Converting US Topo GeoPDF® Layers to GeoTIFF

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Based on Global Mapper v14.2 and GDAL v1.11

Readers are cautioned that this reformat is complex and tedious, with significant learning curves for most people. This paper is offered in the spirit of sharing specialized technical information with a niche audience. These procedures are at best interim solutions to the "PDF in GIS" problem.

This paper may be freely shared, but please use references to http://www.usgs.gov/faq/categories/9797/3704 instead of rehosting copies. Geospatial PDF software is evolving relatively rapidly, each version of this paper will age quickly, but outdated versions that remain online tend to float to the top of search engine results.

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1 Introduction

1.1 Background

In 2009 the U.S. Geological Survey (USGS) began publishing digital quadrangle maps modeled on the legacy 7.5-minute topographic series of 1947-1992. The new maps, branded US Topo in 2010, are published in GeoPDF® format – Portable Document Format (PDF) with geospatial extensions. PDF was chosen as the physical format because it is the only format in common use that

- Can carry vector, text, and raster data.
- Can display complex structures on a typical office computer without specialized software or expertise.
- Allows a map to be printed at correct scale without specialized software or expertise.

PDF geospatial extensions were implemented in US Topo because they add value "for free" – no cost to end users, and do not conflict with base PDF[1].

US Topo was intended to be a map product, not a GIS product. US Topo maps are fundamentally an output of, not an input to, GIS. They are derived directly from national GIS databases and represent a repackaging of existing data, not creation of new data.

Nevertheless, there is demand for the ability to load these symbolized maps into GIS software; the basic benefit of this capability is to supply the GIS user with a pre-built, symbolized background map.

There are several potential solutions to this GIS user problem. The USGS is working on ways to distribute the symbolized layers of US Topo in formats that are more GIS friendly. It is also likely that the major GIS vendors will eventually implement geospatial PDF import functions. Web services (Appendix D) also provide partial solutions. Converting US Topo PDFs to some other format is also an option, and is the subject of this paper.

A common question from GIS users is "how can I convert a US Topo to GeoTIFF?" GeoTIFF is raster image, not an intelligent GIS format, but provides a simple mechanism to display map symbology and annotation. GeoPDF-to-GeoTIFF conversion would seem like a relatively easy way to import US Topos into GIS. Unfortunately, this reformat is not especially simple, mostly due to the lack of powerful software for manipulating layered PDF files and for preserving georeferencing through reformat processes.

1.2 Scope

This paper presents software and procedures for separating the layers of a US Topo and converting the separated layers or combinations of layers to GeoTIFFs. Two methods are discussed:

1. Global Mapper commercial software. This is the easier of the two methods by a wide margin, but it depends completely on proprietary software.
2. Utilities of the open source Geospatial Data Abstraction Library (GDAL). This process is more powerful but more complex. It requires familiarity with Unix-like software setup and command-line processing.

Neither process has been fully automated, though both can be partially automated with scripts. Both produce results of high visual quality.

[1] These extensions are currently added with TerraGo software, so the resulting files can be referred to with the trademarked term GeoPDF®. "Geospatial PDF" is a generic term for georeferenced PDF documents.

Software to manipulate geospatial PDFs is evolving relatively rapidly. Readers are cautioned this document will probably have a short useful life; check for later versions of the software described here and read the documentation distributed with the software.

Section 3.6 briefly addresses the comparable reformat for maps of the USGS Historical Topographic Map Collection (HTMC). HTMC maps are also distributed in GeoPDF format, but have some technical characteristics that differ from US Topo maps.

2 Global Mapper Commercial Software

See http://www.bluemarblegeo.com/products/global-mapper.php for technical and purchasing information about Global Mapper.[2]

The following procedures are for Global Mapper v14.2. Global Mapper documentation indicates that similar procedures should work for all versions beginning with v11.

Global Mapper can load layered geospatial PDFs and preserve the georeferencing. However, Global Mapper PDF display behavior is different than Adobe Acrobat behavior. Global Mapper rasterizes the entire dataset, flattening all layers to a single raster image plane. Therefore, the Global Mapper display of a geospatial PDF does not look like an Acrobat display of vectors, but rather like a file that has already been converted to a raster format such as TIFF or JPEG.

As part of the file load process, Global Mapper gives the user the option to select layers (Figure 1). This layer selection must be done when the file is loaded; once the map is displayed in Global Mapper, it has been converted to one raster image and the layer characteristics of the original PDF are discarded.

When Global Mapper rasterizes a US Topo, it sets the resolution at about two ground meters per pixel, or about 300 lines per inch at 1:24,000 scale. If the data are exported to a raster file, this resolution is maintained by default, though it can be changed. Decreasing the resolution will reduce the file size and lower the image quality. Increasing the resolution will increase the file size, but will not noticeably improve image quality.

The displayed image can be exported to a GeoTIFF (or other raster formats) using the standard Global Mapper export functions.

Global Mapper includes a powerful scripting language, and this process can be scripted to convert any number of maps at one time. Such a script has been written by Stephen Aichele (saichele@usgs.gov). A listing of the script is included in Appendix A of this document. The script and a map cell Shapefile (needed for clipping collars; see the inline documentation of the script listing) are also included in a tar file at ftp://ftpext.usgs.gov/pub/cr/co/lakewood/Larry_Moore/ustopo2tiff/

As explained in the inline documentation, changing the behavior of this script (to alter the layers selected for export, for example), requires changes to the code. More complex versions of this script that would present run-time options to the user could be written.

[2] The USGS has no business relationship with Global Mapper or Blue Marble Geographic, Inc., and does not endorse or sponsor this commercial product. Global Mapper procedures are described here because we believe it currently provides unique capabilities for separating US Topo layers and converting them to GeoTIFF.

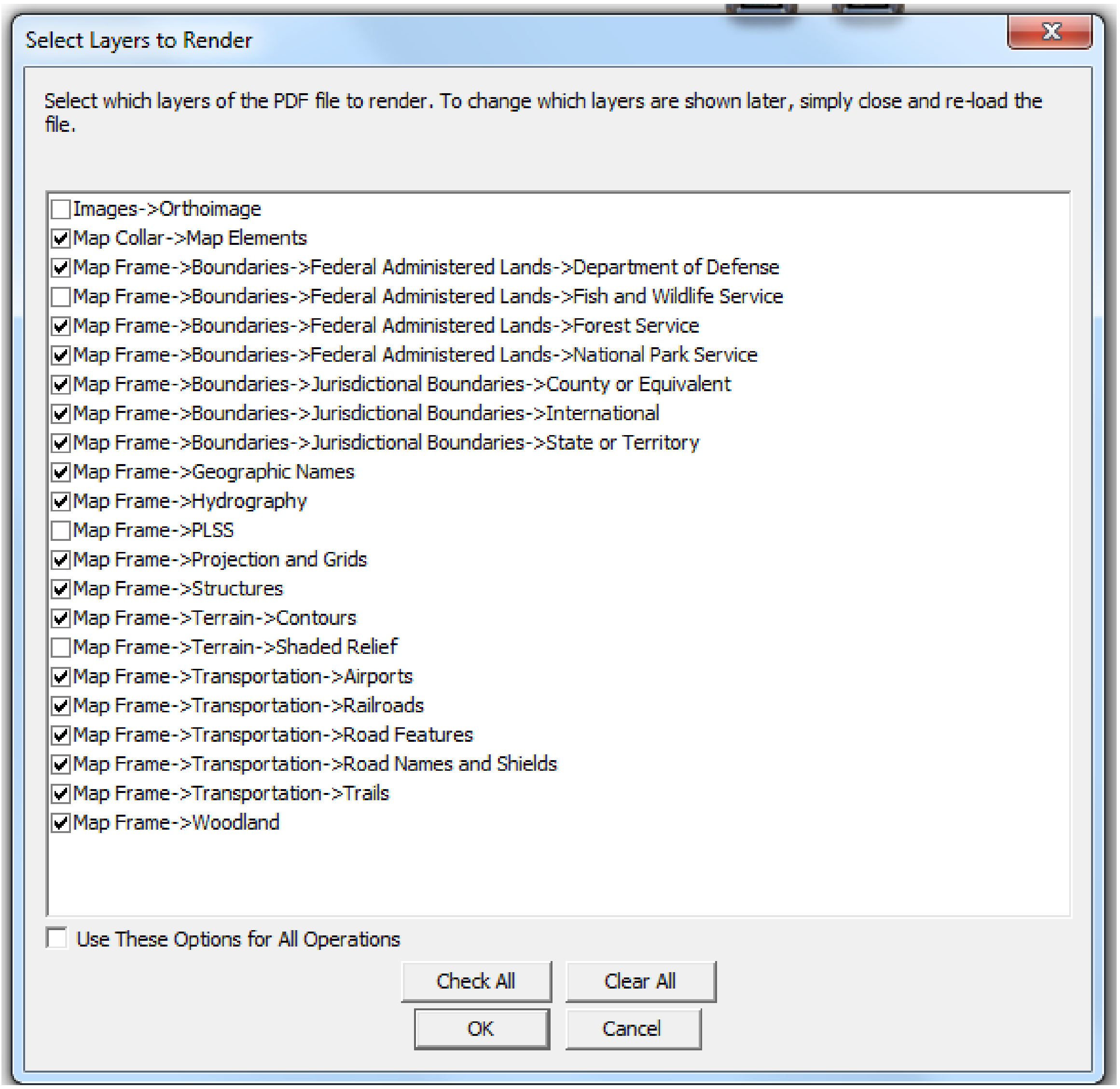

Figure 1. Screen shot of Global Mapper layer selection box. Layers may be clicked on or off when a US Topo geospatial PDF is opened. Note that Global Mapper preserves the default behavior of the US Topo regarding which layers are "on" when the file is opened in Acrobat. Layer selection must be done as part of the file open process; layers cannot be selected later. This example is from a US Topo map published in late 2013. The exact layer list will vary with the vintage of the US Topo; see Appendix B for more information.

3 GDAL Open Source Software

The Geospatial Data Abstraction Library (GDAL) has several advantages over Global Mapper: the software is no-cost and open source, gives the user more options and control, and allows more advanced processing. On the other hand, using GDAL utilities is more difficult. Software setup is complicated compared to installing commercial Windows software. Familiarity with command-line processing is required. Commands are long and tedious. Familiarity with scripting techniques is very helpful.

3.1 Environments

The utilities discussed below can be used in several different environments:

1. Simplest, but least powerful: The critical utilities can be downloaded as pre-compiled Windows binaries that can be run from the Command Prompt application that is included with Windows.
2. More powerful, more difficult: A Unix emulation environment within Windows provides more power and flexibility, especially for scripting. It also allows software to be built from source (though precompiled Windows binaries also work). Examples of such environments are MinGW/MSYS and Cygwin.
3. Most powerful: use a Unix or Linux computer. This is not as difficult as it might sound. Modern Linux distributions are easy to install, and can be run on older computers that are too small to run current Windows versions. Software installation and management for the procedures described below are easier on Linux than on Windows. The OSGeo-Live distribution is a particularly convenient way to access GDAL and other open source GIS software on Linux.
4. The GDAL download page also includes a link to builds for Mac OS X. USGS has not tested these programs or procedures on Macs, but a GIS user who independently investigated these reformats reports that the GDAL utilities work well on a MacBook Pro with OS X.

3.2 Download software

The Geospatial Data Abstraction Library (GDAL) home page is http://gdal.org. The software download page is http://trac.osgeo.org/gdal/wiki/DownloadingGdalBinaries

Precompiled binaries for Windows can be downloaded from http://www.gisinternals.com/sdk/. This paper is based on tests with GDAL version 1.11. To see the version of a distribution package, click on **Information** in the **Package Info** column, and scroll down to **GDAL Version Information**.

See the GDAL documentation for installation instructions. Installation procedures depend partly on the environment you are using.

The GDAL software library and associated utilities are very general and powerful. This paper documents only a few selected GDAL capabilities.

3.3 Example data

Examples in this paper use the Santa Fe, NM, 2013 US Topo map (`NM_Santa_Fe_20131108_TM_geo.pdf`), which can be downloaded from

`http://ims.er.usgs.gov/gda_services/download?item_id=5968958`

…and the Santa Fe, NM, 1952 historical map (`NM_Santa Fe_192271_1952_24000_geo.pdf`), which can be downloaded from

http://ims.er.usgs.gov/gda_services/download?item_id=5383649

Note that this file name includes a space (Santa Fe). It might be convenient to replace this with a non-whitespace character. Further references to this file name in this paper replace the space with an underbar.

3.4 Basic reformat

The basics of separating US Topo layers and converting them to GeoTIFF require only two GDAL programs: `gdalinfo` and `gdal_translate`.

3.4.1 Use gdalinfo to get the names of layers in the PDF

In an appropriate command-line environment, run the command

```
1) gdalinfo NM_Santa_Fe_20131108_TM_geo.pdf –mdd LAYERS
```

The output will contain metadata and coordinate system information, and a section listing the layers in the PDF:

```
Metadata (LAYERS):
  LAYER_00_NAME=Map_Collar
  LAYER_01_NAME=Map_Collar.Map_Elements
  LAYER_02_NAME=Map_Frame
  LAYER_03_NAME=Map_Frame.Projection_and_Grids
  LAYER_04_NAME=Map_Frame.Geographic_Names
  LAYER_05_NAME=Map_Frame.Structures
  LAYER_06_NAME=Map_Frame.Transportation
  LAYER_07_NAME=Map_Frame.Transportation.Road_Names_and_Shields
  LAYER_08_NAME=Map_Frame.Transportation.Road_Features
  LAYER_09_NAME=Map_Frame.Transportation.Trails
  LAYER_10_NAME=Map_Frame.Transportation.Railroads
  LAYER_11_NAME=Map_Frame.Transportation.Airports
  LAYER_12_NAME=Map_Frame.PLSS
  LAYER_13_NAME=Map_Frame.Hydrography
  LAYER_14_NAME=Map_Frame.Terrain
  LAYER_15_NAME=Map_Frame.Terrain.Contours
  LAYER_16_NAME=Map_Frame.Terrain.Shaded_Relief
  LAYER_17_NAME=Map_Frame.Woodland
  LAYER_18_NAME=Map_Frame.Boundaries
  LAYER_19_NAME=Map_Frame.Boundaries.Jurisdictional_Boundaries
  LAYER_20_NAME=Map_Frame.Boundaries.Jurisdictional_Boundaries.International
  LAYER_21_NAME=Map_Frame.Boundaries.Jurisdictional_Boundaries.State_or_Territory
  LAYER_22_NAME=Map_Frame.Boundaries.Jurisdictional_Boundaries.County_or_Equivalent
  LAYER_23_NAME=Map_Frame.Boundaries.Federal_Administered_Lands
  LAYER_24_NAME=Map_Frame.Boundaries.Federal_Administered_Lands.National_Park_Service
  LAYER_25_NAME=Map_Frame.Boundaries.Federal_Administered_Lands.Department_of_Defense
  LAYER_26_NAME=Map_Frame.Boundaries.Federal_Administered_Lands.Forest_Service
  LAYER_27_NAME=Images
  LAYER_28_NAME=Images.Orthoimage
```

The layer names to the right of the equal sign can be used as input to gdal_translate to extract and rasterize layers or combinations of layers.

The number and names of the layers will vary with the US Topo vintage. A complete list of layer names for US Topo maps for the time period 2011-2013 is given in Appendix B.

3.4.2 Use gdal_translate to convert selected layers to GeoTIFFs

To create a GeoTIFF of just the contour layer:

```
2)  gdal_translate -of GTiff NM_Santa_Fe_20131108_TM_geo.pdf santa_fe_contours.tif \
    --config GDAL_PDF_LAYERS "Map_Frame.Terrain.Contours"
```

`-of GTIFF` is the default, and will be omitted from this point on. The backslash at the end of the first line is a Bash shell continuation character. `'^'` is the comparable DOS character. The continuation character is not needed when typing these commands in a command line interface, but is included here to present correct command syntax.

The argument to the `GDAL_PDF_LAYERS` parameter can be multiple layers, separated by commas. For example, `"Map_Frame.Hydrography,Map_Frame.Terrain.Contours"`

The option `GDAL_PDF_LAYERS_OFF` is more convenient if many layers are desired in the output. For most US Topo maps, this command will create a GeoTIFF that closely resembles a traditional USGS topographic map:

```
3)  gdal_translate NM_Santa_Fe_20131108_TM_geo.pdf santa_fe_map.tif \
    --config GDAL_PDF_LAYERS_OFF "Images.Orthoimage,Map_Frame.Terrain.Shaded_Relief"
```

However, this option will also exclude any layers that are "off by default" when a US Topo PDF is opened. Layers such as PLSS, shaded relief, and Fish and Wildlife Service lands must be explicitly included in `gdal_translate` commands.

3.5 Reducing output file size

The output of commands 2 and 3 above are uncompressed RGBA[3] 32-bit TIFFs. For a typical US Topo, this file will be approximately 1 GB, an extremely large file for this kind of image.

One way to reduce output file size is to convert the 32-bit RGBA TIFF to an 8-bit palette color TIFF (PCT), then apply packbits compression. Depending on the density of linework, this will reduce file size to the 5-30 MB range. GDAL includes a Python program to convert an RBG TIFF to a PCT (`rbg2pct.py`). Unfortunately, setting up an environment in Windows that implements the GDAL Python bindings is rather difficult; I have not been able to get this to work in Windows, but only on Linux.

File size can be dramatically reduced by various combinations of JPEG compression, different color models, and reduced resolution. This command, for example, will produce a traditional-looking linemap image with file size about 15 MB:

```
4)  gdal_translate -co COMPRESS=JPEG -co PHOTOMETRIC=YCBCR NM_Santa_Fe_20131108_TM_geo.pdf \
    santa_fe_map.tif --config GDAL_PDF_LAYERS_OFF \
    "Images.Orthoimage,Map_Frame.Terrain.Shaded_Relief" --config GDAL_PDF_DPI 400
```

[3] Display behavior for the alpha channel may vary between software packages. ArcMap displays this file with the background black (probably), making the image look like a film negative. To restore a normal appearance in ArcMap, right-click on the layer, select **Properties**, then the **Symbology** tab, then check the **Alpha** Channel box and set **Band** to **Band_4**.

The compression and YCbCr color model slightly reduces the sharpness of the map linework, but not enough to be noticeable for most applications. Reducing the resolution further is also an option for many applications. See Appendix C for more information about photometric, compression, and resolution effects on file size.

Since most US Topo layers are vectors, the resolution of a map is a bit ambiguous. The orthoimage layer has a ground resolution of 1 meter or 1.5 meter per pixel (depending on map vintage), about 600 DPI and 400 DPI respectively at map scale. 600 DPI is the declared resolution of the PDF and is the default output of `gdal_translate` operations. This output resolution is higher than needed for most applications. Reducing it with the `--config GDAL_PDF_DPI` as described above can substantially reduce the output file size. For most applications, 300 DPI is probably an adequate resolution. Resolutions above 500 DPI provide very little improvement in image quality while rapidly increasing file sizes.

Following are two other `gdal_translate` compression options. The effects of these are more modest than photometric and resolution options, but they may have other benefits for specific applications.

Apply packbits compression (run-length-encoding, a lossless compression technique). For linework layers, this will usually reduce the file size to less than 100 MB:

```
5) gdal_translate –co COMPRESS=PACKBITS NM_Santa_Fe_20131108_TM_geo.pdf \
   santa_fe_contours.tif --config GDAL_PDF_LAYERS "Map_Frame.Terrain.Contours"
```

The `–co` option is for ‘creation options.’ Valid arguments depend on the output file format. See http://www.gdal.org/frmt_gtiff.html for TIFF options.

Remove the alpha channel. This will reduce file size about 25%. However, the processing for this is very slow.

```
6) gdal_translate -b 1 –b 2 –b 3 NM_Santa_Fe_20131108_TM_geo.pdf santa_fe_contours.tif \
   --config GDAL_PDF_LAYERS "Map_Frame.Terrain.Contours"
```

3.6 Historical Maps

From 2010 to 2013 the USGS scanned its entire library of standard topographic quadrangles[4]. Almost 180,000 map sheets have been scanned and published as GeoPDF files. Like US Topo maps, these can be downloaded free of charge. This set of scanned maps is referred to as the Historical Topographic Map Collection (HTMC).

The technical characteristics of HTMC geospatial PDFs differ from US Topo geospatial PDFs in two ways: 1) they are not layered PDFs, but are normal PDF documents with only one image plane, and 2) they are georeferenced to the spatial reference system (SRS) of the original published paper map.[5] In most cases this means the datum is antiquated and the projection is not a common standard projection like UTM, but uses parameters specific to the map sheet.

[4] We estimate that several thousand map sheets probably remain to be discovered and scanned.
[5] To the extent the original SRS can be determined. Maps compiled in the late 19th and early 20th centuries tended to be cast on local, non-standard datums, and the parameters for these datums are not recoverable. These maps are referenced to NAD27 in the HTMC, which in some cases leads to noticeable positional shifts, typically a few meters to a few tens of meters, but occasionally more.

As with US Topo maps, Global Mapper provides the easiest way to convert an HTMC map to a GeoTIFF. Import of HTMC maps is straight forward, and Global Mapper has powerful but easy-to-use functions for export, changing the datum and projection, and even for redoing the georeferencing.

An HTMC geospatial PDF can be converted to a GeoTIFF with `gdal_translate,` using essentially the same command used to convert a US Topo minus the layer declaration:

```
7) gdal_translate NM_Santa_Fe_192271_1952_24000_geo.pdf santa_fe.tif
```

The default resolution of the output of this command appears to be 150 dpi, which may be a result of an error in the ground resolution stored in the HTMC GeoPDFs[6]. The output resolution can be controlled with a `config` parameter:

```
8) gdal_translate NM_Santa_Fe_192271_1952_24000_geo.pdf santa_fe.tif \
   --config GDAL_PDF_DPI 500
```

The output of this command will be a very large file. Much smaller output files can be created using the same options described for US Topo maps:

```
9) gdal_translate -co COMPRESS=JPEG -co PHOTOMETRIC=YCBCR \
   NM_Santa_Fe_192271_1952_24000_geo.pdf santa_fe.tif --config GDAL_PDF_DPI 300
```

The actual scan resolution of most (about 88%) HTMC maps is 600 DPI. About 12% were scanned at 508 DPI, and a few dozen oversized maps were scanned at other resolutions down to 400. Setting the output resolution higher than the actual scan resolution will increase file size without improving image quality. For many applications, setting the output resolution lower than the original scan resolution should be considered. Resolutions in the range of 300-500 DPI are probably a favorable tradeoff between visual quality and file size.

In this example, the resulting GeoTIFF is referenced to a polyconic projection, with a non-standard coordinate system, on NAD27. To convert this to a UTM projection on NAD83/WGS84[7] use the program `gdalwarp`:

```
10) gdalwarp –t_srs ‘+proj=utm +zone=13 +datum=NAD83’ santa_fe.tif \
    santa_fe_nad83_utm.tif
```

Double quotes around the SRS parameters might be needed in the Windows Command Prompt environment. For this particular map, this conversion will “move” the even 7.5-minute lat/lng values of the projection line corners 52 meters east and 3 meters south (2.166 and 0.125 map millimeters respectively).

`gdalwarp` is a powerful program, with many options. The above example uses “proj4” syntax for the target spatial reference system (`t_srs`), but other formats for both source and target references systems are supported. In the example, no source SRS need be specified, as the input file is a GeoTIFF.

[6] For most, perhaps all, HTMC 1:24,000-scale GeoPDFs GDAL utilities report a ground resolution of 4.016 meters/pixel. This is incorrect in all cases, and we believe is an error in the product. USGS is investigating how this happened, and whether or not anything can be done about it without remaking all the GeoPDFs. The error does not impact normal display and print operations, and can be easily worked around with GDAL command parameters as described in this paper.

[7] The National Geodetic Survey (NGS) has documented that NAD83 and WGS84 are equivalent at map scales of 1:5,000 and smaller.

Converting a digital version of an old map to a modern datum often leads to confusing coordinate readouts. See the paper at `http://thor-f5.er.usgs.gov/drg/datum_shifts_v2.pdf` for an explanation of the effects of datum shifts on displays of historical maps.

4 Key URLs

The two Santa Fe geospatial PDF maps used in this paper, the Global Mapper script, a Shapefile of 7.5-minute cells, and a copy of this paper are in a .zip file at: ftp://ftpext.usgs.gov/pub/cr/co/lakewood/Larry_Moore/ustopo2tiff/, file name ustopo2gtif_v2.zip.

Global Mapper: http://www.bluemarblegeo.com/products/global-mapper.php

GDAL (Geospatial Data Abstraction Library): http://www.gdal.org

MinGW/MSYS: http://www.mingw.org (home) http://sourceforge.net/projects/mingw/files (download)

GDAL utility documentation pages:

- gdalinfo: http://www.gdal.org/gdalinfo.html
- gdal_translate: http://www.gdal.org/gdal_translate.html
- gdalwarp: http://www.gdal.org/gdalwarp.html
- rgb2pct.py: http://www.gdal.org/rgb2pct.html
- TIFF creation options: http://www.gdal.org/frmt_gtiff.html
- Geospatial PDF configuration options: http://www.gdal.org/frmt_pdf.html

OSGeo: http://www.osgeo.org/

OSGeo-Live (open source GIS software bundled with a Linux distribution): http://live.osgeo.org/en/index.html

The Historical Topographic Map Collection: http://nationalmap.gov/historical/

HTMC FAQs: http://www.usgs.gov/faq/?q=categories/9796

US Topo: http://nationalmap.gov/ustopo/

US Topo FAQs: http://www.usgs.gov/faq/?q=categories/9797

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HDR, Inc: Michael Davis.

Appendix A. Global Mapper script for batch GeoPDF-to-GeoTIFF reformat

```
// This Global Mapper script converts USGS GeoPDF US Topo maps to Geotiffs.
// The script supports two outputs: maps with collars, or with collars clipped.
//      Read inline documentation below.
//
// Author: Steve Aichele, saichele@usgs.gov
// Modified by Larry Moore, lmoore@usgs.gov, 2/2013, 1/2014
//
// Lots of stuff is hardcoded that may have to be modified depending on
//      1) vintage of US Topo and
//      2) desired content of output
//
// RUN INSTRUCTIONS:
// Place this script, and GeoPDF USTopos in a directory.
// Open GlobalMapper 13.1 or higher and run this script.
//
// If you want to clip map collars, the shapefile "All_7.5min_cells.shp"
//      must be in the same directory as the script and PDFs.
//
// USTopos with collars will have the prefix "WC" appended to the quad name


GLOBAL_MAPPER_SCRIPT VERSION="1.00"
UNLOAD_ALL

// set starting directory
DIR_LOOP_START DIRECTORY="." FILENAME_MASKS="*.pdf" RECURSE_DIR=NO


// Layer list follows.
// Comment out lines for layers you don't want in the output TIFF
// Notes:
//      There is variation in the actual content of different vintages of US Topos...
//      ...and also variation in layer names due to bugs and editorial design changes.
//      Having "extra" layers in this list does not hurt anything,
//              but having a layer missing means it cannot be exported to GeoTIFF
//       The list below is *all* layers that occur in any US Topo from late 2010 through
//           2013 (that is, the set of current US Topo maps as of the end of 2013)
//       The presence of a layer in this list does *not* necessarily mean that layer is
//           present in all US Topo maps. The product is evolving, both in content and design.
//
// Comment out specific layers as necessary. Default is to include everything except the
//       orthoimage, PLSS, and several federal land boundary types (which occur on relatively
//       few maps)
//
IMPORT FILENAME="%FNAME_W_DIR%" \
       TYPE="PDF" RECTIFY="Automatic" \
        LOAD_FLAGS="2,400, \
              Map Collar->Map Elements<SEP> \
              //
              Map Frame->Boundaries<SEP> \
              Map Frame->Boundaries->Boundaries<SEP> \
              Map Frame->Boundaries->Boundary Names<SEP> \
              Map Frame->Boundaries->Federal Administered Lands<SEP> \
              Map Frame->Boundaries->Federal Administered Lands->Bureau of Land Management<SEP> \
              Map Frame->Boundaries->Federal Administered Lands->Department of Defense<SEP> \
              Map Frame->Boundaries->Federal Administered Lands->Fish and Wildlife Service<SEP> \
              Map Frame->Boundaries->Federal Administered Lands->Forest Service<SEP> \
              Map Frame->Boundaries->Federal Administered Lands->National Park Service<SEP> \
              Map Frame->Boundaries->Federal Adninistered Land<SEP> \
              Map Frame->Boundaries->Federal Adninistered Land->Department of Defense<SEP> \
              Map Frame->Boundaries->Federal Adninistered Land->Fish and Wildlife Service<SEP> \
              Map Frame->Boundaries->Federal Adninistered Land->Forest Service<SEP> \
              Map Frame->Boundaries->Federal Adninistered Land->National Park Service<SEP> \
              Map Frame->Boundaries->Jurisdictional Boundaries<SEP> \
              Map Frame->Boundaries->Jurisdictional Boundaries->County or Equivalent<SEP> \
              Map Frame->Boundaries->Jurisdictional Boundaries->International<SEP> \
              Map Frame->Boundaries->Jurisdictional Boundaries->State or Territory<SEP> \
              Map Frame->Boundary Features and Names<SEP> \
```

```
//
Map Frame->Contour Names<SEP> \
Map Frame->Contour Names->Contour Features<SEP> \
Map Frame->Contour Names->Contour Names<SEP> \
Map Frame->Contours<SEP> \
Map Frame->Contours->Contour Features<SEP> \
Map Frame->Contours->Contour Names<SEP> \
//
Map Frame->Geographic Names<SEP> \
Map Frame->Geographic Names->Geographic Names<SEP> \
//
Map Frame->Hydrography<SEP> \
Map Frame->Hydrography->Hydrographic Features<SEP> \
Map Frame->Hydrography->Hydrographic Names<SEP> \
Map Frame->Hydrography->Hydrography Features<SEP> \
Map Frame->Hydrography->Hydrography Names<SEP> \
Map Frame->Hydrography Features and Names<SEP> \
//
Map Frame->Land Cover<SEP> \
Map Frame->Land Cover->Woodland<SEP> \
//
//Map Frame->PLSS<SEP> \
//Map Frame->Public Land Survey System<SEP> \
//Map Frame->Public Land Survey System->PLSS Grids<SEP> \
//Map Frame->Public Land Survey System->PLSS Names<SEP> \
//
Map Frame->Projection and Grids<SEP> \
Map Frame->Projection and Grids->Geographic and Grid Ticks<SEP> \
Map Frame->Projection and Grids->Geographic and Grid Tics<SEP> \
Map Frame->Projection and Grids->Grid Lines<SEP> \
Map Frame->Projection and Grids->Projection Coordinate Values<SEP> \
Map Frame->Projection and Grids->Projection Line Mask<SEP> \
Map Frame->Projections and Grids<SEP> \
//
Map Frame->Structure Features and Names<SEP> \
Map Frame->Structures<SEP> \
Map Frame->Structures->Structure Features<SEP> \
Map Frame->Structures->Structure Names<SEP> \
Map Frame->Structures->Structures<SEP> \
Map Frame->Structures->Structures Names<SEP> \
//
Map Frame->Terrain<SEP> \
Map Frame->Terrain->Contour Features and Names<SEP> \
Map Frame->Terrain->Contours<SEP> \
//Map Frame->Terrain->Shaded Relief<SEP> \
//
Map Frame->Transportation<SEP> \
Map Frame->Transportation->Airport Features and Names<SEP> \
Map Frame->Transportation->Airport Names<SEP> \
Map Frame->Transportation->Airports<SEP> \
Map Frame->Transportation->Railroad Features and Names<SEP> \
Map Frame->Transportation->Railroad Names<SEP> \
Map Frame->Transportation->Railroads<SEP> \
Map Frame->Transportation->Road Features<SEP> \
Map Frame->Transportation->Road Names and Shields<SEP> \
Map Frame->Transportation->Roads<SEP> \
Map Frame->Transportation->Trails<SEP> \
Map Frame->Transportation Names<SEP> \
Map Frame->Transportation Names->Airport Names<SEP> \
Map Frame->Transportation Names->Airports<SEP> \
Map Frame->Transportation Names->Railroad Names<SEP> \
Map Frame->Transportation Names->Railroads<SEP> \
Map Frame->Transportation Names->Road Names and Shields<SEP> \
Map Frame->Transportation Names->Roads<SEP> \
//
Map Frame->Woodland<SEP> \
Map Frame->Woodland Features<SEP> \
//
//Images->Orthoimage<SEP> \
      ,1" \
```

```
        SAMPLING_METHOD="NEAREST_NEIGHBOR" AUTO_CONTRAST="NO" CONTRAST_SHARED="YES"
CONTRAST_MODE="NONE" \
        CLIP_COLLAR="NONE"  TEXTURE_MAP="NO"

// This command, if uncommented, creates GeoTiff's with Collars
EXPORT_RASTER FILENAME="%DIR%WC_%FNAME_WO_EXT%.tif" TYPE=GEOTIFF PALETTE=HALFTONE

// This command, if uncommented, outputs GeoTIFFs without map collars -- everything outside the
projection line is deleted
// Clipping requires a shapefile of the standard 7.5-minute cells to define where the clip is done
// EXPORT_RASTER FILENAME="%DIR%%FNAME_WO_EXT%.tif" TYPE=GEOTIFF PALETTE=HALFTONE
POLYGON_CROP_FILE="All_7.5min_cells.shp"

UNLOAD_ALL

DIR_LOOP_END
```

Appendix B. List of US Topo layers

The layers present in US Topo maps vary due to addition of new content and product design changes. It is likely the layer table of contents will never be completely stable. The following two lists or layers are based on an analysis of the ~54,000 current US Topo maps as of October 1, 2014 – mostly maps published from October 2011 through September 2014.

Scripts for either Global Mapper or `gdal_translate` can include "extra" layers, which are simply ignored by the program (`gdal_translate` will display warning messages). Fairly general scripts can therefore be written by including all the layer names that refer to a feature type of interest.

The names in the lists use GDAL syntax. To convert to Global Mapper syntax, replace underbars (_) with spaces, and periods (.) with `->` Example:

- [GDAL syntax] `Map_Frame.Terrain.Contours`
- [Global Mapper syntax] `Map Frame->Terrain->Contours`

Table 1. The current layer set, which applies to all maps published in fiscal year 2014 (October 2013 through September 2014). This set of layers is expected to be relatively stable for the foreseeable future, though it is unlikely it will completely stable or permanent. Highlighted layers are folders that contain no data of their own.

Map_Collar
Map_Collar.Map_Elements
Map_Frame
Map_Frame.Projection_and_Grids
Map_Frame.Geographic_Names
Map_Frame.Structures
Map_Frame.Transportation
Map_Frame.Transportation.Road_Names_and_Shields
Map_Frame.Transportation.Road_Features
Map_Frame.Transportation.Trails
Map_Frame.Transportation.Railroads
Map_Frame.Transportation.Airports
Map_Frame.Hydrography
Map_Frame.PLSS
Map_Frame.Terrain
Map_Frame.Terrain.Contours
Map_Frame.Terrain.Shaded_Relief
Map_Frame.Woodland
Map_Frame.Boundaries
Map_Frame.Boundaries.Jurisdictional_Boundaries
Map_Frame.Boundaries.Jurisdictional_Boundaries.International
Map_Frame.Boundaries.Jurisdictional_Boundaries.State_or_Territory

Map_Frame.Boundaries.Jurisdictional_Boundaries.County_or_Equivalent
Map_Frame.Boundaries.Federal_Administered_Lands
Map_Frame.Boundaries.Federal_Administered_Lands.National_Park_Service
Map_Frame.Boundaries.Federal_Administered_Lands.Department_of_Defense
Map_Frame.Boundaries.Federal_Administered_Lands.Forest_Service
Map_Frame.Boundaries.Federal_Administered_Lands.Fish_and_Wildlife_Service
Map_Frame.Boundaries.Federal_Administered_Lands.Bureau_of_Land_Management
Images
Images.Orthoimage

Table 2. Layers that are deprecated as of October 2013, but which are still present in the set of current maps. These layers will gradually disappear from the set of current maps in 2015 and 2016. Non-current US Topo maps, going back to October 2009, will of course continue to have a wider variety of layers and layer names.

Layer Name	*Last use*
Map_Frame.Boundaries.Boundaries	Apr-13
Map_Frame.Boundaries.Boundary_Names	Apr-13
[8]*Map_Frame.Boundaries.Federal_Adninistered_Land	Sep-13
*Map_Frame.Boundaries.Federal_Adninistered_Land.Department_of_Defense	Sep-13
*Map_Frame.Boundaries.Federal_Adninistered_Land.Fish_and_Wildlife_Service	Sep-13
*Map_Frame.Boundaries.Federal_Adninistered_Land.Forest_Service	Sep-13
*Map_Frame.Boundaries.Federal_Adninistered_Land.National_Park_Service	Sep-13
Map_Frame.Boundary_Features_and_Names	Sep-13
Map_Frame.Contour_Names	Oct-12
Map_Frame.Contour_Names.Contour_Features	Oct-12
Map_Frame.Contour_Names.Contour_Names	Oct-12
Map_Frame.Contours	Apr-13
Map_Frame.Contours.Contour_Features	Apr-13
Map_Frame.Contours.Contour_Names	Apr-13
Map_Frame.Geographic_Names.Geographic_Names	Apr-13
Map_Frame.Hydrography.Hydrographic_Features	Feb-13
Map_Frame.Hydrography.Hydrographic_Names	Feb-13
Map_Frame.Hydrography.Hydrography_Features	Apr-13
Map_Frame.Hydrography.Hydrography_Names	Apr-13
Map_Frame.Hydrography_Features_and_Names	Sep-13
Map_Frame.Land_Cover	Apr-13
Map_Frame.Land_Cover.Woodland	Apr-13
Map_Frame.Projection_and_Grids.Geographic_and_Grid_Ticks	Sep-12
Map_Frame.Projection_and_Grids.Geographic_and_Grid_Tics	Apr-13

[8] *Five boundary layers containing a typo, affecting only 84 Alaska maps

Map_Frame.Projection_and_Grids.Grid_Lines	Apr-13
Map_Frame.Projection_and_Grids.Projection_Coordinate_Values	Apr-13
Map_Frame.Projection_and_Grids.Projection_Line_Mask	Apr-13
Map_Frame.Projections_and_Grids	Sep-13
Map_Frame.Public_Land_Survey_System	Dec-12
Map_Frame.Public_Land_Survey_System.PLSS_Grids	Dec-12
Map_Frame.Public_Land_Survey_System.PLSS_Names	Dec-12
Map_Frame.Structure_Features_and_Names	Sep-13
Map_Frame.Structures.Structure_Features	Jan-12
Map_Frame.Structures.Structure_Names	Jan-12
Map_Frame.Structures.Structures	Apr-13
Map_Frame.Structures.Structures_Names	Apr-13
Map_Frame.Terrain.Contour_Features_and_Names	Sep-13
Map_Frame.Transportation.Airport_Features_and_Names	Sep-13
Map_Frame.Transportation.Airport_Names	Apr-13
Map_Frame.Transportation.Railroad_Features_and_Names	Sep-13
Map_Frame.Transportation.Railroad_Names	Apr-13
Map_Frame.Transportation.Roads	Apr-13
Map_Frame.Transportation_Names	Oct-12
Map_Frame.Transportation_Names.Airport_Names	Oct-12
Map_Frame.Transportation_Names.Airports	Oct-12
Map_Frame.Transportation_Names.Railroad_Names	Oct-12
Map_Frame.Transportation_Names.Railroads	Oct-12
Map_Frame.Transportation_Names.Road_Names_and_Shields	Oct-12
Map_Frame.Transportation_Names.Roads	Oct-12
Map_Frame.Woodland_Features	Sep-13

Appendix C. GeoTIFF file sizes with various GDAL options

The following table shows GeoTIFF file sizes for various types of data content converted using `gdal_translate` and with several combinations of photometric, compression, and resolution. There is little variation in visual quality between any of these combinations, but a wide range of file sizes. Particular applications may have reasons for preferring certain combinations. These data are from tests on only a few US Topo and HTMC instances, and the amount of variation that can be expected between maps has not been studied.

Even so, it is clear that for applications that do not have specialized requirements for format or individual pixel color value preservation, the YCBCR color model with JPEG compression and relatively low resolution is the best choice.

The “traditional line map” column is a color composite that includes all vector layers, the map collar and grids, and the green timber layer, but omits the orthoimage, shaded relief, and any land boundary layers represented with transparent area fill.

		GeoTIFF File Size in Megabytes			
		Derived from US Topo Layers			HTMC map
Photometric/ Compression	Output Resolution (dpi)	Contours and hydrography	Traditional line map	Orthoimage	
RGB/LZW	600	30	50	514	395
	400	16	30	232	184
RGB/JPEG	600	85	63	92	70
	400	27	36	49	38
YCBCR/JPEG	600	18	25	34	27
	400	10	14	18	15
RBG/Packbits	600	82	222	460	620
	400	32	103	205	276

Appendix D. Finding USGS GIS data

As noted in the introduction to this paper, US Topo maps are outputs of GIS. They are a repackaging of GIS data for non-specialist map users, and were not intended to be GIS inputs. Before going to the work of reversing this process and making GeoTIFFs for GIS uses, consider USGS products designed for GIS use. Web services (point 2 below) can be especially convenient for accessing GIS-friendly base map data.

Following is a summary of distribution interfaces for all data products of the USGS National Geospatial Program. US Topo and HTMC maps are not GIS data, but are included for completeness.

1. *The National Map* Viewer and Download Platform (http://nationalmap.gov/viewer.html) is the primary interface for all data of *The National Map* (http://nationalmap.gov). Many NGP data products can be downloaded through this viewer, but the wide variety of available data makes this application relatively complex. For more about data download through the viewer, see http://www.usgs.gov/faq/?q=taxonomy/term/9852.
2. Data from many of *The National Map* databases are also available through GIS services. See http://viewer.nationalmap.gov/example/services/serviceList.html for a list.
3. Current US Topo topographic maps, and legacy maps in the Historical Topographic Map Collection, can be downloaded through *The National Map* Viewer and Download Platform (point 1 above), or through two simpler interfaces dedicated to topographic quadrangle maps; see http://www.usgs.gov/faq/?q=categories/9797/3571.
4. Individual data themes (e.g., elevation, hydrography, geographic names...) also maintain interfaces to specific products. Go to *The National Map* homepage (http://nationalmap.gov), click on “Products and Services” in the left-side list, and navigate to data theme sites.
5. More orthoimage, elevation, and land cover data are served from the Earth Resources Observation and Science (EROS) Center, including satellite data not served through other interfaces. See http://eros.usgs.gov/find-data for general information. The Earth Explorer viewer (http://earthexplorer.usgs.gov/) is the primary download application. Some archived datasets are also served through Earth Explorer; see the Long Term Archive page at https://lta.cr.usgs.gov/.
6. Bulk data deliveries are also available for some products:
   - For PDF topographic maps (both current and historical) and elevation data, see http://www.usgs.gov/faq/?q=categories/9797/3572.
   - For most orthoimage and land cover data, see http://gisdata.usgs.gov/bulk.php.

For paper maps, books and scientific reports, educational literature, and other hardcopy products, visit the USGS Store (http://store.usgs.gov/) or the USGS Publications Warehouse (http://pubs.er.usgs.gov/). To search for other types of earth science data from USGS scientific disciplines, start at the USGS home page (http://usgs.gov). You can also contact USGS by email or phone (http://www.usgs.gov/ask).