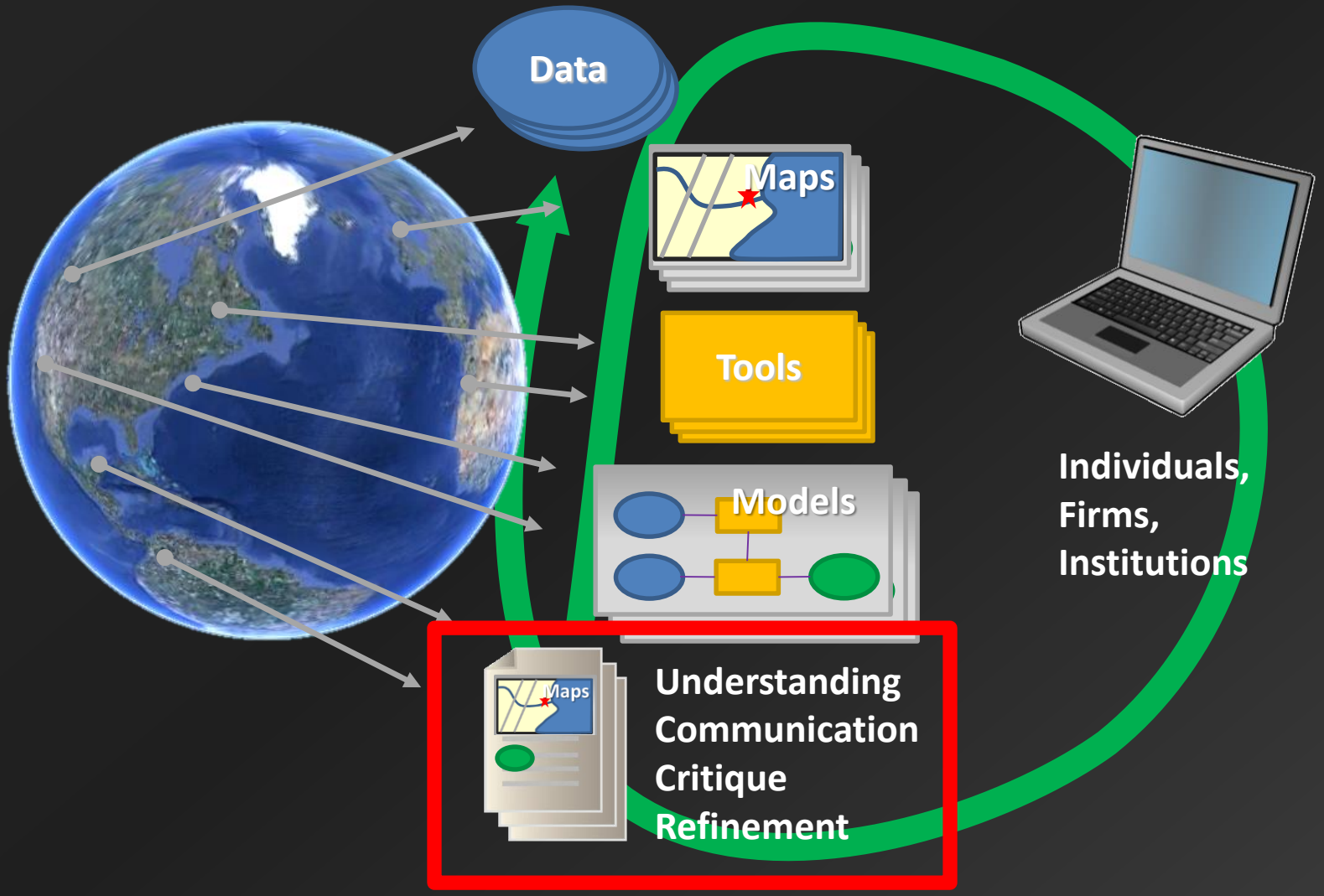
Harvard Lab for Computer Graphics and Spatial Analysis
Pushed Geography into the Mainframe Era



Local Problems Occurring Globally



New Modes of Scholarship, Planning, Design and Administration



New Responsibilities for Decision Makers and Scholars

De-Mystifying GIS

See: GIS Models in Decision-Making Situations for a discussion.

Abstraction

A Situation

Observations / Data
- Purposes, Methods
- Referencing systems

Purpose / Questions

Conceptual Model:
- Things / Conditions
- Relationships / Processes

Research / Scholarship

Background:
- Prior work
- Design / Discussion

Data Model

Database Schema:
- Entities / Phenomena
- Attributes / Organization

Operations:
- Transformations
- Associations

Investigation:
- Portrayal
- Logic / Experiments

New Maps / New Data

Understanding

Critique

Fitness of Data
- Adequate for purpose?
- Assessment of error: Commission / Omission

Fitness of Operations:
- As representations of Processes and Relationships
- Assessment of error

New Information
- Concise / Confusing
- Credible / Unfounded
- Useful / Not Useful

Degree of Confidence

Information Needs
- Critical Entities
- Attributes / Precision

Simulation Challenges
- Processes
- Relationships

Useful Knowledge
- About models
- About the situation

Paul Cote 2008

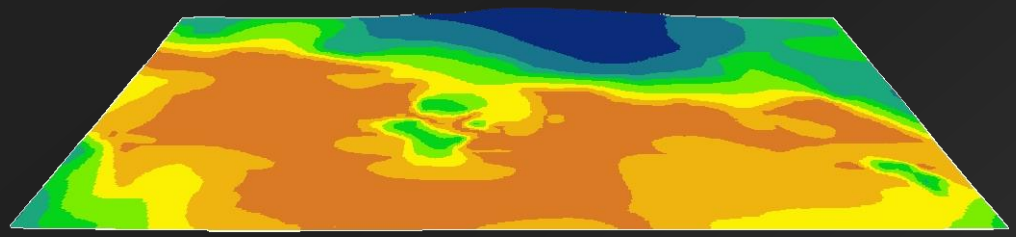
Discussion / Maps / Data Model / Documentation

Describe decision-making scenarios in terms that may be represented with data

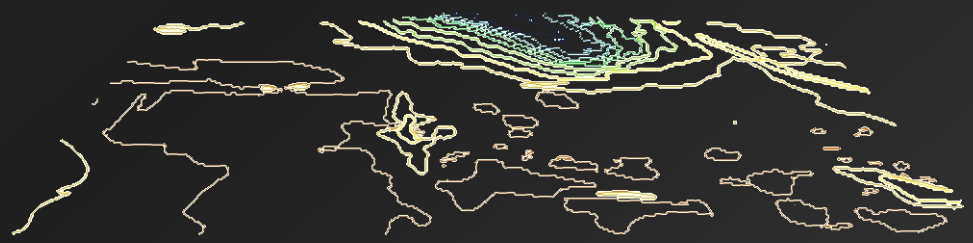
Gathering, Evaluating, and Organizing Data

Terrain

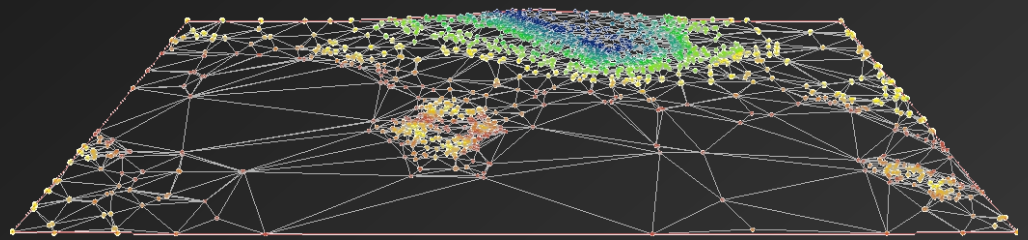
Elevation Model



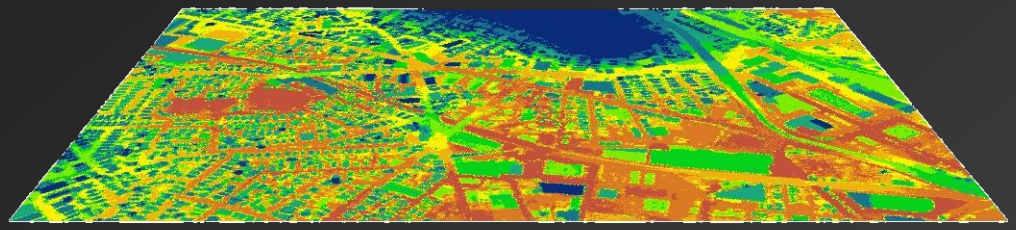
Contours



Terrain Mesh



LIDAR

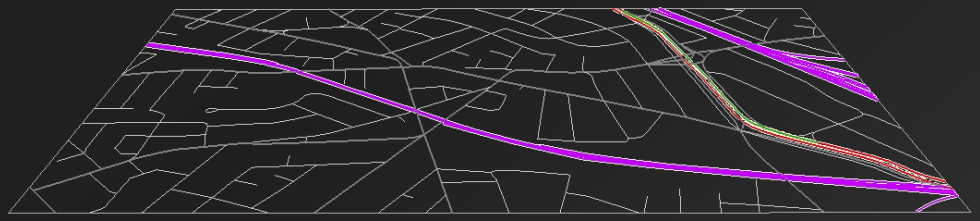


Data

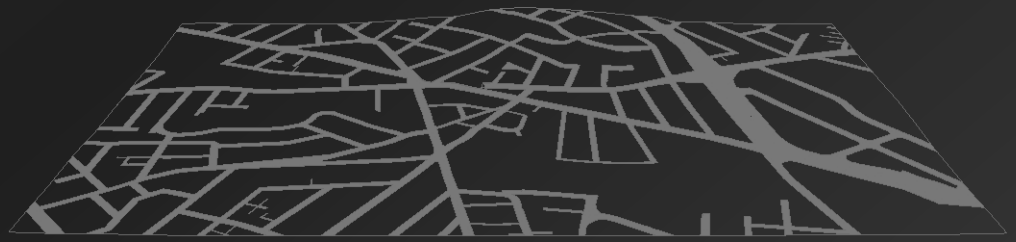
Built Condition

Orthophotography

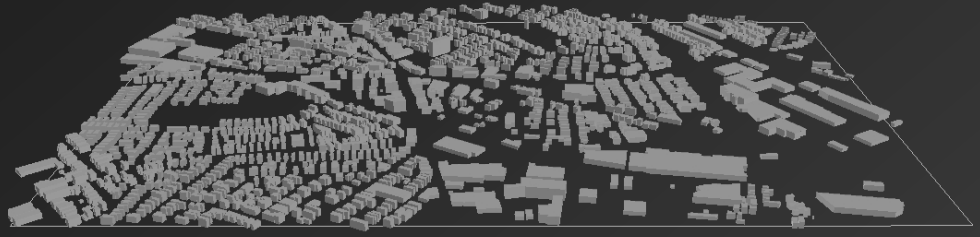
Networks



Edge of Pavement



Buildings



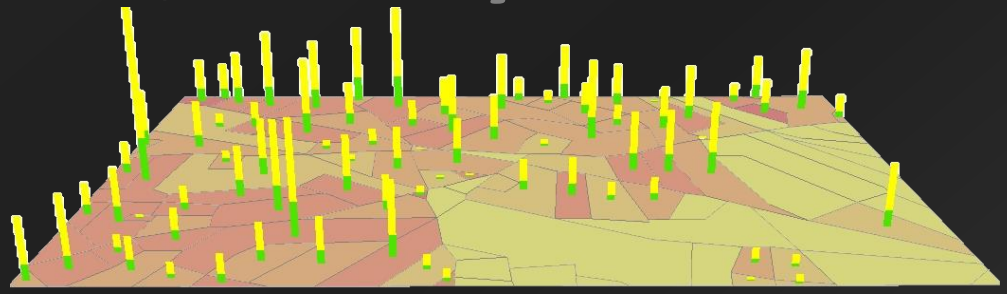
Topographic Model

Data

Culture, Plans, History

Demography

Census

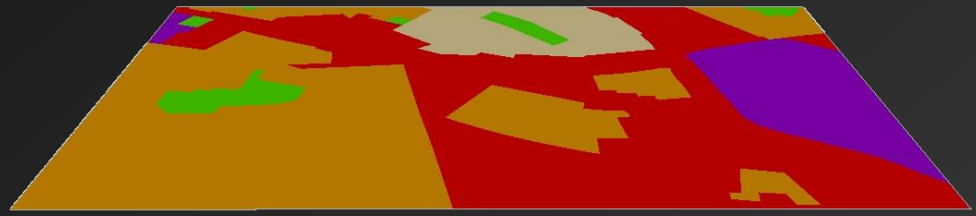


Administration

Property Parcels

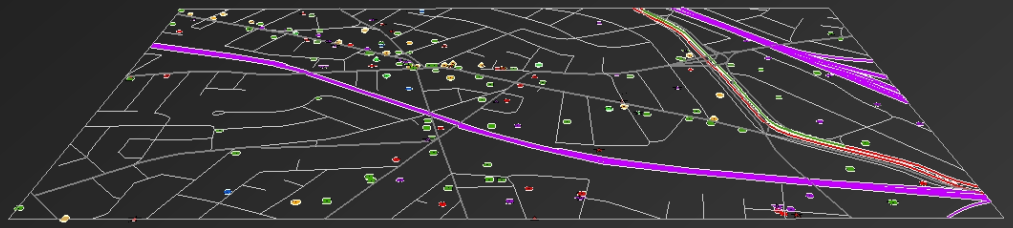
Regulation

Zoning



Economic Activity

Businesses

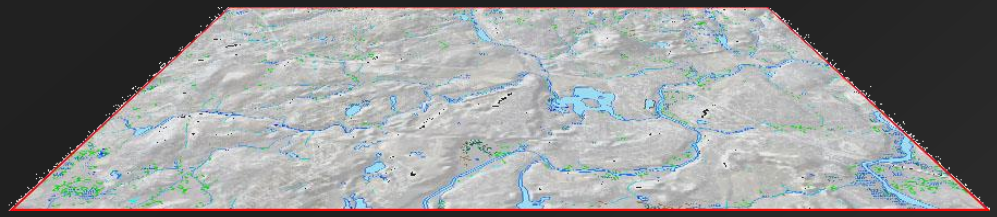


History

Antique Maps

Natural Systems

Hydrography

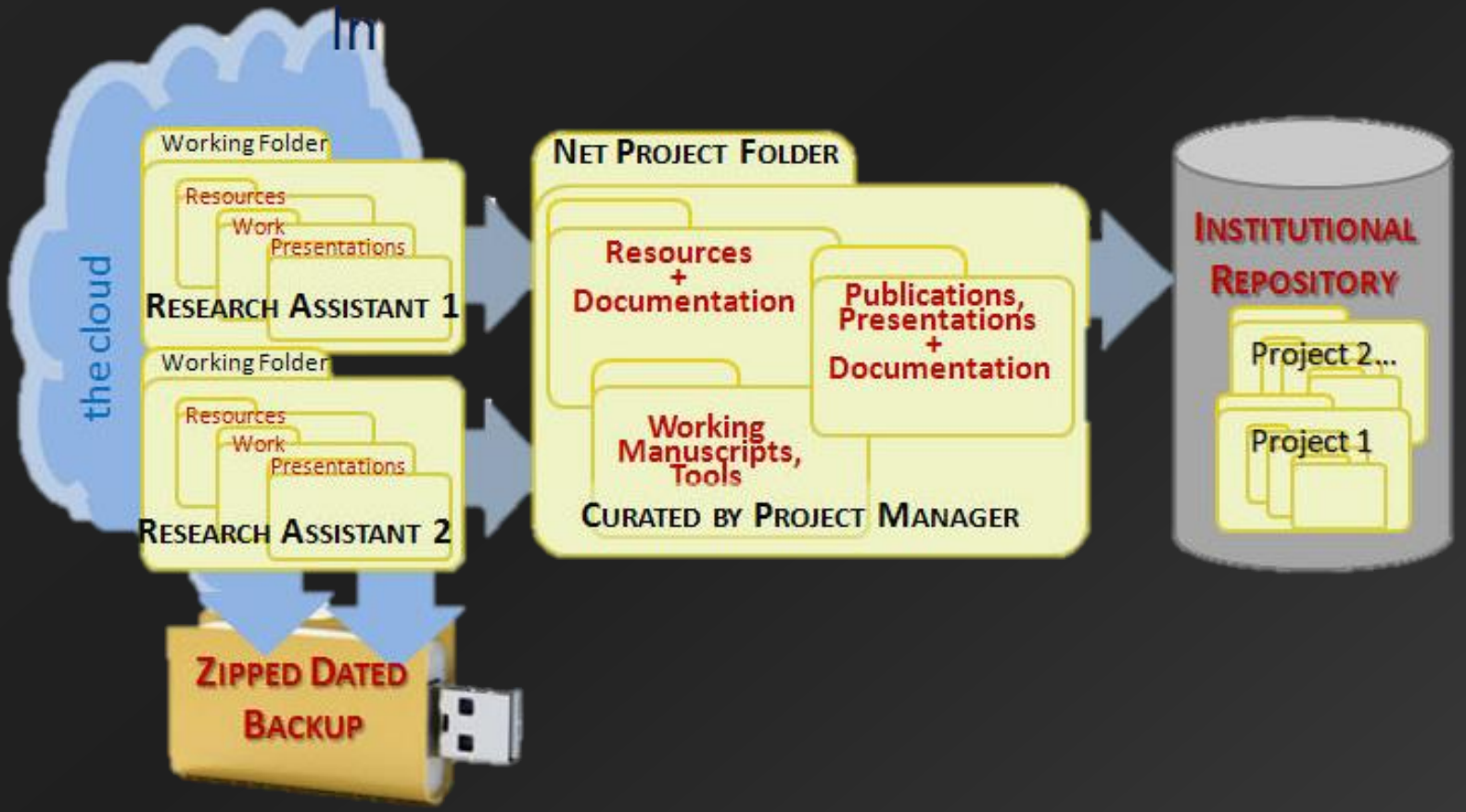


Soils

Land Cover

…and much more

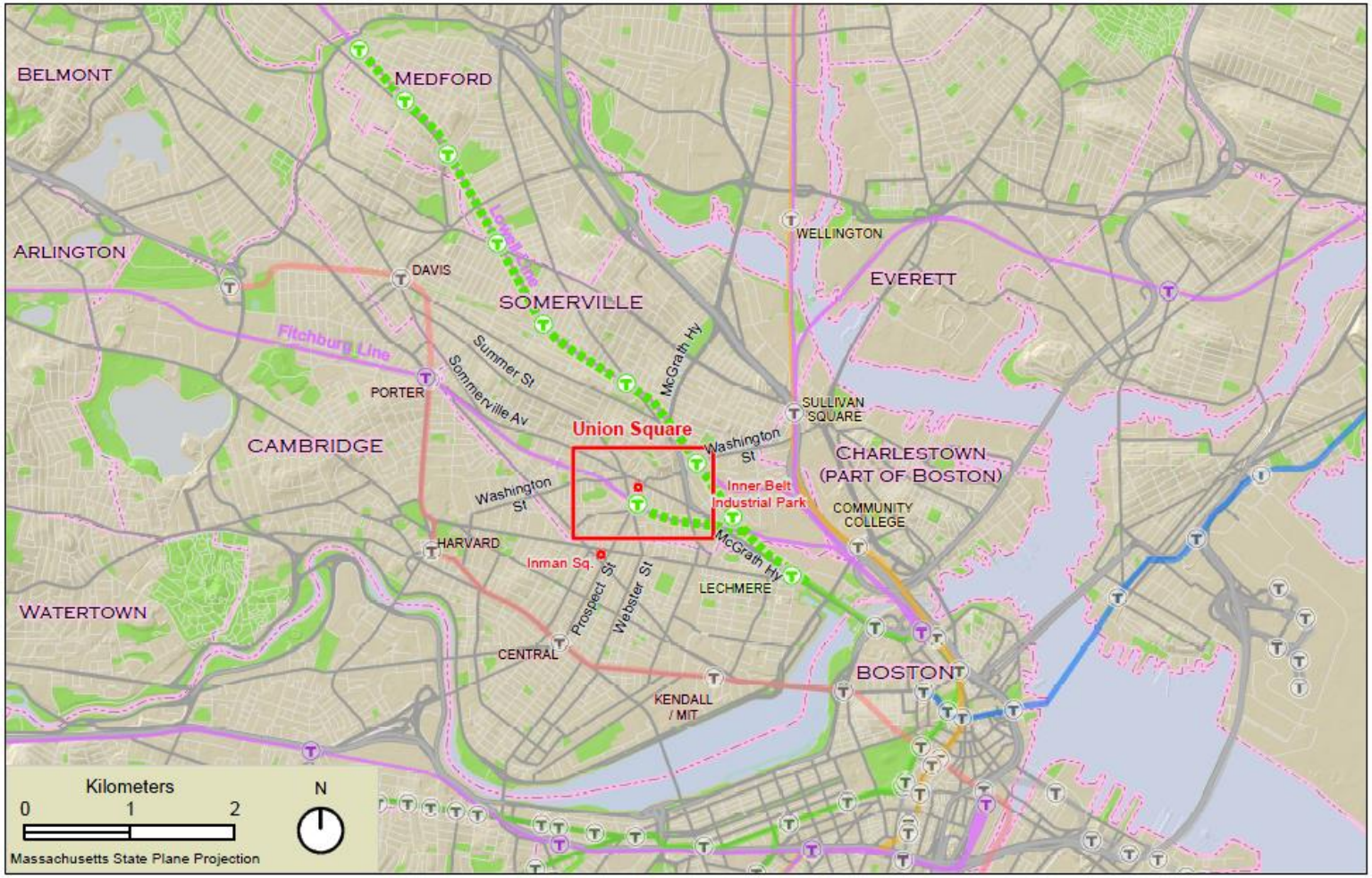
Organizing Data and Models for re-Use



Elements of Cartography:

Setting the stage for Design and Decision.

Topography & Context



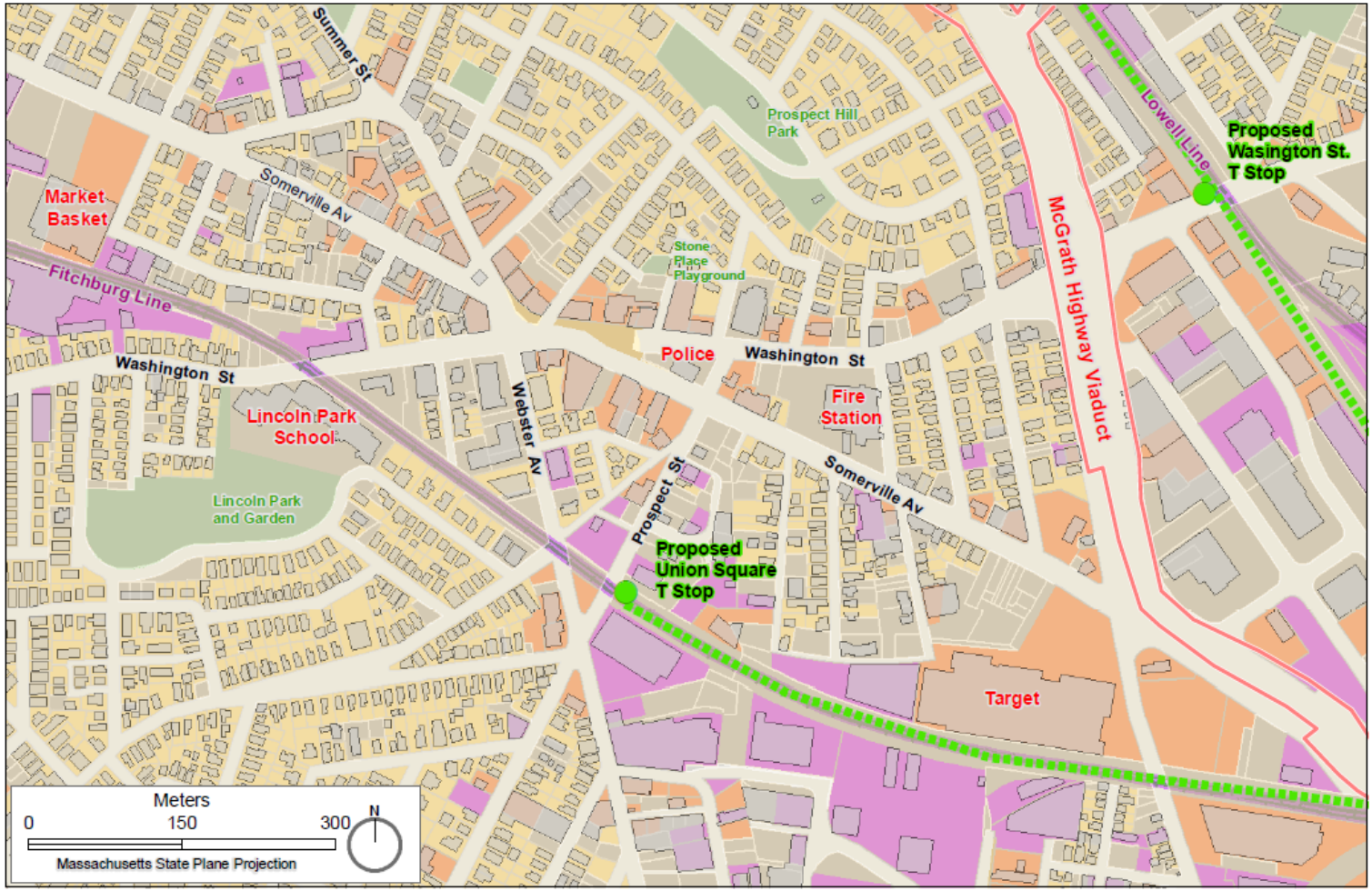
Union Square and the Green Line Extension

Just over 2 kilometers from downtown Boston and Harvard University, Union Square is a vibrant commercial center not yet served by rapid transit. The Massachusetts Executive Office of Transportation is under a federal order to extend the Green Line Trolly system through Somerville by 2014. This extension will follow the existing Lowell Line on the commuter rail and will include a spur to Union Square along the Fitchburg Line. New transit access has a potential to ennliven Union Square and the Inner Belt Industrial park, located just to the east.

Proposed Extension
Commuter Rail
Existing Light Rail

Sources:
Map: Paul Cote; Fundamentals of GIS Assignment 1; September 2009
Roads: Massachusetts Executive Office of Transportation, 2007
MBTA System: Massachusetts Executive Office of Transportation, 2006
Proposed GreenLine Extension and Stops from

Transforming Categories



Union Square, Land Use

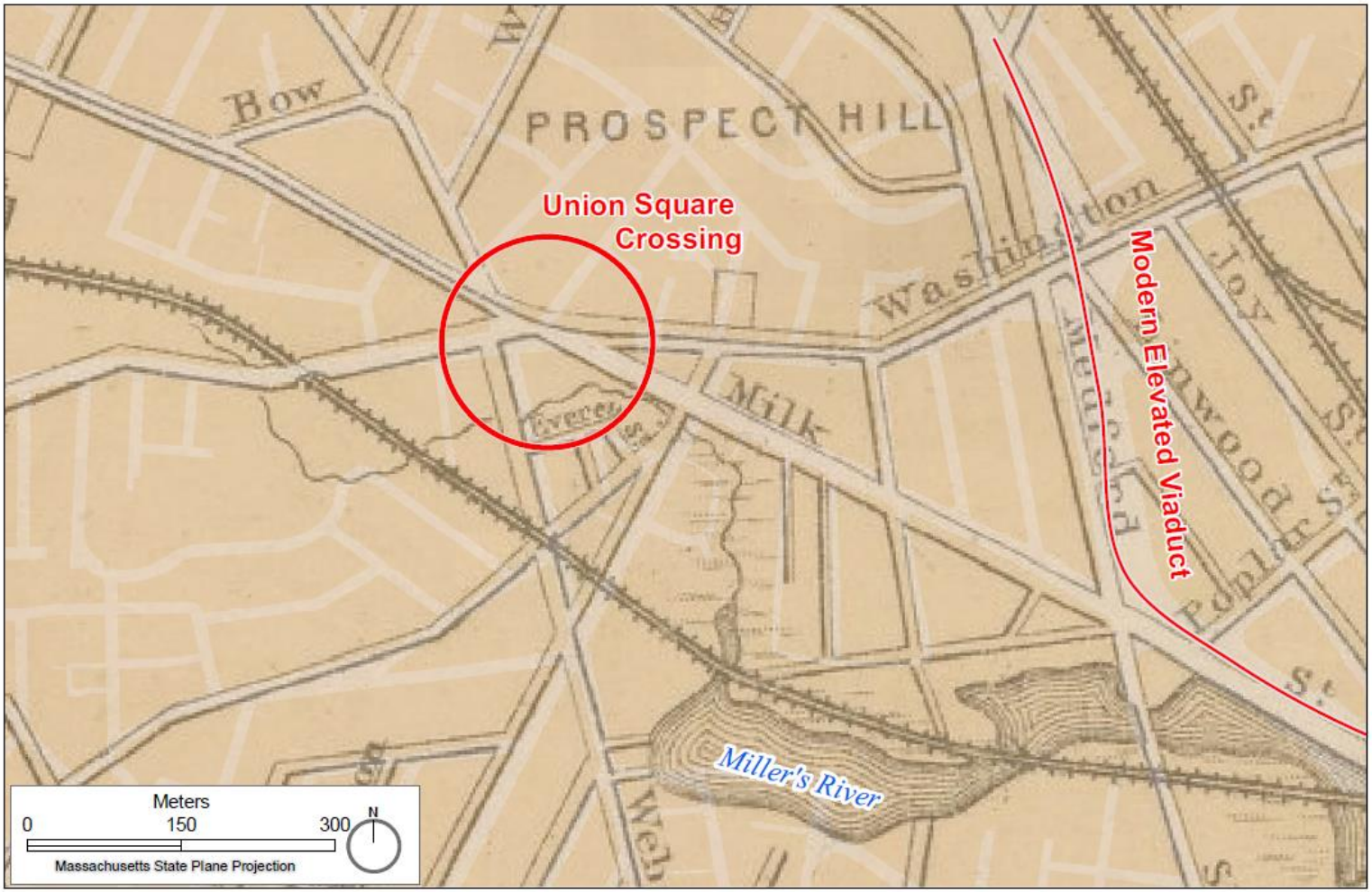
The 2007 property parcel data from the city of Somerville indicates that Union Square is a mixed use area with substantial proportions of Commercial Residentail and Industrial, all mixed together at a fairly fine grain. This map also shows substantial areas whose land use is defined as "Tax Exempt." Many of these parcels appear to be vacant, others are occupied by city services, yet others require furthwer investigation.

Generalized Land Use

- Residential
- Commercial
- Exempt
- Industrial

Sources:
Map: Paul Cote; Fundamentals of GIS Assignment 1; September 2009
Property Parcel Land Use: 2007 Somerville Tax Assessor (classes generalized)
Parks: City of Somerville 2007

Integrating History



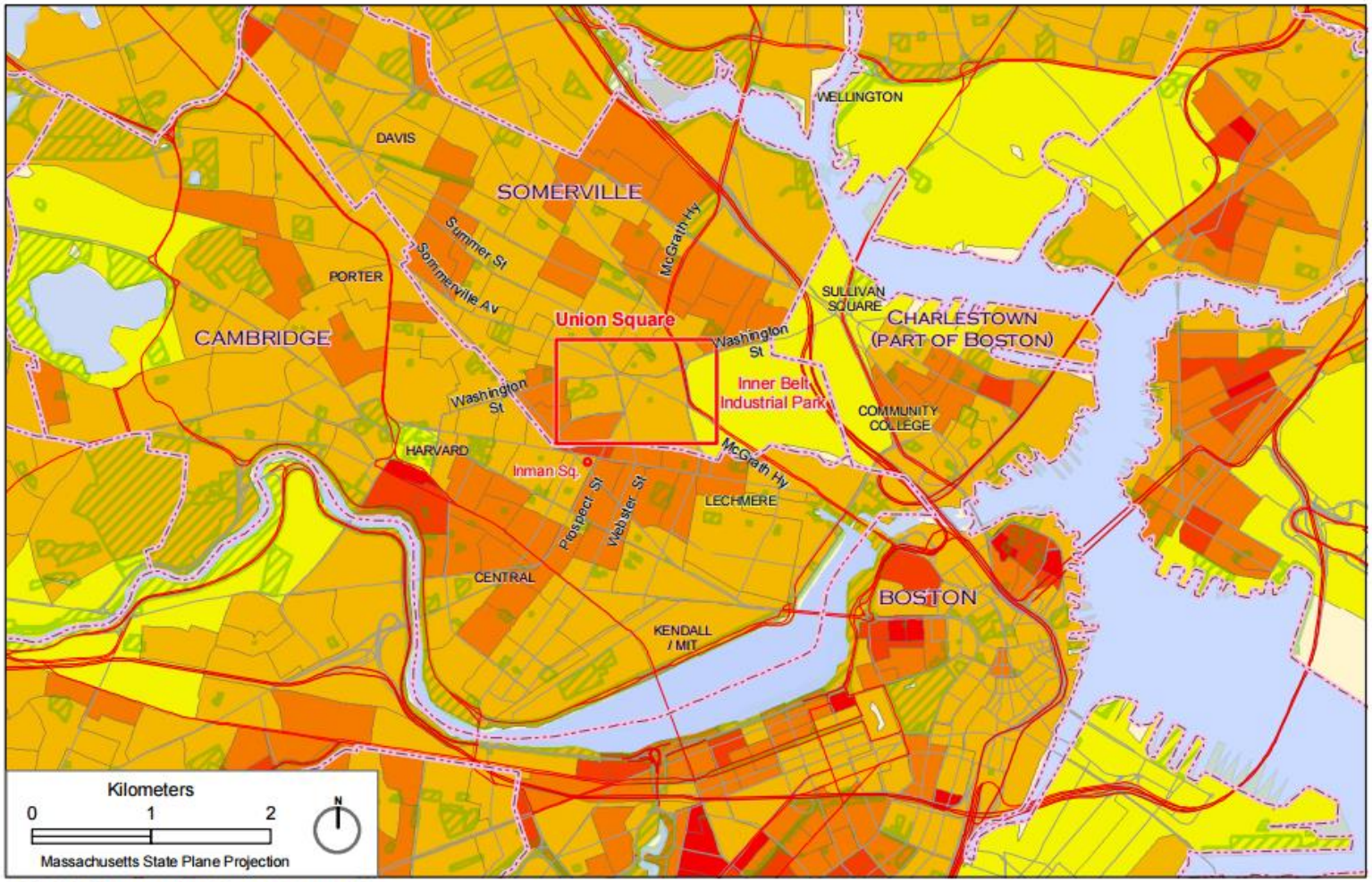
Union Square, 1871

This overlay of an 1871 map of Boston and Adjacent Cities and Towns shows the historic road alignments as represented on the old map in black outlines. The curent streets, as of 2006 are shown underneath in the lighter tone. There are a couple of critical differences to note. First, is the connection of washington street to Milk Street (now Somerville Av.) Second, we can see how Medford street worked before this area was transformed by the viaduct for McGrath O'Brian Highway. One wonders whether the many smaller streets that do not show up on the old map did not exist, or were deemed too small to show at the scale of Greater Boston. Also worth noting is the encroachment of Millers River on Union Square portrayed on the old map.

Sources:
Map: Paul Cote; Fundamentals of GIS Assignment 1; September 2009
Map of the Compact Areas of Boston and Neighboring Towns by Willis Gray and HF Walling, 1871. Courtesy David Rimsey Collection.
Modern Roads, City of Somerville 2004

Map Traps and Tricks

Portraying Intensive Statistics



2000 Population Density

At a blockgroup lavel of aggregation, union square does not appear to be a particularly densly populated place. This pattern may not be entirely accurate, since some blockgroups include large areas of industrial land.

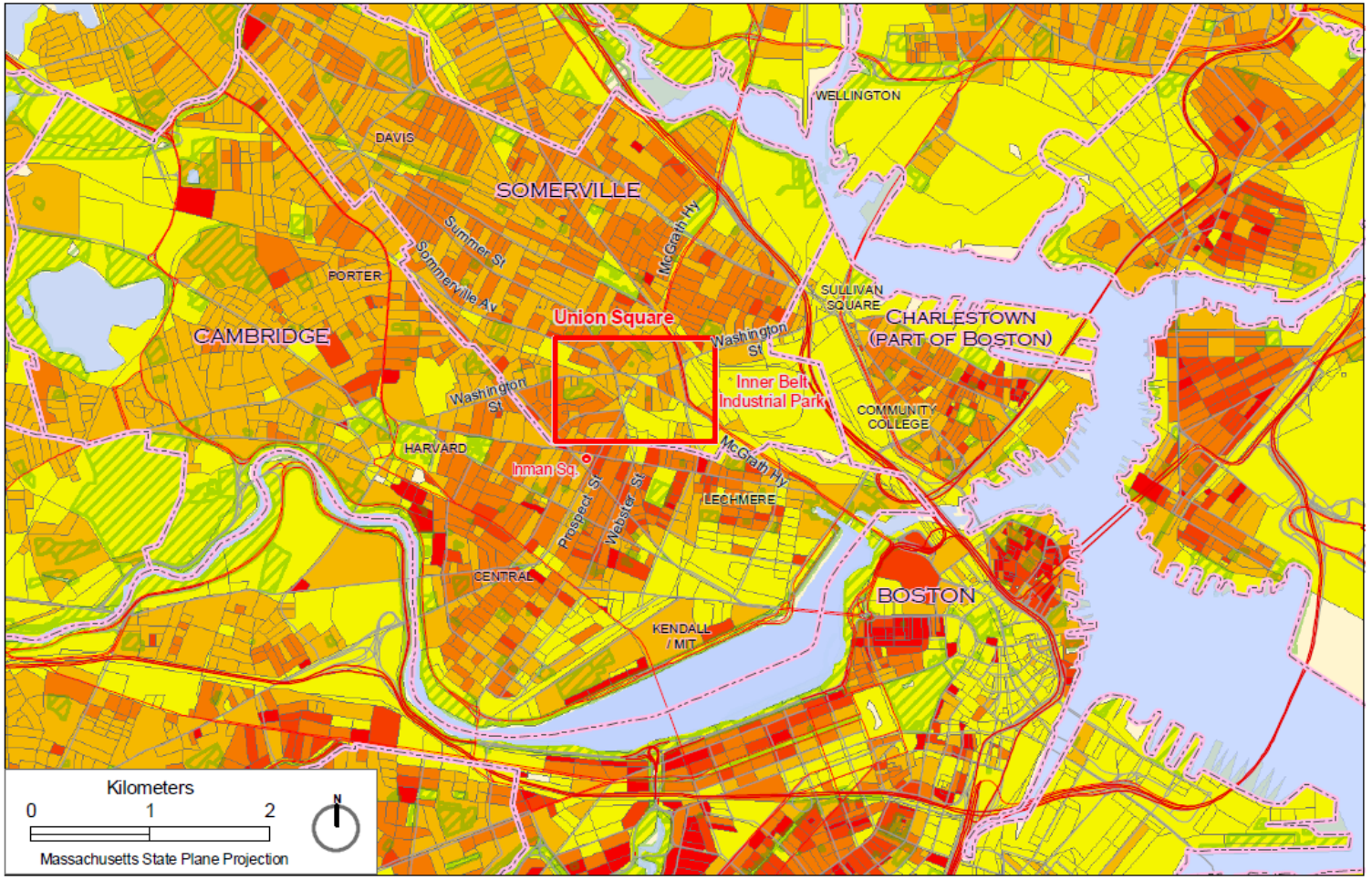
People per Hectare (Blockgroup)

0 - 10 | 10 - 100 | 100 - 200 | 200 - 300 | 300 - 1650

Parks

Sources:
Map: Paul Cote; Fundamentals of GIS Assignment 1; September 2009
Blockgroup Population Density: US Census Bureau, 2000 via Geolytics.

Portraying Intensive Statistics



2000 Population Density

When viewed at a block level of aggregation, we can see that those areas of union square that are not primarily industrial or commercial do have a relatively high residential population density, between two hundred and three hundred persons per hectare.

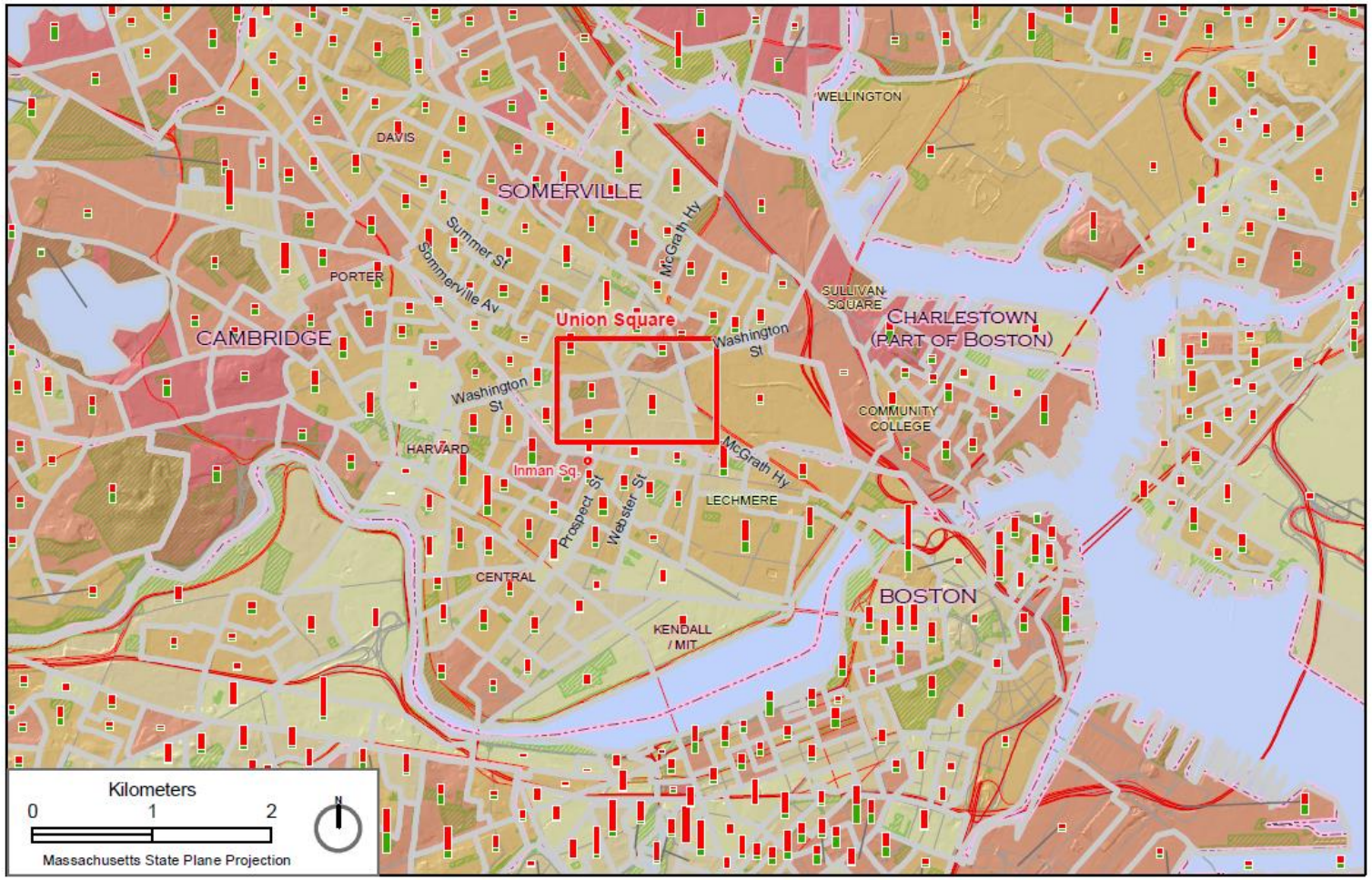
People per Hectare (Block)

0 - 10 | 10 - 100 | 100 - 200 | 200 - 300 | 300 - 1650

Parks

Sources:
Map: Paul Cote; Fundamentals of GIS Assignment 1; September 2009
Block Population Density: US Census Bureau, 2000 via Geolytics.

Portraying Extensive Statistics



2000 Census: Housing Tenure

These data from the 2000 census show the general pattern of housing tenure in the Boston / Cambridge / Somerville Area. There may be finer patterns of ownership that are washed out by the relatively course aggregation of household data to blockgroups. Interpreters of this map should be cautioned that areas with a high percentage of renal or owner occupied prperties may not necessarily have large numbers of units. The inclusion of proportional sysmbols on this map facilitates a reading of the proportion and the actual amounts of units involved.

Households: Percent Owner Occupied (Blockgroup)

0 - 10% | 10% - 25% | 25% - 40% | 40% - 60% | 60% - 100%

1000 Units { Renters / Owners

Sources:
Map: Paul Cote; Fundamentals of GIS Assignment 1; September 2009
Housing Tenure Data: 200 US. Census Blockgroup dta via Geolytics

Modeling Decision-Making Situations

What might happen if we made this decision or that?

An Accessibility Model

Thing or Condition 1

Considered Change

- Market Locations (to be added, removed, preserved or modified

Relationship

- May be Accessible to

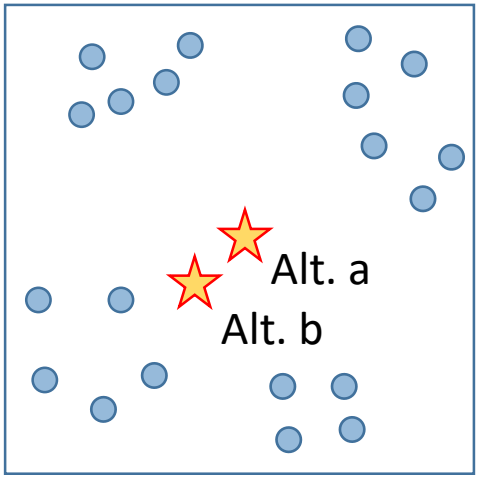
Thing or Condition 2

- Elderly Residents

Spatial Mechanism

- Who will be walking ***on sidewalks*** to the market and returning home with a cart full of Groceries.

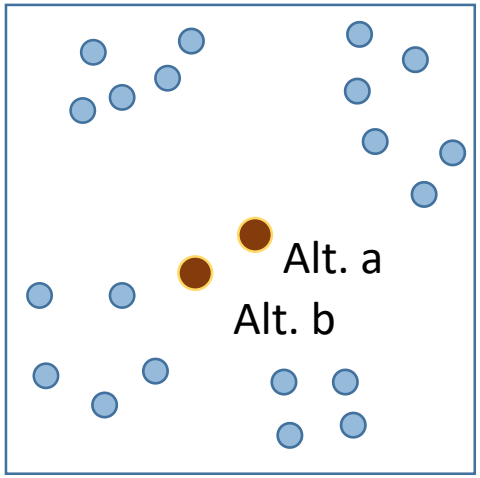
Conceptual Model: Things, Conditions, Relationships



Health Center Alternatives

Household

? Accessibility



Smokestack alternatives

Household

? Exposure?

An Exposure Model

- Smokestack emissions from Incinerator Locations (to be added, removed, preserved or modified)
- May have health impacts on
- Young residents at home or in schools
- Who are ***downwind*** of the incinerator smokestack

Thing or Condition 1

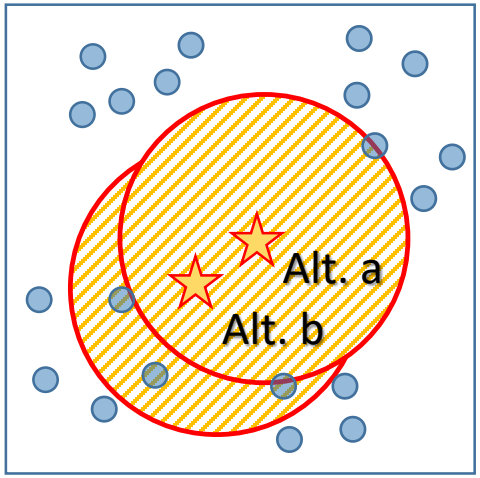
Considered Action

Relationship

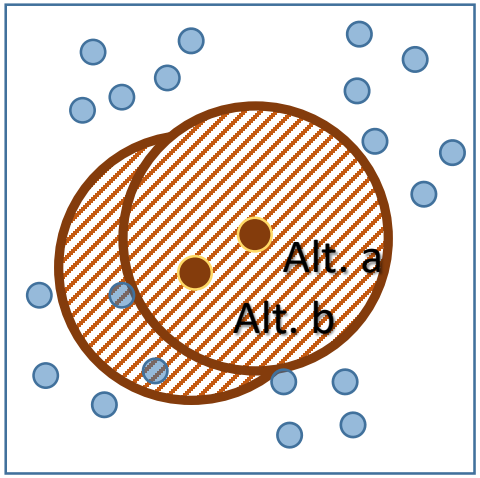
Thing or Condition 2

Spatial Mechanism

Spatial mechanism estimated as simple distance.



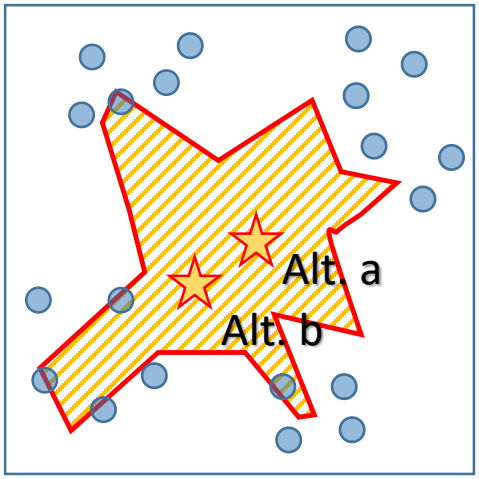
Spatial mechanism estimated as "Walking distance for mom with Baby carriage as far as X Meters[1]."



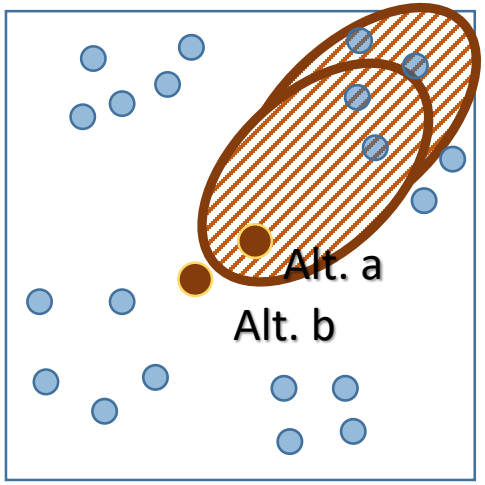
Spatial Mechanism estimated as "Aerial transmission of particulates as far as X Kilometers[1]."

Our spatial mechanism is described in terms of actual things and the actual way that they move or influence. Our ability to model (simulate) a real spetial mechanism with data and procedures is an important challenge. First the real spatial mechanism must be described clearly. It is helpful to consult existing research to see how this has been done.

Articulated spatial mechanism.

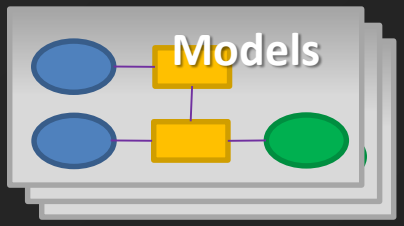


Accessibility Estimated as X Minutes pushing a baby carriage on sidewalks street crossings.[2]

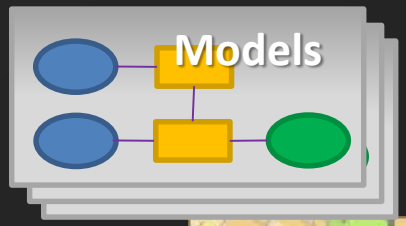


Impacts estimated as: Particulates carried X Kilometers by seasonal winds and smokestack height. [2]

[2] Most spatial mechanisms involve distance mediated by some condition. Established through research. GIS models can involve very elaborate representachanisms. At the same time, each involves siginifcant simplifications that should not escape mention.



Model Example 1: Compare Alternatives for a Transit Facility



6245 People within 500m Walking Distance

Attributes of trollystop_pop

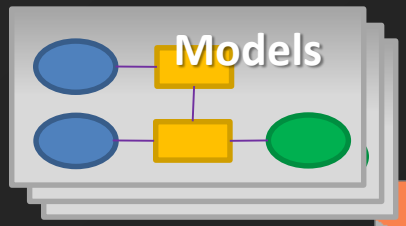
OBJECTID *	FREQUENCY	SUM_P001001
1	52	6245

Record: 1 Show:

Attributes of prop_tro...

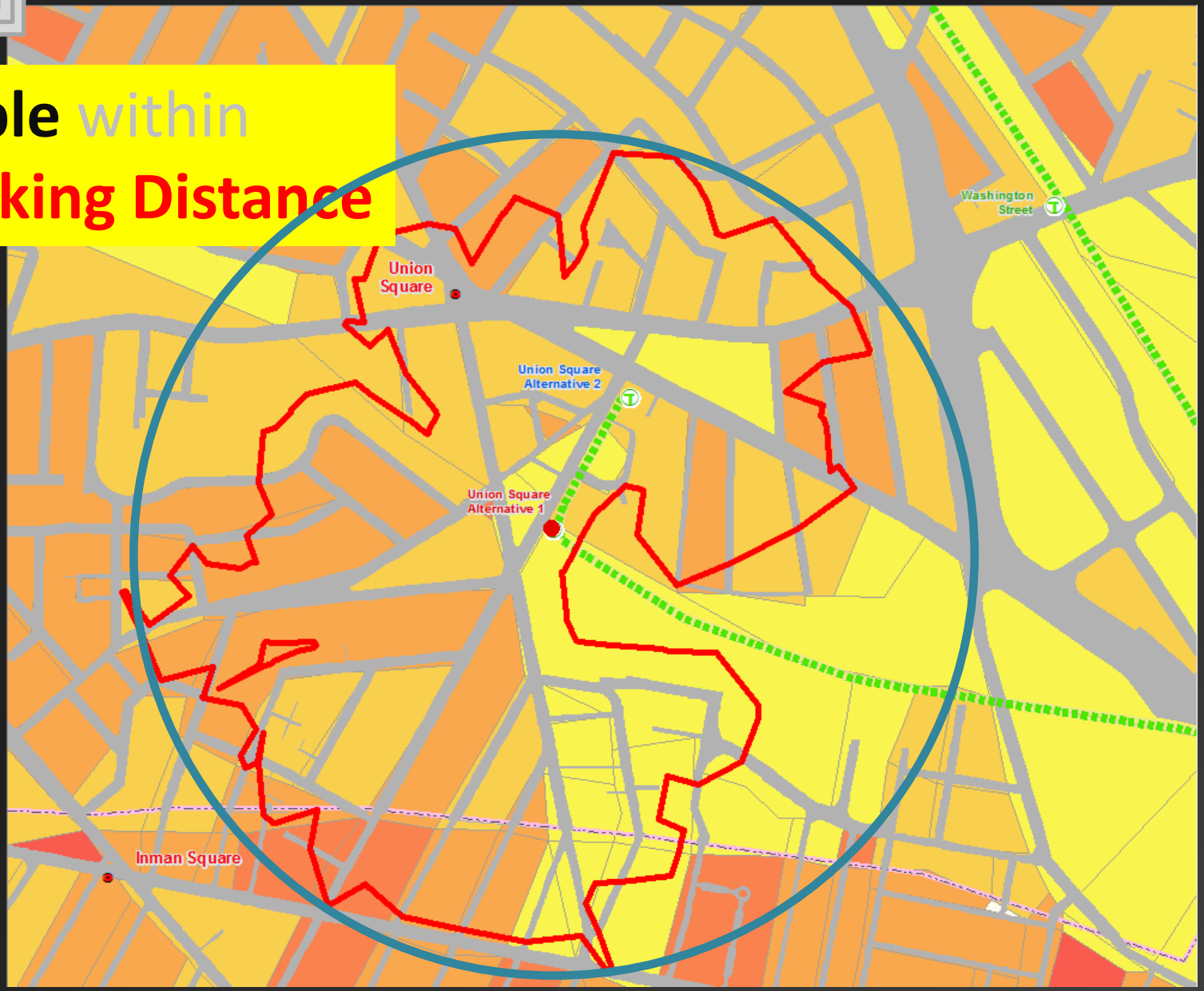
FID	Shape *	Id	name
0	Point	0	Mystic River
1	Point	0	Winthrop St
2	Point	0	College Av
3	Point	0	Ball Sq
4	Point	0	Lowell St
5	Point	0	Gillman Sq
6	Point	0	Washington St
7	Point	0	Lechmere Sq
8	Point	0	Union Sq Ctr
9	Point	0	Brickbottom EOT
10	Point	0	Union Sq Spur
11	Point	0	Target
12	Point	0	Twin Cities

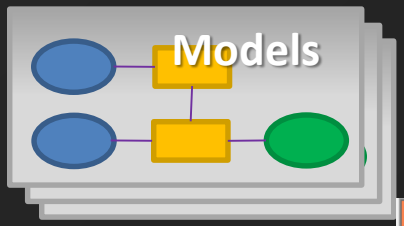
Record: 1



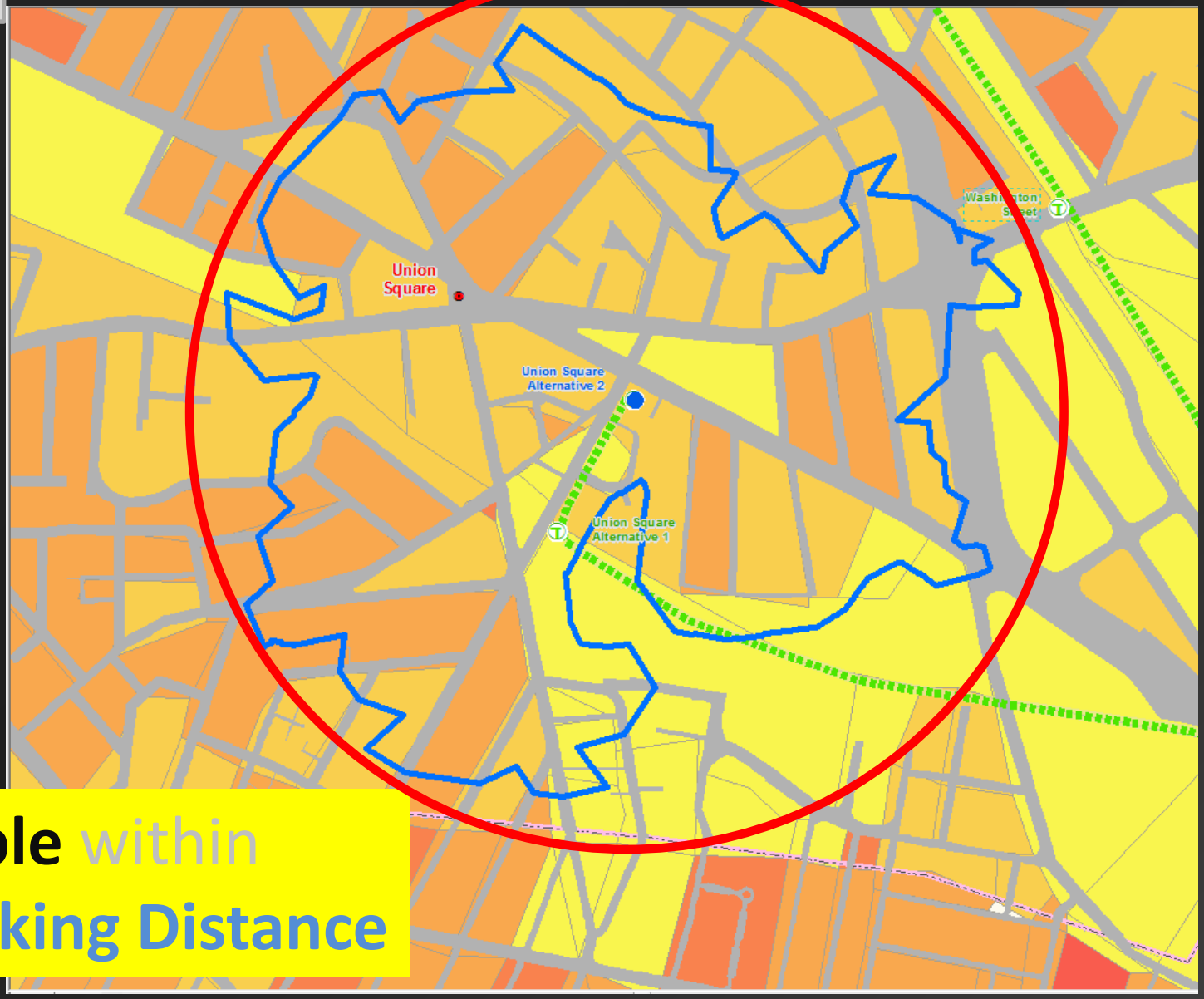
Conceptual Models and Data Models

3614 People within
500m Walking Distance

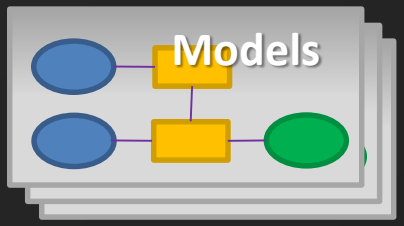




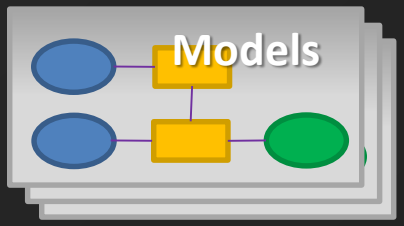
Conceptual Models and Data Models



3338 People within
500m Walking Distance



Model Example 2:
What is the Build-out Potential of a Neighborhood?



Buildout Potential

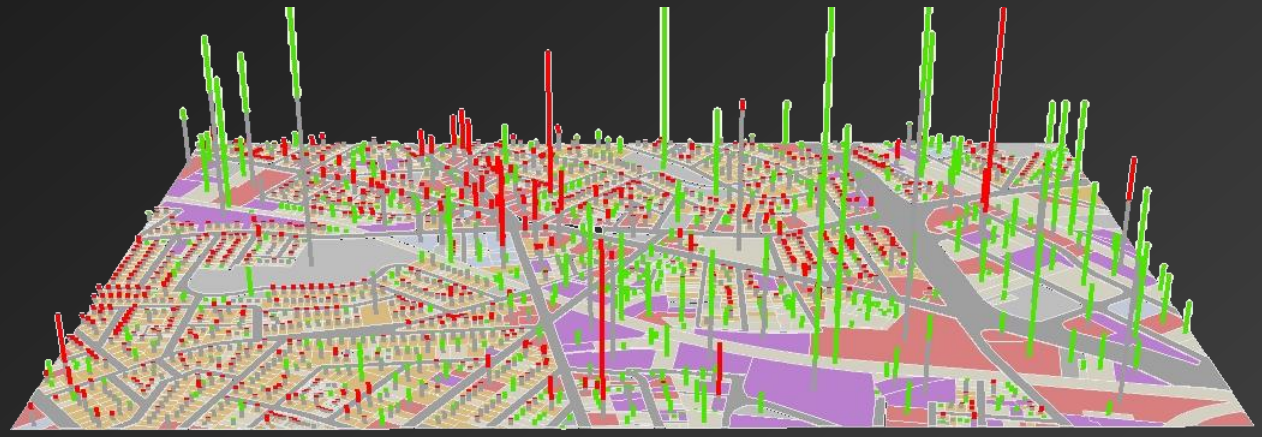
Property Parcels

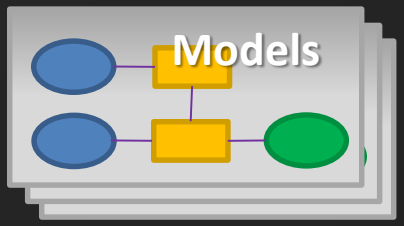
Building and Lot Area

Zoning

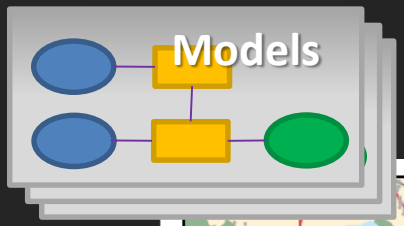
Permitted Floor Area Ratio

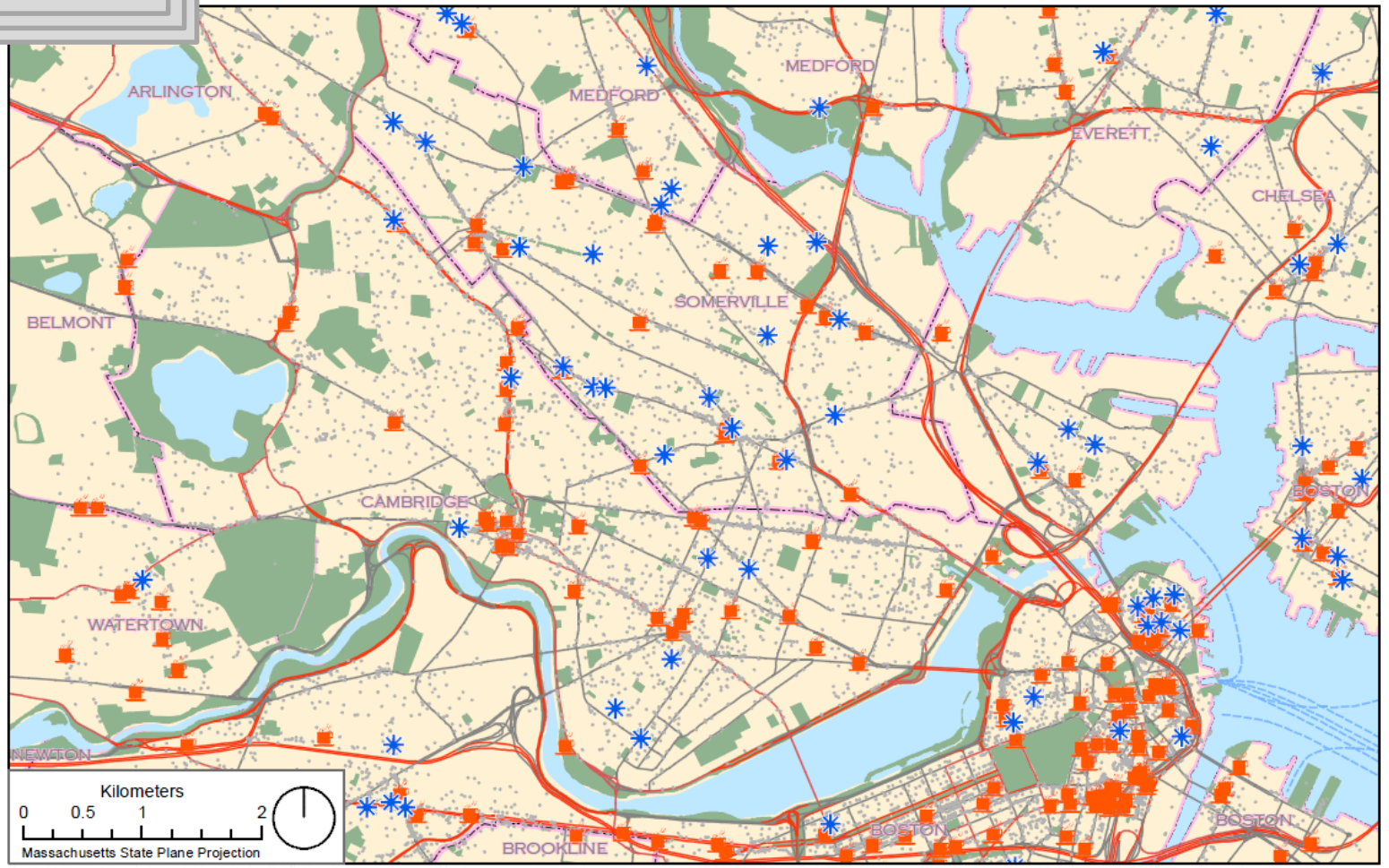
Development Potential





Model Example 3:
Discover unique juxtapositions of cultural activity.





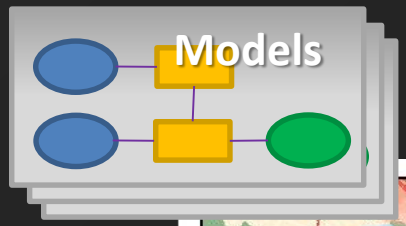
City of Leisurely Laundry

Data about commercial activity provides interesting perspectives on neighborhood amenities. This map explores the elements of a conceptual model that may be stated in terms of the proximity of Coffee Shops and Laundromats. These data will allow us to wxplore a value system defined as: "Areas that are within 500 meters of a coffee shop and a laundromat are considered "High Quality Urban Areas." Areas are rated as higher quality if they have a variety of coffee shops and laundromats to choose from.

Amenities

Laundry Bakery All Business

Map: Paul Cote, Harvard GSD 2011
Source: Coffee Shops and Laundromats:
2010 InfoUSA, via ESRI Business Analyst



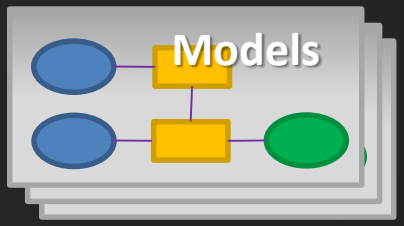
City of Leisurely Laundry

Each location on this map is shaded according to the number of Bakeries (red shades) and the mumber of Laundromats (blue shades). IN the areas that have at least one laundromat and one bakery within 500 meters, the darkness of the purple shade reflects the combined count of bakeries and launfaries nearby. The dark purple in the North End and near Porter Square confirms our intuitition about these high-wuality urban areas. Areas that are dark blue or Dark Red should be considered for the addition of the missing determinant of urban quality!

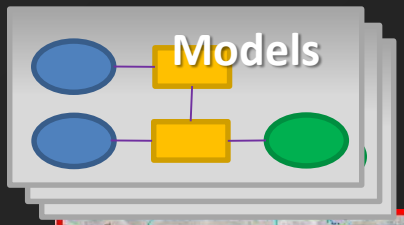
Amenities within 500 Meters

Bakeries	Laundries	Both
High : 22	High : 6	High : 24
Low : 0	Low : 0	Low : 2

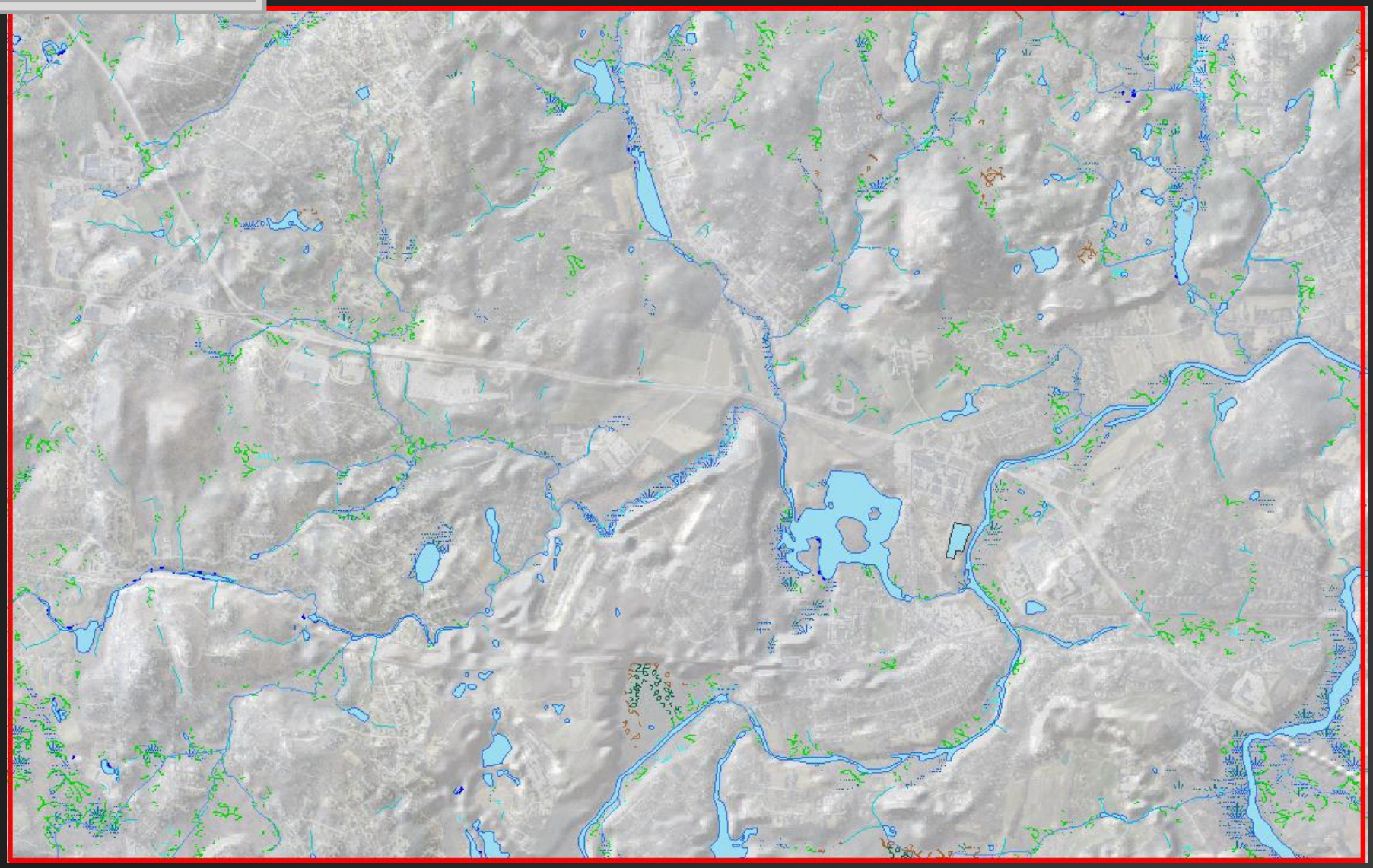
Map: Paul Cote, Harvard GSD 2011
Source: Coffee Shops and Laundromats:
2010 InfoUSA, via ESRI Business Analyst

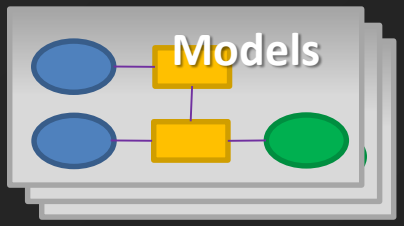


Model Example 4:
How do land cover, soils and slope affect surface water quality?

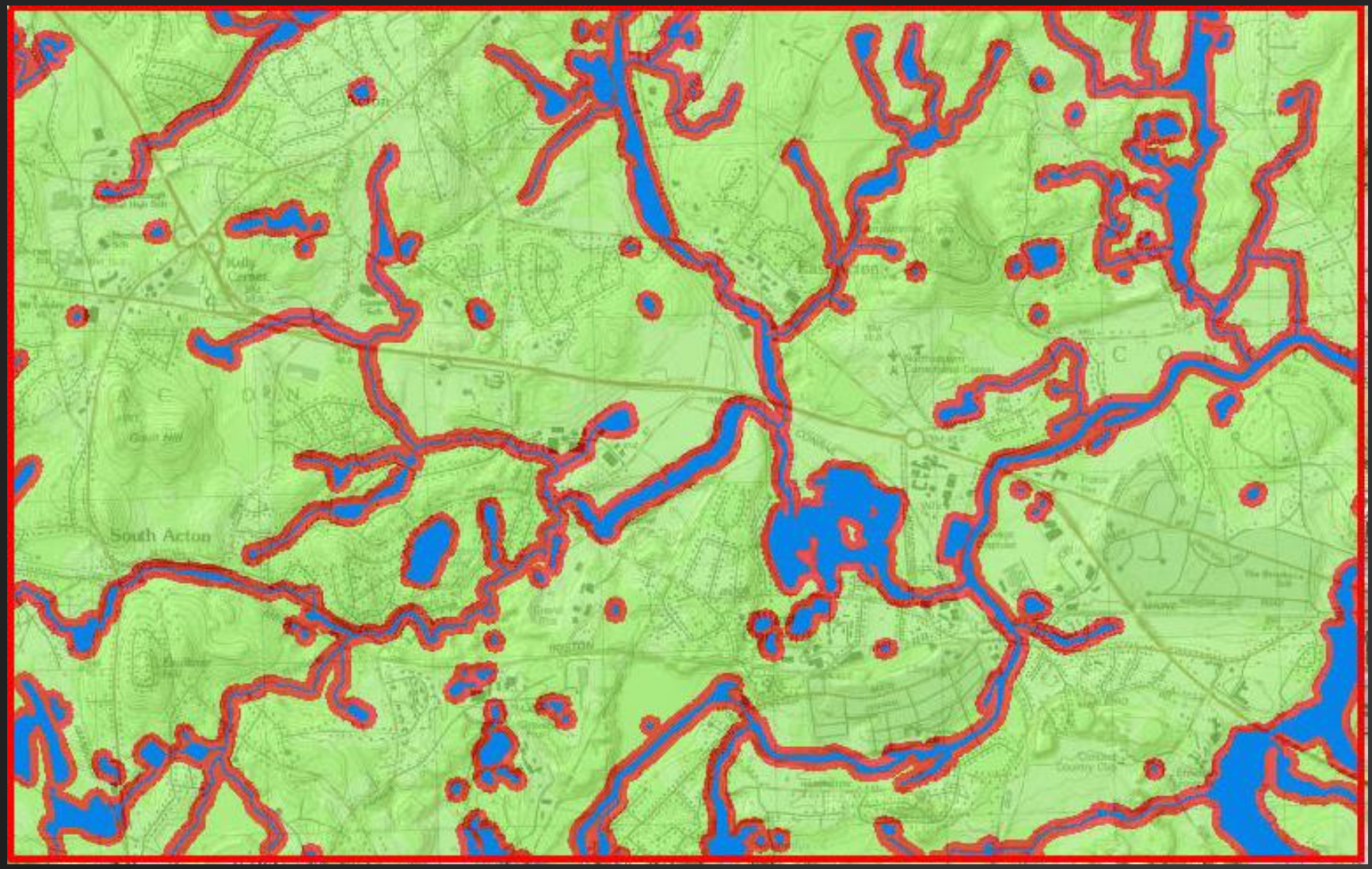


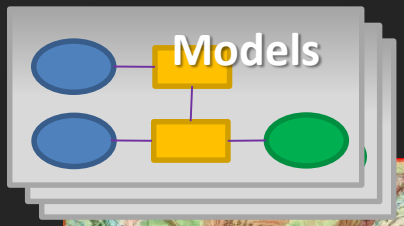
Hydrology





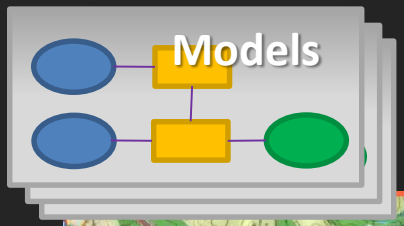
Naïve Runoff Protection Policy



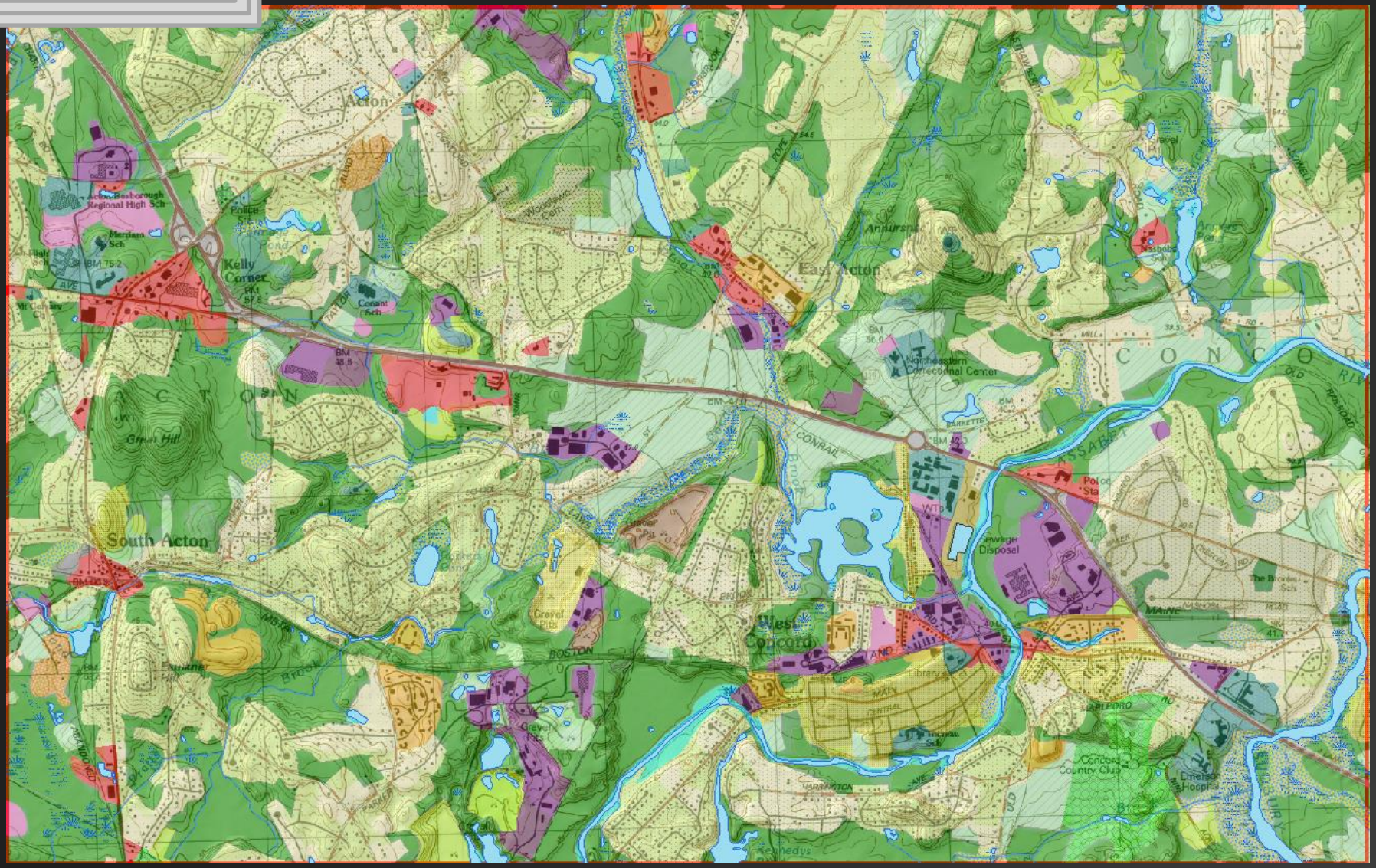

Models

Slope


Acton
East Acton
South Acton
West Concord
Kelly Corner
Police
Woodlawn Cem
Arlington Cem
Nashoba Sch
Northeastern Correctional Center
CONRAIL
Police Sta
Sewage Disposal
The Brooks Sch
MAINE
NASHOBA
BOSTON
Concord Country Club
Emerson Hospital
Green Hill
Gravel Pits
Conant Sch
Merriam Sch
Acton-Boxborough Regional High Sch


Models

Land Cover


Acton
Kelly Corner
East Acton
South Acton
West Concord
CONRAIL
BOSTON
MAINE
Concord Country Club
Emerson Hospital
Sewage Disposal
Northeastern Correctional Center

Runoff Protection Model