Regional Mapping Methodology
Phase 6 Land Use
(ArcGIS 10.2+ methods)

Goals:

To develop a regional 10m land use dataset for the Chesapeake Bay watershed and adjacent counties from the best available national data and select state datasets. The dataset will inform the Phase 6 watershed model and include all of the classes specified below.

Mapped Classes (listed in production order):

Impervious Roads (IR) – paved and unpaved roads and bridges.
Impervious Non-Roads (INR) – buildings, driveways, sidewalks, parking lots, runways and some private roads.
Forest (FOR) – large contiguous patches of trees and shrubs assumed to have an unmanaged understory
Tree Canopy (TCH, TCIR, TCINR) – small fragments of trees or shrubs over herbaceous, impervious roads, and impervious non-roads.
Water (WAT) – all streams, ponds, swimming pools, canals, ditches, wet detention basins, reservoirs, etc. mapped in the National Hydrography Dataset, NWI ponds & lakes, and the National Land Cover Dataset (Open Water). Assumes all single-line streams are 15' wide.
Wetlands (TWET, FWET, HWET) – National Wetlands Inventory (NWI) non-pond, non-lake wetlands divided into tidal, floodplain, and headwater subclasses based on NWI attributes and landscape position.
Turf Grass (TG) – all herbaceous lands within developed areas including remaining fractions of land within a pixel after accounting for tree canopy, impervious, water.
Extractive (EXT) – mapped disturbed/active, abandoned and reclaimed mines less areas of Open Space and Impervious confused with extractive.
Open Space (OS) – non-fertilized herbaceous and non-forest scrub/shrub that is justifiably not turf or extractive (e.g., beaches, vacant lots, transmission line right-of-ways, junkyards, fairgrounds, gravel roads, railroads).
Cropland (CRP): leftover areas of rural herbaceous lands with majority crops according to the Cropland Data Layer 2008 – 2013.
Pasture/Hay (PAS): leftover areas of rural herbaceous lands with majority pasture/hay according to the Cropland Data Layer 2008 – 2013.
Specialty Crops (SPC): leftover areas of rural herbaceous lands with majority pasture/hay according to the Cropland Data Layer 2008 – 2013.

Overlays:

Riparian forest buffers (RFB) - variable width, contiguous with edge of surface waters.
Federal lands (FED) – all federally owned/managed properties
Municipal Separate Storm Sewer Systems (MS4) – areas with Phase I or Phase II stormwater permit. These are typically areas draining into municipally owned/operated storm sewer drainage networks within the 2010 Census Urban Areas.
Sanitary Sewer Service Areas (SSA) – areas served by centralized wastewater treatment systems
Combined Sewer Service Areas (CSA) – areas served by centralized combined wastewater/stormwater treatment systems.
Wetland Efficiencies (WETe) – nutrient reduction percentages due to the interception of overland flow from downslope wetlands.
Riparian Forest Buffer Efficiencies (RFBe) – nutrient reduction percentages due to the interception of overland flow by riparian forest buffers.

Sediment Delivery Factors (SDF) – fraction of sediment produced through erosion that is transported to a modeled river reach.
Stream Sediment Ratios (SSR) – ratio of sediment in streams originating from erosion of stream banks vs uplands.

Data Storage:

1. Store temporary and final files in the Region_P6_LandUse.gdb and Regional_P6_Final.gdb geodatabases in G:\ImageryServer\Local_LULC_Data.

Processing and naming conventions:

   a. Set Geoprocessing> Environment... variables, for projection, extent, snap, and resolution.
      i. Projection: USGS Albers Equal Area Conic, NAD '83, meters
      ii. Extent and snap: IMP11_10m or TC11_10m
      iii. Cell size: 10m
2. Datasets highlighted in **RED**, below, should be saved in the final.gdb.

IMPORTANT NOTE: Several processing steps call for AGGREGATING high-res rasters (<10m) to 10m cells to create continuous percentage impervious or tree canopy datasets. The AGGREGATE tool can only increase the cell size using an integer cell factor. Therefore, if the local data cell size is not an integer value in meters (e.g., 0.91 m in PG county), you will have to follow the AGGREGATE step with RESAMPLE (bilinear) and a MapAlgebra step, e.g., Int((Float("IMP_10m2") / 121)*100) to reset the range from 0..100. You may have to also COPY the resulting raster to ensure it is an 8-bit unsigned integer.

Use of the Raster Calculator (under Map Algebra) presents several advantages for implementing conditional and mathematical commands in that you can work with both floating point and integer data and you can combine commands to speed up the process.

Base Datasets

nlcd_2011_landcover_2011_edition_2014_03_31.img
nlcd2011_usfs_treecanopy_cartographic_3-31-2014.img
nlcd_2011_impervious_2011_edition_2014_03_31.img
NAVTEQ 2014 Streets (represents 2013 conditions)
NAVTEQ Land Use A & B
National Wetlands Inventory
National Hydrography Dataset- High Resolution (1:24K): Flowline, Area, and Waterbodies

Produce Initial 10m Land Cover Datasets

1. Extract nlcd_2011_landcover_2011_edition_2014_03_31.img; nlcd2011_usfs_treecanopy_cartographic_3-31-2014.img; nlcd_2011_impervious_2011_edition_2014_03_31.img by mask of study area buffered by 3km. Snap to original NLCD 2011 landcover dataset. Save as **LC_2011, TC_2011, and IMP_2011**.
2. Use bilinear resampling to resample NLCD tree canopy and impervious to 10m and nearest neighbor resampling for the land cover. Save as: **LC11_10m, TC11_10m, and Imp11_10m**.

Impervious Roads (IR)
NAVTEQ has several categories denoting road width. These include: PHYS_LANES which mostly define number of lanes (e.g., include the addition of turn lanes), TO_LANES and FROM_LANES which indicate number of lanes for features with enhanced spatial accuracy, and LANE_CAT which indicates the number of traffic lanes in a single direction. The majority of roads have PHYS_LANES = 0, both TO_LANES & FROM_LANES = 0, and LANE_CAT = 1. These are mostly 2 lane roads. Those with LANE_CAT >=2 are assumed to be 4-lane roads. Because 80% of all roads are rural, 2-lane roads. Assume an average width of about 7m ((80% * 6.5m) + (20% * 8.7m)) or 3.5m per lane. In order of preference, rely on PHYS_LANES, TO_LANES & FROM_LANES, and finally LANE_CAT. Assume no single-lane roads lacking a shoulder or parking lanes.

1. In the Streets feature dataset, create a new short field "Tot_Lanes"
    a. Set Tot_Lanes = To_Lanes + From_Lanes
    b. Select records with OBJECTID <1,000,000 and export OBJECTID, LANE_CAT, PHYS_LANES, and TOT_LANES as Query1.dbf.
    c. Select records >=1,000,000 and export OBJECTID, LANE_CAT, PHYS_LANES, and TOT_LANES as Query2.dbf.
    d. Import both DBF files into EXCEL and create new fields: Zone, Aimp, Bimp, and Cimp. Use the following queries to establish the width (% of 10m pixel) values for each unique road type where B = LANE_CAT, D=PHYS_LANES, E=TOT_LANES, and F=Zone. The zone field will be used to determine the number of pixels to expand the 10m road network
        - Zone =IF(OR(D2>=9,E2>=9),3,IF(OR(D2=2,D2=1,E2=2,E2=1,AND(E2=0,B2=1)),1,2))
        - Aimp =IF(OR(F2>1,B2>1),100,70)
        - Bimp = IF(OR(D2>8,E2>8),100,IF(OR(D2=8,E2=8,B2=3),90,IF(OR(D2=7,E2=7),73,IF(OR(D2=6,E2=6),55,IF(OR(D2=5,E2=5),38,IF(OR(D2=4,E2=4,AND(E2<3,B2=2)),20,IF(OR(D2=3,E2=3),3,0)))))))
        - Cimp =IF((E2=11),43,IF(OR(D2=10,E2=10),25,IF(OR(D2=9,E2=9),8,0)))

2. Import and append (in the import process) the two EXCEL tables into ACCESS. Export from ACCESS (using wizard- and with table closed) to text file: street_widths2.txt. COPY ROWS of street_widths2.txt to expedite the join table process (otherwise ArcMAP stalls when trying to equate a new field to a joined field). Save as **street_widths2_CopyRows**.
3. Convert Streets to 10m raster (Feature to Raster) using <u>ObjectID as the value field</u>. Save as **Streets_ID**. Build Raster Attribute Table. Note: Tried THINNING the streets raster but in areas with dense road networks (e.g., forks, cloverleafs, etc) some road pixels were converted to null to enforce the THIN command. See Appendix for THIN procedure in case needed in future. Consider using road density (LD200) in future to determine what roads to thin and which one's not to thin.
4. Join attributes from street_widths2_CopyRows (Object_1) to Streets_ID (value). Check to ensure join occurred properly. Create new short integer fields: Aimp2, Bimp2, Cimp2, and Zone2. Set these fields equal to Aimp, Bimp, Cimp, and Zone from the joined table. Remove joins.
5. Because Streets_ID is such a large dataset, SPLIT the raster into tiles (I used 4 tiles: 2x and 2y, NEAREST, save as GRIDS to new folder "Streets"). Note that sometimes the resulting tiles will be

corrupt without ArcGIS providing any info regarding their corruption. Therefore, view each tile to ensure there is complete data in the tile before proceeding.

6. Export tiled rasters from the folder “Streets” to a geodatabase “Roads.gdb”.
7. Use ModelBuilder (LOOKUPS3) to iterate rasters and reclassify them based on their Aimp2, Bimp2, Cimp2, and Zone2 values. Save results to a new file geodatabase: Streets.gdb. Save as outputs as A_%Name%, B_%Name%, etc.
8. Mosaic the 4 datasets associated with Zone, Aimp, Bimp, and Cimp together (CELL STATISTICS: MAXIMUM, Extent and Snap to LC11_10m). I did this running four instances of ArcCatalog simultaneously. Save as Zone, Aimp, Bimp, and Cimp in Roads.gdb.
9. SETNULL zero values in Bimp and Cimp to null, else = Bimp and Cimp respectively. Save as Bimp_f1 and Cimp_f1.
10. Expand value 2 in Zone by 1 pixel. Save as ExpZ_2x1. Expand value 3 in Zone_f2 by 2 pixels. Save as ExpZ_3x2.
11. Use COST ALLOCATION to allocate values from Bimp_f1 into ExpZ_2x1 by 50m. Use COST ALLOCATION to allocate values from Cimp_f1 into ExpZ_3x1 by 100m. Save as CA_Bimp_f1 and CA_Cimp_f1 respectively.
12. Mosaic CA_Cimp_f1, CA_Bimp_f1, Aimp using CELL STATISTICS (Maximum, Extent and Snap set to LC11_10m). Save as **IR_prep.**
13. Mosaic IR_prep and Imp11_10m using CELL STATISTICS (Maximum, Extent and Snap set to LC11_10m, mask as IR_prep). Save as **IR_reg4.**
14. Mosaic IR_reg4 and IRtc to New Raster with IRtc listed at top and using FIRST as the priority and mask set to NonFerry (because some ferry routes inadvertently were included in the road coverage). Turn off background processing to ensure it works. Tried this several times after rebooting and failed each time. Repeat attempt using Cell Statistics (minimum). Save as **IR_final.**

Impervious Non-Roads (INR)

1. SetNull("IMP11_10m" < 20, "IMP11_10m"). Save as Imp20pct. This step virtually eliminates all secondary roads and other stringy features. Some impervious surfaces associated with low-density residential areas are also eliminated but these were incompletely detected anyway and will be compensated for through the use of Census data.
2. Create a reverse mask of IR_reg4 using Setnull(Isnull(IR_reg4)==0,1). Save as **nonRd_mask**.
3. Extract values from Imp20pct using **nonRd_mask**. Save as **INR_reg7**. Go to Tree Canopy section.
4. Mosaic INR_reg7 and INRtc to New Raster with INRtc listed at top and using FIRST as the priority. Turn off background processing to ensure it works. Save as **INR_final**.

Water

Water includes all ponds, lakes, and streams.
Datasets: NHD-H Area, Waterbody, and Flowline; NWI ponds and lakes; NLCD water.

1. Definition query on NWI polygons: identify all freshwater ponds and lakes.
2. Definition query on NHD-H Area: NOT “FYTPE” = 403 AND NOT “FTYPE” = 343 (inundation areas around lakes and dams/weirs). Export as NHD_Area.
3. Definition query on NHD-H Waterbody: NOT “FYTPE” = 466 AND NOT “FTYPE” = 361 (swamp/marsh and playa). Export as NHD_Waterbody

4. The linework appeared to be more accurate in the NHD compared with the NWI so identify all NWI polygons not intersecting the defined NHD Area and Waterbody data. Save as NWI_Xtra. Merge NWI_Xtra, NHD_Area, and NHD_Waterbody. Save as **WaterFeatures**.
5. Convert WaterFeatures to 5m raster (used Polygon to Raster tool). Save as WaterFeatures_5m.
6. Aggregate (sum) WaterFeatures to 10m with a cell factor of 2. Note that the extent raster in the Environment settings must also be a 5m raster. Save as WaterFeatures_2c.
7. Convert values in Waterfeatures_4c to subpixel values in RasterCalculator. Int(Float(WaterFeatures_2c)/4*100). Save as **WaterFeatures_10m**.
8. Perform Definition query on NHD Flowline: NOT "FType" = 428 AND NOT "FType" = 566 (pipeline and shorelines). When converting to raster, the definition query IS recognized.
9. Add a short integer field = 50 to NHD Flowline. The "50" assumes that 50% of each 10m stream pixels is water (~15-ft). This is an educated guess and a proxy until we can develop something better using the 10m DEM. Convert Flowline to 10m raster (this took 21 hours). SPLIT the raster into 24 tiles (save them as GRIDS). Then use ModelBuilder to iterate the tiles and THIN (Background Zero, No filter, Round corners, Max thick = 100) them, saving them to a Streams.gdb. The thining process creates a binary rasters. Use ModelBuilder again with the RasterCalculator to create masks (1, null). SetNull("%streams0%" == 0,50). Save results as Mask_%Name% in Streams.gdb.
10. Mosaic (using Cell Statistics MAX) all Mask_%Name% rasters to a new dataset and save as **Streams_thin** in Regional_P6_Final.gdb.
11. Create a mask of the NLCD "Open Water" (11) class using a value of 100 for open water. Save as NLCD_water. Mosaic WaterFeatures_10m, NLCD_water, and Stream_thin using Cell Statistics (maximum). Save as **Water2**.
5. Eliminate impervious non-road fractions from water pixels. COMBINE INR_reg7 and Water2. Total the fractions from both INR_reg7 and Water2 in new short "Total" field. Total = 100 - ([INR_reg7] + [Water2]). Create new short "New_WAT" field. Select all records where "Total" > 0, set New_WAT = [Water2]. Switch selection. New_WAT = [Water2] + [Total]. Use Lookup to reclass Combo_INR_WAT using New_WAT values. Save as WATnr.
15. Eliminate impervious road fractions from water pixels. COMBINE IR_reg4 and Water2. Total the fractions from both IR_reg4 and Water2 in new short "Total" field. Total = 100 - ([IR_reg4] + [Water2]). Create new short "New_WAT" field. Select all records where "Total" > 0, set New_WAT = [Water2]. Switch selection. New_WAT = [Water2] + [Total]. Use Lookup to reclass Combo_IR_WAT using New_WAT values. Save as **WATr**.
6. Mosaic WATr, WATnr and Water2 to New Raster with WATr and WATnr listed at top and using FIRST as the priority. Turn off background processing to ensure it works. Save as **WAT**.

Wetlands

Wetlands are represented by the NWI polygons combined with state wetland polygon layers where available. Wetland ponds are included in the "Water". In the regional WET_mask, wetlands are classed as Tidal, Floodplain, and Headwaters depending on their landscape location.

1. Identify all NWI wetlands that are not lakes or ponds or rivers. Save as NWI_NoLakePond
2. Convert NWI_NoLakePond to 1m raster. Save as NWI_1m
3. Aggregate NWI_1m to 10m cells with extent and snap set to LC11_10m. Save as WET_prep.
4. Subtract WAT from WET_prep. Save as WAT_WET. Mosaic WAT_WET into WET_prep (FIRST). Save as **WET**.

Forests

"Forests" include contiguous (cardinal connectivity) patches of tree canopy (>=50% canopy) extending to road edges that contain at least a circular acre of interior forest.

1. Create a pervious mask. MOSAIC TO NEW RASTER (maximum): IR_reg4 and INR_reg6. Save as **IMP_All4**. Identify all null values using raster calculator: Setnull(Isnull(Imp_All3)==1, 1). Save as **Perv_mask7**. Note: in future add xRail to the mask for fragmenting forests.
2. Set mask to Perv_mask7. Identify cells greater than or equal to 50% tree canopy. In Raster Calculator: SetNull("TC11_10m" < 50,1). Save as TC_gte50_6.
3. Use raster calculator and Setnull to reclass LC11_10m scrub-shrub (class 52) to 1; else nodata (set mask as Perv_mask6). Save as shrub.
4. MOSAIC TO NEW RASTER (maximum): TC_gte50_6 and shrub. Save as for_shrub.
5. REGIONGROUP (4, within, nolink) for_shrub to assign each patch a uniqueID. Note that only cardinal connectivity is specified to exclude stringing patches. Save as RG_patch.
6. SETNULL tool: RG_Patch Count <= 40; else = RG_Patch to subset patches greater than 1 acre. Save as RG_patch2
7. Convert RG_patch2 to polygons (do not simply lines because you want to error on the side of overestimating the perimeter). Add field (Double): AP_ratio. Calculate the Area:Perimeter ratio for each polygon (Shape Area / Shape Length). Select all polygons with AP_ratios > 17.95. Export as CoreFor. This threshold represents the AP ratio in meters for a 1-acre circle with radius of 35.9 m. Note that the original plan was to use Zonal Geometry (thickness) on RG_patch2. Tried doing this for the entire area but after 36 hours I aborted the process. Therefore convert RG_patch2 to polygons. Select increments of 25% of records and save as Patch1..4. Convert each back to raster. Ran batch of four Zonal Geometry (Thickness) functions. This process was necessary to ensure any articfical tiling of the rasters doesn't fragment a contiguous patch of cells. However, after 4 days the process was not yet complete for even a quarter of the records. The AP ratio process yields similar (but not the same) results as zonal geometry.
8. Add short field "common" to CoreFor and set equal to 100. Convert to raster with extent, snap, and cell size set to LC11_10m. Save as For_prep.
9. Create a mask of non-railroads. SetNull(IsNull(xRail_100)=0,1). Save as NonRail. Multiply NonRail by For_prep by 100. Save as FOR_noRail.
10. Add WAT and WET to a raster catalog and convert to raster dataset (maximum). Save as WW_mask. Create a mask of non water and non wetlands: SetNull(IsNull("WW_mask") == 0,1).
11. Extract FOR by WW_mask and NonRail. Save as **FORESTS**.

<u>Tree Canopy and Fractional Herbaceous</u>

Tree canopy includes all trees that do not qualify as forests. However, there are four types of tree canopy that need to be mapped: tree canopy over impervious roads (TCIR), tree canopy over impervious non-roads (TCIR), and tree canopy over pervious herbaceous (TCH). Note that it is possible to further split TCH into tree canopy over turf (TCT) and tree canopy over open space (TCOS) using the developed mask but that was not done in this version. The above breakdown is particularly important because about 50% of the NAVTEQ 2-lane roads are classed as forest in the road corrected NLCD. At the 10m pixels scale, derived from regional data, it is very difficult to know whether subpixel fractions of different land cover types overlap or are exclusive of one another. It is assumed that trees are planted on pervious surfaces with minimal overlap with impervious surfaces. Therefore, impervious and tree canopy fractions are assumed not to overlap unless the sum of their fractions exceeds 100%. Only the portions over 100% are assumed to overlap. For example, a pixel with 70% IR and 50% TC would be converted to 20% TCIR, 30% TCT, and 50% IR. A pixel with 50% IR and 50% TC would have 0% TCIR because we assume no overlap if sum is less than 100%. The understory of tree canopy pixels free of

impervious surfaces is assumed to be herbaceous (i.e., turf or open space) cover. Note that some forest pixels have less than 50% tree canopy, particularly those that are scrub-shrub. However, we are unconcerned with classifying the non-tree fractions of forest pixels because these fractions are assumed to represent natural gaps in the canopy (e.g., tree falls) inherent in any natural forest. Assume canopy over water = water. Also note that remaining pervious portions not covered by tree canopy or impervious surfaces are assumed to be open herbaceous lands- i.e., turf grass in developed areas.
Examples:

Partially impervious pixel with 50% TC and 70% IR:
TCIR = 20%
TCHr = 30%
IRtc = 50%
HBir = 0%

Partially impervious pixel with 50% TC and 30% IR:
TCIR = 0%
TCHr = 50%
HBir = 20% (TURF in all areas)

Partially impervious pixel with 94% TC and 55%% INR:
TCINR = 49%
TCHnr = 45%
INRtc = 6%
HBnr = 0% (because assume minimal overlap between impervious cover and canopy. If we assumed maximum overlap, the TCINR and HBr would increase by 6% and INRtc would equal 0%)

Pervious pixel with 70% TC and 50% WAT
TCHp = 50% (not counting 20% of overlap between TC and WAT)
WAT = 50%

Pervious pixel with 40% TC and 25% WAT
TCHp = 40%
WAT = 25%
HBp = 35% (TURF in developed areas and AG in undeveloped areas)

Note that this analysis excluded TC and IMP outside the areas of intersect between TC and IR and INR.

1. Combine IMP11_10m and TC11_10m within Developed mask. Extract using nonRd_mask.
2. Create a new short fields, “TOT”, “TCH”, “TCIMP”, and “TG”
3. TOT = (IMP11_10m + TC11_10m).
4. Select all values of TOT >100 and set TG = 0, TCH = 100 - IMP11_10m, TCIMP = TC11_10m – (TCH + TG).
5. Switch selection and set TG = 100 – (IMP11_10m + TC11_10m), TCH = TC11_10m, TCIMP = 0.
6. Reclassify using Lookup TCH = **TCH4**, TG = **TG4**.

Thus- areas with Impervious surface values less than 20% are excluded

1. Set NonFor as mask. COMBINE IR_reg4 and TC11_10m. Save as Combo_TC_IR. Must REDO
    a. Add a new short field, “TCIR” = ([TC] + [IR]) - 100. This represents the portion of tree canopy overhanging roads.
    b. Set all negative TCIR values to zero. Unselect all records.
    c. Add a new short field, “TCHr”= ([TC] – [TCIR]). This represents the portion of tree canopy with an herbaceous understory.
    d. Add a new short field, “IRtc” = (IR – TCIR). This represents a reduced estimate in impervious road percentage after accounting for tree canopy.
    e. Add a new short field, “HBir” = 100 – (TCIR + TCHr + IRtc).

2. Use Lookup to reclassify Combo_TC_IR using values from TCIR field. Save as **TCIR**.
3. Use Lookup to reclassify Combo_TC_IR as TCHr using values from TCHr field. Save as TCHr.
4. Use Lookup to reclassify Combo_TC_IR as IRtc using values from IRtc field. Save as IRtc.
5. Use Lookup to reclassify Combo_TC_IR as HBir using values from HBir field. Save as HBir.
6. Set NonFor as mask. COMBINE INR_reg7 and TC11_10m. Save as Combo_TC_INR
    a. Add a new short field, "TCINR" = ([TC] + [INR]) - 100. This represents the portion of tree canopy overhanging buildings, driveways, and parking lots.
    b. Set all negative TCINR values to zero. Unselect all records.
    c. Add a new short field, "TCHnr" = ([TC] – [TCINR]). This represents the portion of tree canopy with an herbaceous understory.
    d. Add a new short field, "INRtc" = (INR – TCINR)
    e. Add a new short field, "HBnr" = 100 – (TCINR + TCHnr + INRtc).
7. Use Lookup to reclassify Combo_TC_INR as TCINR using values from TCINR field. Save as **TCINR**.
8. Use Lookup to reclassify Combo_TC_INR as TCHnr using values from TCHnr field. Save as TCHnr.
9. Use Lookup to reclassify Combo_TC_INR as INRtc using values from INRtc field. Save as INRtc.
10. Use Lookup to reclassify Combo_TC_INR as HBnr using values from HBnr field. Save as HBnr.
11. Create a non-impervious, non-forest mask.
    a. SetNull(IsNull("Forests") == 0,1). Save as **NonFor**
    b. Multiply NonFor by PervMask6. Save as TCH_mask.
12. Extract data from TC11_10m using TCH_mask. Save as TCHp. This represents the portions of tree canopy with an herbaceous understory not associated with impervious cover.
13. Account for water proportions underlying TCHp. Note that water is already accounted for in TCIR and TCINR through the IR and INR development steps. Set nodata values to 0 in Water2. Con(Isnull(Water2)=1,0,Water2). Save as Water_w0.
14. Combine TCHp and Water_w0. Save as Combo_TCHp_WAT.
    a. Add short field "TCwtr" = [TCHp] – (100 - [Water_w0]). Note that values <= 0 mean that the proportions of water in the cell can be accommodated without affecting the TCH.
    b. Set all negative TCwtr values to zero. Unselect all records.
    c. Add short field TCHpp = [TCHp] – [TCwtr]
    d. Add short field "HBp" = 100 – ([TCHpp] + [Water_w0])
15. Use Lookup to reclassify Combo_TCHp_WAT as TCHpp using values from TCHpp field. Save as TCHpp.
16. Use Lookup to reclassify Combo_TCHp_WAT as HBp using values from HBp field. Save as HBp.
17. Mosaic TCHr, TCHnr, and TCHpp to New Raster (maximum). Save as TCH. Note: this takes almost 4 hours.
18. Remove wetlands from TCH. Extract TCH values under mask of non-wetlands. Save as **TCH2**.

Turf Grass

Turf grass includes all herbaceous lands within developed areas. These include the herbaceous fractions of tree canopy, impervious, wetland, and water pixels and herbaceous land cover classes: herbaceous, pasture/hay, and cropland.

1. Identify secondary roads. Perform definition query on NAVTEQ 2013 streets shapefile (already projected into Albers Equal Area, NAD '83): FUNC_CLASS = '5' AND SPEED_CAT >= '5' AND AR_AUTO = 'Y' AND FRONTAGE = 'N' AND BRIDGE = 'N' AND TUNNEL = 'N' AND RAMP = 'N' AND FERRY_TYPE = 'H'. Speed category 5 = 31-40 mph. Add short field "common" = 1. Convert to raster using values from "common" field. Save as Secondary_Rds.
2. Expand Secondary_Rds by 100m (10 cells). Save as Exp2ndRds_100. Note that previously I used the LineDensity function on secondary roads but this created odd patterns when thresholded to

identify dense road areas. Because the Census Blocks will be used to subset the buffered road data, no need to create a raster of line density.

3. Using the 2010 Census Blocks, **BLK2010_ALLCB_pophu** (attributed with Total Housing Units, Housing10, and Shape Area). Add one new field (SHORT): common.
4. Create a map of natural areas: Mosaic Forests, Water2, and NWI_noLake to New Raster. Save as **Natural**.
5. Sum the area of natural lands by Census Block UID (ZONAL SUM BY TABLE). I did this in 9 iterations of 80,000 records (could try all at once in future). Saved each table as a DBF, opened in EXCEL and saved in XLSX format. Opened and appended these 9 separate files together in ACCESS. Exported result (without formatting to to avoid Clipboard limitations) and saved as Blk_test.xlsx. Exported attribute table of BLK2010_ALLCB_pophu as Blk2010.xlsx. In EXCEL, use vlookup to join "AREA" from zonal sum table to Census Block attributes as a new field "NatArea". Add field NonNat area and set equal to ShapeArea - NatArea (all in m2). Add new field Lotsize = If(Housing10 = 0,0,if(NonNat<0, (ShapeArea/4046.86) / Housing10, (NonNat/4046.86)/Housing10). Add field TurfMask = If(and(lotsize>0,lotsize<=5,1,0). Save as Blk2010_mask.xlsx. Copy the UID and TurfMask columns to a new worksheet and save as **Blk2010_mask2.csv.**
6. Import records from Blk2010_mask3.csv to ArcMap and join to BLK2010_ALLCB_pophu. Turn off unnecessary fields leaving: BlockID10, Housing10, Pop10, UID, and TurfMask. EXPORT data as new feature dataset: Blks2010 _v2. Convert to raster based on values in TurfMask field and save as Blks10_dev5. Setnull (Blks10_dev5 = 0,1). Save as **Blks10_dev5mask**. This entire step took only a few hours compared to days via alternative methods.
7. Extract Exp2ndRds_100 within Blks10_dev5mask. Save as **Dev_prep.**
8. Perform definition query on LandUseA.
    a. NOT FEAT_TYPE = 'MILITARY BASE' AND NOT FEAT_TYPE = 'PARK/MONUMENT (NATIONAL)' AND NOT FEAT_TYPE = 'PARK (STATE)' AND NOT FEAT_TYPE = 'PARK (CITY/COUNTY)' AND NOT FEAT_TYPE = 'ANIMAL PARK' AND NOT FEAT_TYPE = 'BEACH'
9. Perform definition query on LandUseB:
    a. NOT FEAT_TYPE = 'NATIVE AMERICAN RESERVATION'
10. Merge LandUseA and LandUseB (all golf courses and airports)
11. Save as LandUseA_B. Add common field, set = 1, to LandUseA_B and convert to raster. Save as **LU_AB**
12. Reclass IR_final and INR_final to masks using Setnull("XXX" ==0,1) in RasterCalculator. Save as IR_mask and INR_mask.
13. Mosaic LU_AB, Dev_prep, INR_mask, IR_mask to new raster (maximum). Turn off background processing. Save as **Dev_iMask**. Note: this took 5.5 hours to complete.
14. Reclassify LC11_10m "herbaceous" (class 71) and "scrub/shrub" (52), as 1, else = nodata. Save as OS_hss.
15. Convert Railroads to 10m. Save as Rail. Extract Rail under Perv_mask6. Save as xRail.
16. Mosaic Forest, OS_hss, and xRail to New Raster: FOR_OS. Create a mask of non-FOR_OS: SetNull((IsNull("FOR_OS") == 0),1). Save as NonFOR_OS.
17. Extract Dev_iMask under NonFOR_OS mask. Save as **Developed.**
18. Mosaic HBir, HBnr, and HBp to New Raster (maximum). Save as Frac_Herb2.
19. Make a mask of non-fractional turf within developed areas. Set mask to Developed. SetNull(IsNull("Frac_Herb2")==0,1). Save as NonFracTurf
20. Set mask to NonFracTurf. Reclassify LC11_10m with developed open space (21), barren (31), pasture/hay (81), and cropland (82) = 100; else = NoData. Save as LC_turf.

21. Use Raster Catalog to mosaic LC_turf and Frac_herb2. Save as TG. Note that mosaic does not recognize masks. Set mask as Developed and extract TG. Save as TG2.
22. Add HBir, HBnr, and TG2 to raster catalog and convert to raster dataset (maximum). Save as TURF.
23. Remove wetlands and water from TURF. Extract Turf under mask of non-wetlands/water mask. Save as **TG2**.

Open Space

Open space represents non-fertilized herbaceous and non-forest scrub/shrub that is justifiably not turf or extractive (e.g., beaches, vacant lots, transmission line right-of-ways, junkyards, fairgrounds, gravel roads, railroads).

1. Multiply OS_hss and xRail rasters by 100. Save as OS_hss_100 and xRail_100. Set zero values to null in OS_hss_100. Save as OS_hss_100_v2. Extract OS_hss_100_v2 outside natural areas. Save as HSS_100.
2. Create a Raster Catalog called OS_prep. Load HSS_100, xRail_100 to the Catalog. Convert raster catalog to raster dataset (maximum). Save as **OS**.

Agriculture

The acreages of different crop types in Phase 6 are derived from the Census of Agriculture and not mapped. The area potentially used as agriculture is mapped and is represented by the lands remaining after accounting for all other land uses. The extent of agriculture is determined by reported values in the Census of Agriculture. The map of “potential agricultural land” is determined by identifying all pasture/hay lands and herbaceous fractions of tree canopy outside lands that are developed, open space, or natural.

1. Mosaic Developed, Natural, and OS_mask to New Raster (maximum). Save as NonAG.
2. Create a mask of potential agricultural areas. SetNull(IsNull("Not_AG") == 0,1). Save as AG_mask
3. RegionGroup (8, within, nolink) values from AG_mask. Save as RG_AG.
4. SetNull (RG_AG.count <=4 & RG_AG.count > 500,000). Save as RG_AG2
5. Using the 2008 – 2013 frequency rasters for Crops and Pasture/Hay, tabulate cumulative proportions of areas within each patch of RG_AG2. Save as **Agriculture**.

P6 Land Use Composite

To ensure complete accounting of local land use/cover data while also scaling to 10m cells, most of the above classes are represented as continuous integer rasters with values ranging from 0..100 indicating the percentage of a particular class within each pixel. This makes it challenging to create a single map representing the full extent of all classes unless one creates hybrid classes such as “Impervious/Tree canopy”, “Tree canopy/Turf”, “Impervious/Tree canopy/Turf”. This process could be confusing if we represent all possible class combinations in a single dataset. Therefore, we will create separate continuous rasters for each land use class and overlay them for review in a hierarchical order such that high level classes (1, 2, 3…) have visual priority over lower level classes. The disadvantage of this approach is that the full extent low priority classes may be obscured by high-level classes. This problem can be minimized during review of the data by enabling viewers to turn layers on/off in the web interface designed for data review.

Proposed display order from top (1) to bottom (14):

1. Impervious Roads
2. Impervious Non-Roads
3. Water
4. Wetlands
5. Forest
6. Open Space
7. Tree Canopy Herbaceous
8. Tree Canopy Impervious-Roads
9. Tree Canopy Non-Roads
10. Turf Grass
11. Cropland
12. Pasture/Hay

Overlays used to divide the data into subclasses for management purposes include:

1. Federal property boundaries
2. Municipal Separate Storm Sewer System boundaries (MS4s)
3. Sewer Service Areas
4. Wetland efficiencies
5. Riparian buffer efficiencies