A Color Managed Raw Workflow from Camera to Final Print

The power and control that digital technology brings to photography is drawing more and more photographers to adopt it. The immediacy and spontaneity of digital format are addictive. But digital format is not perfect. Getting accurate and predictable color is still a challenge to many users, and color management is often a source of confusion and frustration. It doesn't have to be that way.

A digital image in a camera (left) and the printed digital image (right)

The goal is to process a digital image from a camera to a final print as efficiently and accurately as possible. This process can be nonintuitive, and the steps are complex, which makes them prone to error. However, that's a far cry from where we were a few short years ago. At least today, the process actually works.

The time has passed when you had to adjust your monitors' controls to have the screen image bear some resemblance to the final output. If you're still doing that, you may need to revisit your workflow because it's like trying to lift yourself off the ground by pulling your shoelaces. Make color management work for you rather than against you. Color management is at the core of Adobe® Photoshop® CS2, Camera Raw, Adobe Bridge, and printed output—you can't avoid it, despite the presence of the Color Management Off setting in Photoshop. There's no way to turn color management off in Photoshop; it always displays images through your monitor profile, and it always makes some assumptions when you request a color conversion. The answer is to be aware of and in control of those assumptions.

The good news is that color management really works. The bad news is that color management isn't as easy as we all wish it were. However, there are steps you can take to make your own workflow less confusing and more efficient. This document is intended to help photographers make accurate prints from their raw captures. For more information about color management theory and practices, see *Real World Color Management* by Bruce Fraser, Chris Murphy, and Fred Bunting.

Adobe

The color management problem

A small amount of theory is necessary to understand color management. If you don't know that there's a problem, it's difficult to envisage a solution, so let's take a glance at the problem color management tries to solve.

Computers are amazing inventions, but they know absolutely nothing about color or tone (or art, truth, or beauty). They're very complicated calculators that juggle ones and zeroes to a specified order; everything we do with computers involves representing things—text, pictures, sound, movies—by numbers. The color management problem stems from the way we typically use numbers to represent color.

We've come to represent the color of pixels by specifying three values: a red, green, and blue amount, making up the familiar red, green, blue (RGB) color model. An RGB image is made of three grayscale images: one records the red channel, a second records the green channel, and a third records the blue channel. RGB color is appealing because it directly relates to the way we capture color through red, green, and blue filters (or their opposites: cyan, magenta, and yellow) and to the way monitors display images that use red, green, and blue phosphors or light-emitting diodes (LEDs). It's simple, relatively understandable, and completely ambiguous to actual color appearance.

Red, green, and blue light combine to make white light.

RGB values are basically control signals that you send to devices such as monitors, or receive from devices such as scanners and cameras. The red value in RGB tells a display how many electrons to send to the red phosphors to make them emit a specific amount of red light, and the red value indicates how many photons passed through the red filter of the scanner or camera to record the signal. The problem is that, like people, each device has its own idea of what constitutes the color red (and, for that matter, green and blue). Different scanners and cameras produce different RGB values when they are confronted with the same original or scene. Different monitors produce different colors when given the same RGB values because scanners and cameras use different filter sets, and displays use different phosphors or LEDs to produce the color.

The first purpose of color management is to render the ambiguous RGB values unambiguous by associating them with a specific color as perceived by humans, that is, *color appearance*. Color management accomplishes this goal by associating a profile with each image. Profiles can be quite complex, but all you need to know about them is that they correlate ambiguous RGB, CMYK, and gray device values with numbers in different systems that are directly based on human perception. These numbering systems have names like CIE XYZ and CIE LAB. The CIE numbering systems specify an actual color appearance (for example, a specific shade of red), so they let the profiles tell the color management systems exactly which colors a given set of RGB values represent.

The second purpose of color management is to match that specific color appearance as the image travels through the reproduction chain from camera, to display, and then to print. You can't match a color's appearance until you know what the color appearance is, so color management's role in specifying color appearance is fundamental.

When photographers shoot film, color management is simply a useful tool—photographers have the film itself as a reference for the intended color appearance. But with digital capture, color management becomes a necessity because without it, you don't know what you've captured.

Color management setup

A computer running Photoshop with a Sony Artisan display and a GTI light box

Color management begins with your monitor. According to the experts, you must have an accurately calibrated and profiled display so that you can have confidence that what you are seeing has a meaningful relationship to your image. If you're serious about digital photography, a monitor calibration and profiling package that includes a measurement device—a colorimeter or spectrophotometer—is essential. So-called calibration tools that rely on the unaided eye may be OK for recreational users of Photoshop, but the human eye's powerful adaptability to different lighting conditions makes it highly questionable for calibrating monitors, where the goal is to return the monitor to the same state each time you calibrate it.

The next step toward color management nirvana is to set the color settings in Photoshop to define how you will handle color and profiles.
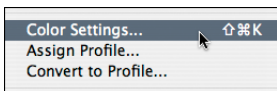

*To set the color settings in Photoshop CS2, choose Edit > Color Settings.*

We suggest that you start with U.S. Prepress Defaults and then change the settings to suit your needs. The U.S. Prepress Defaults settings are better than the NAGP default settings, but they're still less than ideal. For most photographers, we recommend the following changes:

- Change your Gray working space to match the gamma of your RGB working space.

- Deselect Profile Mismatches: Ask When Pasting because you *always* want to paste the color appearance.

- Deselect Profile Mismatches: Ask When Opening. When it's selected, Photoshop displays an alert and presents you with various options when you open an image in a different RGB space from the one you've selected as your RGB working space. Because you haven't seen the image yet, you almost certainly don't have any grounds for making one choice over another. Deselecting the option makes the Preserve Embedded Profiles setting under Color Management Policies dictate the color handling, which keeps the profile that was embedded in the image and uses that profile to display the image.

- Select Missing Profiles. It displays an alert when you open a file that has no profile embedded. When this option is deselected, you'll have to guess how to interpret the color when you open files without embedded profiles, which creates extra work.

By default, Photoshop CS2 comes with its color settings set to North American General Purpose 2.
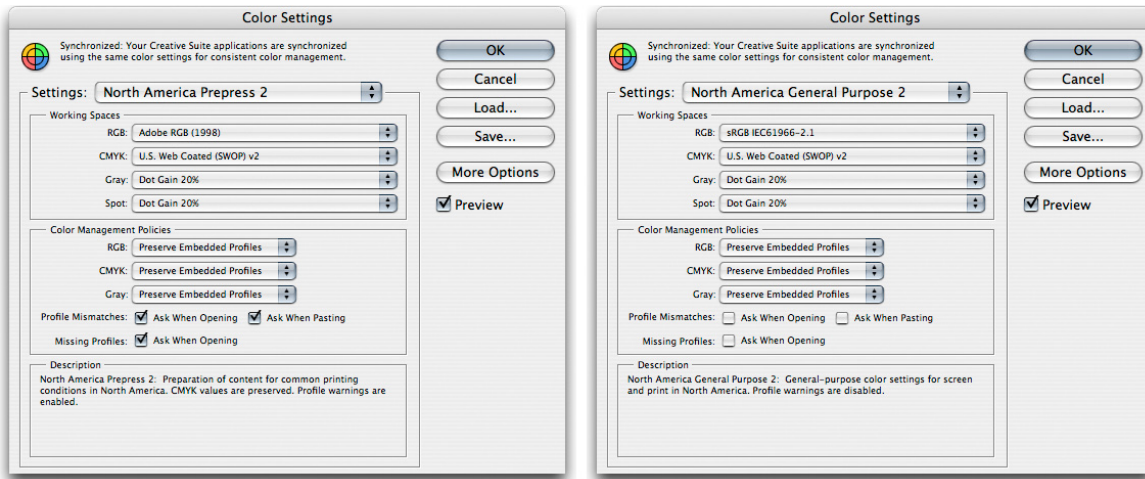

*U.S. Prepress Defaults settings (left), NAGP default settings (right)*
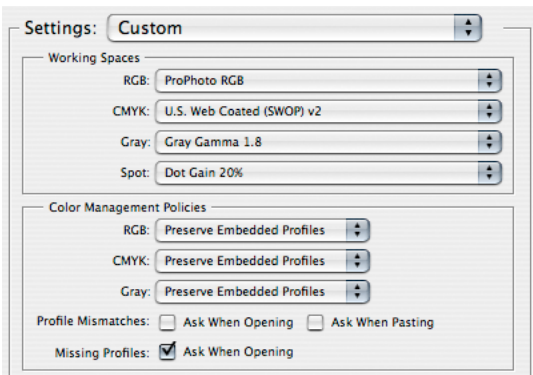
The suggested color settings

Use Photoshop Color Settings to confirm that Photoshop uses the correct display profile by opening the RGB Working Space menu. Your display profile is listed as Monitor RGB - [yourdisplayprofilename]. Don't choose your display profile from the menu; just make sure that the correct profile is listed. Doing so reduces the chance that you'll make judgment errors in color correction later.
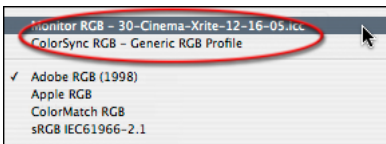
Be sure your display profile shows up on the RGB Working Space menu, but don't choose it as your working space.

After you've changed your color settings, click Save, and then type a descriptive name in the Save dialog box. Photoshop automatically points you to the correct folder for saving Color Settings (.csf) files. If you need to temporarily alter your color settings, you can recover your preferred settings by choosing them from the Settings menu in Color Settings rather than having to manually set each option.
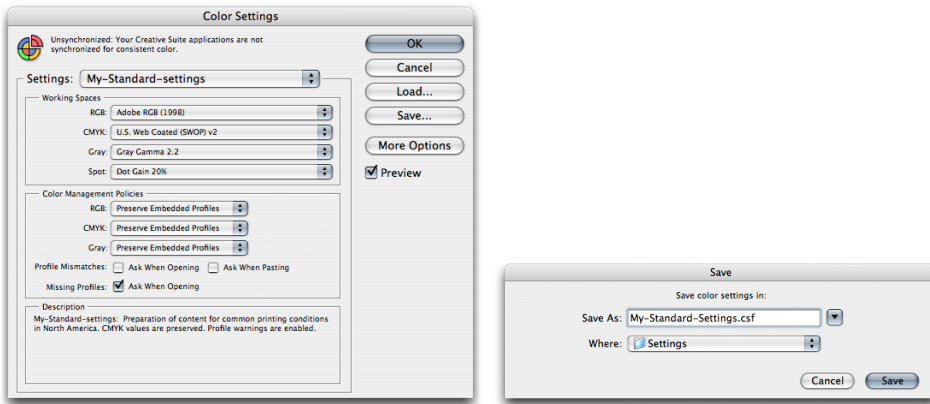
Click Save in the Color Settings dialog box (left) to save your custom color settings (right).

Configuring Camera Raw

After you've changed the Color Settings in Photoshop, you can begin to process raw images with Adobe Camera Raw. One of the best features of Camera Raw is that all of the heavy color management lifting has already been done for you. Camera Raw contains built-in profiles for each supported camera and offers a choice of four different output spaces, listed from largest to smallest: ProPhoto RGB, Adobe RGB, Colormatch RGB, and sRGB.
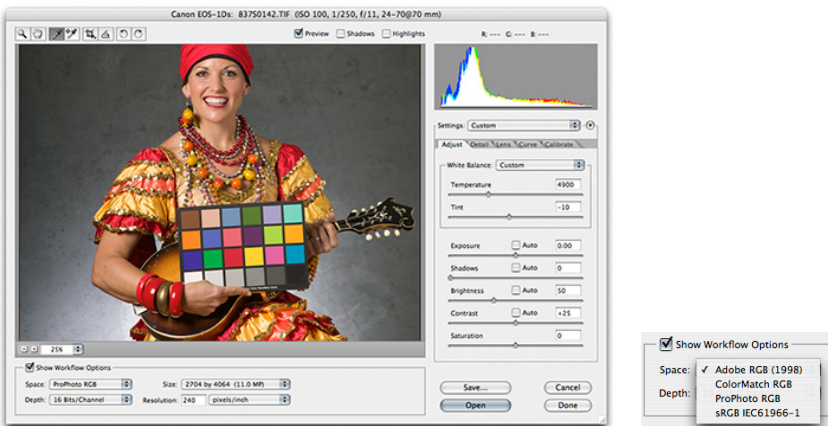

The Camera Raw dialog box and the four output spaces

Camera Raw's image preview and histogram show the results of the eventual conversion from raw to processed image, so rather than relying on expert advice or arcane theory in choosing a color space for output, you can actually see the effects of choosing one space or another right in the Camera Raw dialog box.
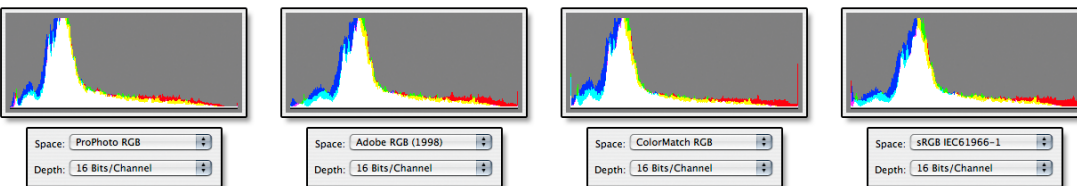
Each output space renders a slightly different histogram.

As you choose different output spaces from the Space menu, the preview might change. The main difference among the four spaces that Camera Raw supports is the color gamut, or the range of color, that they can contain.

At this point, we should put to bed the myth that digital cameras capture sRGB. The truth is that cameras are not limited to capturing a gamut as small as sRGB. Very often, camera sensors capture saturated colors that fall outside the gamut of even Adobe RGB. For some images, if the goal is to maintain the maximum gamut, the only color space that can do so is ProPhoto RGB.

ProPhoto RGB
Adobe RGB
sRGB
4800 Matt Paper
Horseshoe Shape of Visible Color
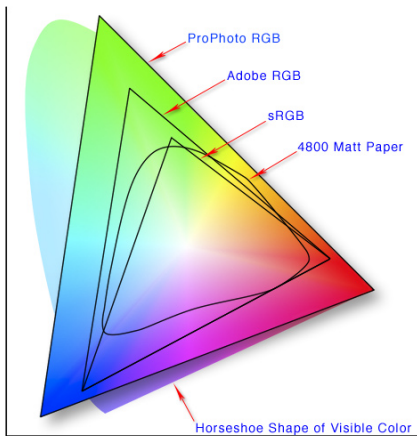
This gamut map of the various color spaces shows that there are colors that can be printed on an Epson 4800 that fall outside both sRGB and even Adobe RGB. ProPhoto RGB can contain all colors that a digital camera can capture–even highly saturated colors. Cameras don't capture and printers don't print in sRGB color space.

The histogram in Camera Raw is a bar graph that shows the relative population of pixels at each tonal level from 0 (black) to 255 (white). White spikes at the right indicate highlight clipping, and white spikes at the left indicate shadow clipping, but colored spikes at either end indicate clipping of a saturated color.

You can see exactly what's being clipped by holding down Option or Alt as you move the Exposure slider (for highlight clipping) or the Shadows slider (for shadow clipping). If what's being clipped is important to keep in the image, you may want to try a larger space. But if you see saturation clipping (as opposed to highlight or shadow clipping) in ProPhoto RGB, you've almost certainly made a saturation boost that is driving the color into science-fiction territory. There's no correct or incorrect decision of when and what to clip because that decision depends on the image and what you want to do with it. So you should use the histogram as a guide to select the output space that does the best justice to the image.
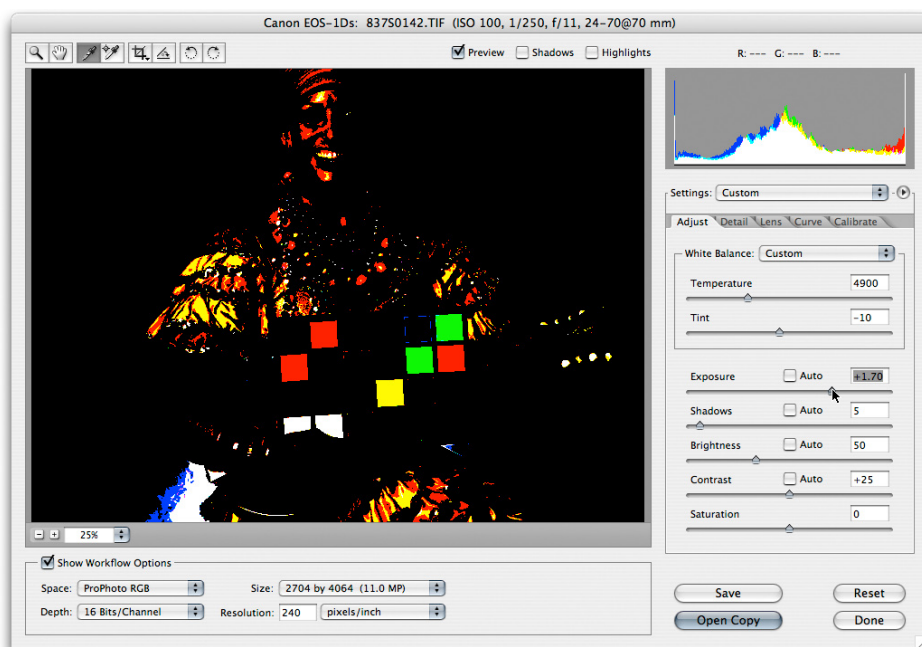
To show clipping, hold down Option or Alt and move the Exposure or Shadows slider.

If you find that you consistently use one space more than the others, it's convenient—but not essential—to revisit the Color Settings dialog box and choose that space as the Photoshop RGB Working Space. Remember to save the new color settings after you've made this change.

To find the RGB space Gamma value, with Advanced enabled, choose Custom RGB from the RGB Working Space menu. The initial settings are based on the current RGB space, so you will find the Gamma value in the Custom RGB dialog box. Don't make any changes; just note the Gamma value, click Cancel, and then change the Gray Working Space value to match your RGB space Gamma setting.
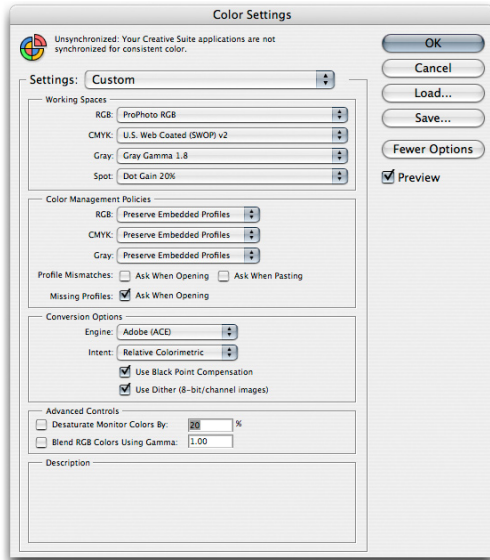
To choose ProPhoto RGB as a Photoshop Working space, click the More Options button in the Color Settings dialog box to display the advanced options shown above.

Camera Raw has one limitation that Photoshop doesn't: All Camera Raw adjustments are global. The image parameters you choose are applied to all of the pixels in your image. You can't make selective adjustments to parts of the image. So the goal of any image adjustment in Camera Raw is for you to get an optimum overall image adjustment, and then make any localized image adjustments to postconversion processing in Photoshop, where a broad range of selection techniques is available.

When you open a Camera Raw-processed image in Photoshop, you are presented with a globally optimized image. Depending on your image's needs, your own desires, and aesthetics, you may decide to make more image adjustments or decide to leave the image alone. However, as far as color management is concerned, you're only halfway finished.

Previewing prints

If your final intent is to produce a print, the next steps will either be extremely difficult or lead to a satisfying and predictable result. We hope that this document nudges you toward the latter outcome.

The marketing-driven view of color management is that its goal is obtaining a color that is WYSIWYG (what you see is what you get). The truth of the matter is that no printing technology can reproduce the bright, saturated colors your monitor can display. (Though it's equally true that print can reproduce colors that your monitor can't display, such as metallics and fluorescents, and more importantly, dark saturated colors, particularly in the yellows, oranges, greens, and cyans.)

Photoshop has the incredibly useful capability to use a printer profile and alter the display to accurately represent what your final print will look like (usually referred to as soft proofing). To use this capability, choose View > Proof Setup. When you soft proof, you choose the exact printer profile, the rendering intent for the conversion, and the way you want Photoshop to display the soft proof. You can also turn the preview on and off to toggle between the original image and the simulated print.
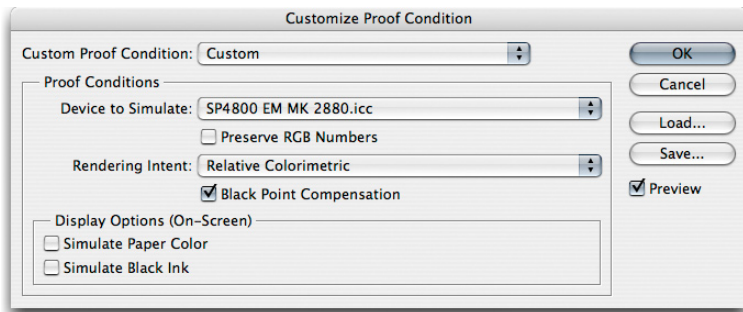
The Customize Proof Condition dialog box

This deceptively simple dialog box contains a lot of power, so it's worth taking the time to understand what each setting actually does.

The Proof Condition options let you choose the profile for the print process you want to simulate, which may be a profile from a photo printer on your computer to a printing press on the other side of the planet.
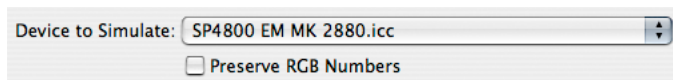
Choose your printer profile from the Device To Simulate menu.

The Preserve Color Numbers option is available only when both the image and the selected printer profile share the same color mode—for example, an RGB image and an RGB printer profile or a CMYK image and a CMYK printer profile. This option shows you the outcome if you send the image with no conversion to the printer that has the profile you selected. As such, it provides a dramatic illustration of how badly you need color management, but otherwise has little practical use for most photographers.

The Rendering Intent menu lets you choose a rendering intent for the conversion from the image's source space to the simulated print space. You can think of rendering intents as different ways of handling out-of-gamut colors (that is, colors that are present in the source image that the destination printer is incapable of reproducing). For most photographic images, the choice is between Perceptual and Relative Colorimetric, but one of the more useful aspects of the Proof Setup dialog box is that you can see what happens to the image as you choose different rendering intents.
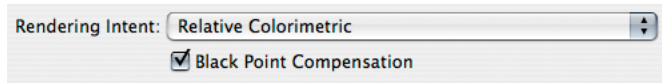
You can change the Rendering Intent settings to fit your image's needs.

The Use Black Point Compensation option is a proprietary Adobe feature that ensures that the source image is converted in such a way that it uses the full dynamic range of the output device. We suggest you always leave this option selected.

All of the aforementioned settings control the conversion from the source image to the simulated print. However, the last two Display options, Simulate Paper Color and Simulate Black Ink, control the way that simulation is rendered to your screen. These options require some care to use them effectively.
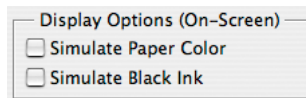
Choose these options to change how the image appears on-screen.

When both Simulate Paper Color and Simulate Black Ink are deselected, Photoshop translates the simulated paper white to the brightest white and simulated printed black to the darkest black that your monitor can display. If you're printing to a bright, glossy photo paper, this view is remarkably accurate, but for lower dynamic range processes, such as watercolor or uncoated rag paper on an inkjet, this view may produce an overoptimistic example of the final contrast of the print.

Select Simulate Black Ink to lighten the shadows to show the literal tone of printed black. Select Simulate Paper Color to show both the literal tone of printed black and of paper white. But when you select these options, Photoshop has to display the simulated paper white as something darker than monitor white and the simulated black ink as something lighter than monitor black, so the image suddenly looks much worse than it did when the options were deselected.

Compared to a high-quality image in Photoshop, the image looks flat and dim, and the colors appear unsaturated. This image is actually a reasonable prediction of your print. Images printed with ink on paper simply can't contain the same dynamic range as an image on a computer's screen. The printed color black is much lighter than on-screen, and the maximum luminosity of the paper white is very dim and often contains a slight colorcast. The trick is to use Photoshop soft proofing to make your image look as good as your paper, ink, and printer can make it.


Soft proofing with Simulate Paper Color and Simulate Black Ink deselected (left) and selected (right)

Here are two pieces of useful advice when using the Simulate options. First, when you select Simulate Paper Color, it's extremely important that you hide any white user interface elements before attempting to evaluate the image. Our eyes seek out the brightest object in the scene, interpret it as white, and judge all of the other colors relative to that perceived white. If you hide the white user interface elements, your eye adapts to the simulated paper white, which lets you see the objects that are on-screen as a reasonable rendition of the image. Second, look away from the screen when you select Simulate Paper Color. By looking away, you see a simulation of the true rendition of the eventual print.
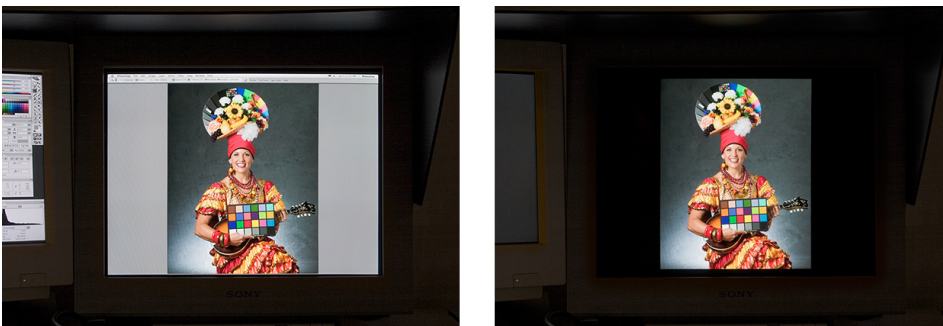
The screen on the left has white user interface elements that interfere with the eye's white adaptation. The screen on the right has the palettes and tool bar hidden (by pressing Tab) and a black background (produced by pressing F twice). You can also click the Full Screen mode button on the Tools palette.

The Proof Setup submenu (choose View > Proof Setup) contains a list of saved settings, so if you find yourself using the same setup over and over again, you can save this setting, and then choose it from the View menu.
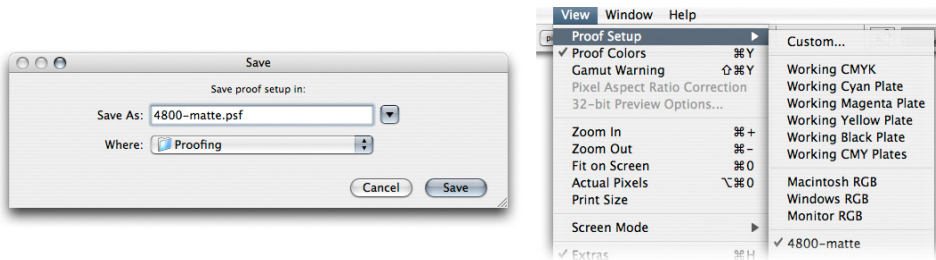

Save a custom proof setup (left) and choose it from the Proof Setup submenu (right).

One of the Proof Setup simulation's greatest features is that the simulation is live, so you can edit the image while viewing the simulated print. To edit the image while viewing the simulated print, duplicate your original image. For the duplicate, keep the Proof Colors option deselected. Move the duplicate next to your original image that has Proof Colors selected, and then compare the two interpretations.

The image on the left is the duplicate. The image on the right has Proof Colors selected.

Generally, you can make some fine adjustments to your image to make it look as good as possible before you actually print it. While the exact correction varies, you'll need to adjust the overall contrast of your image by soft proofing. You may also want to adjust the overall color saturation, and perhaps the precise saturation of specific colors, all of which is relatively easy to accomplish by using Adjustment Layers. Even though you can never make a print look as good as it can look on-screen, you can make substantial improvements over the simple and relatively nonspecific rendering the unaided color profiles offer. The aim is to make the print look as good as it can, before you spend the time, ink, and paper to print it.
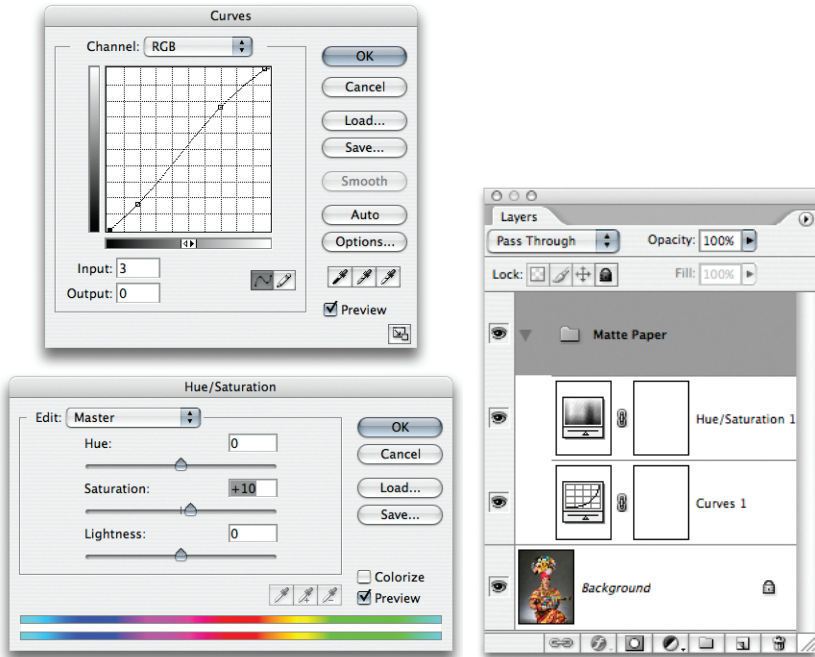
The top left shows a slight increase in the image contrast for an image. The lower left shows a saturation increase for the image. Both of these settings improved the image's rendering. The Layers palette (right) shows a layer group named Matte Paper that contains the two adjustment layers used to correct for the paper on which the image will be printed.

After soft proofing and putting the printer and paper–specific corrections in a layer set (which is useful if you plan to make prints in the future), you're ready to print your image. You can now close your duplicate image without saving it.


The original RGB image (left), and the soft proofed and adjusted image using the Adjustment Layers option (right)

Making the print

You're in the home stretch, but this is where things get tricky. You need to pay close attention to mechanical, but critical, settings when printing. There are about 50 possible combinations of settings, and most of them do not produce good results. The following print path seems to be very reliable, so we suggest you follow it unless you find it doesn't fit your needs.

You should always print from the Print With Preview dialog box in Photoshop. This dialog box offers you the very useful capability of performing the conversion to printer space on-the-fly as part of the print stream, so you don't end up with several images that have been hard-converted to printer space (which makes them less than optimal for any use, other than printing to the print condition for which they've been converted).
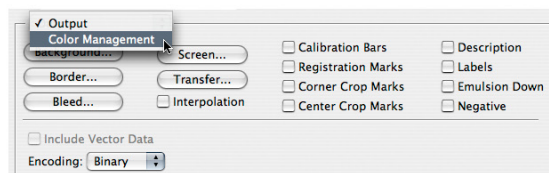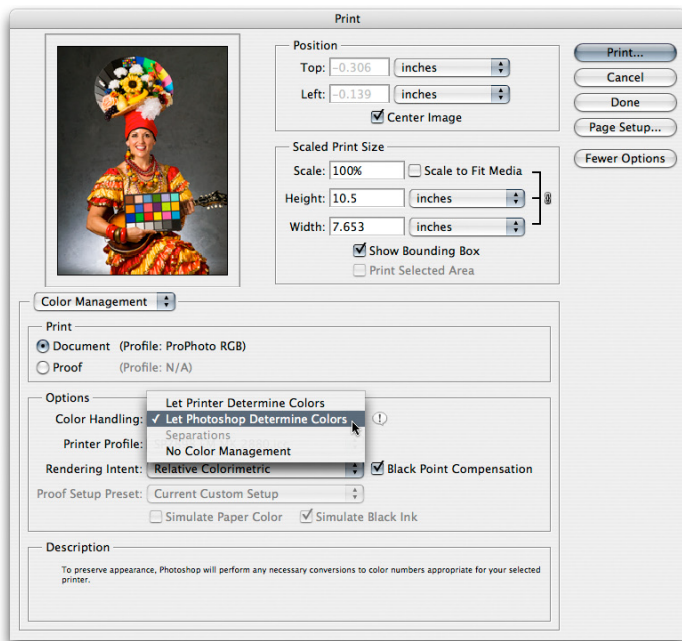

The figure on the left is the main Print with Preview dialog from Photoshop. If you do not see the Color Management options, select Color Management from the drop down menu instead of Output options.

The Print With Preview dialog box allows you to tell Photoshop how to send the image data to your printer. In the Color Management settings, there are critical settings you must make correctly in order to have consistant and quality output. In the Print section, make sure Document is selected, the dialog will show you the current document profile.

In the Options section, you'll see Color Handling. Here it can get confusing, but the odds are good that you want to select Let Photoshop Determine Color. There may be valid reasons and certain situations where you may need to select Let Printer Determine Color or No Color Management. But if you have an ICC profile for your printer, it's generally better to let Photoshop do the heavy lifting with color management.

Next, you need to choose your ICC profile for your printer, paper, and ink combination. Choosing the wrong profile is a common error because profile names may not be very descriptive. After setting the profile, be sure to select the same rendering intent that you used in your soft proof setup. In general, you'll always want to select Black Point Compensation as this maps the black of the image to the black of the output device.

At this point, Photoshop is still in control. Your final step is to configure the printer driver, while keeping in mind that it has no knowledge of what Photoshop has already done, and Photoshop has no knowledge of what the driver will subsequently do. You need to correctly set two very important settings.
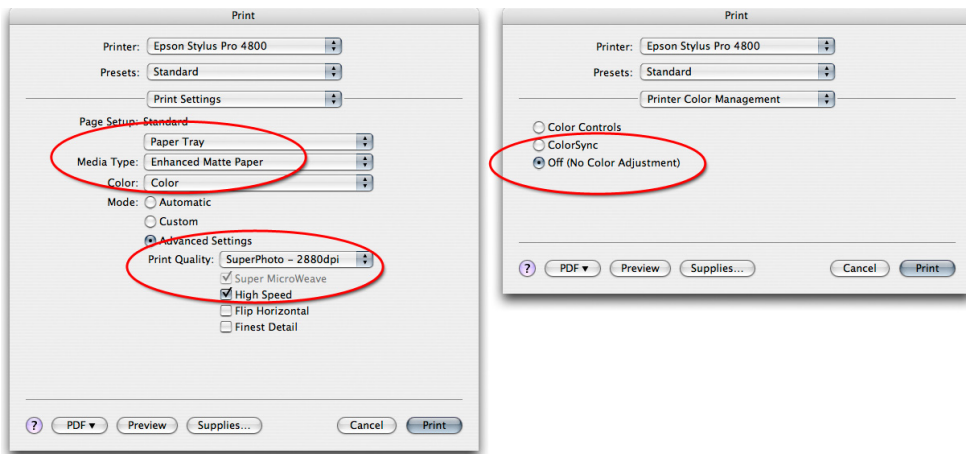

In Mac OS, print settings control media and resolution (left). The color management option (right) lets you select No Color Adjustment for the printer driver.

The first important group of settings is the media type and the associated print parameters, such as print quality and resolution. These settings control the amount of ink the printer lays down, so it's critical that they match both the actual paper stock and the printer profile you're using. Profiles are paper-specific, so using a glossy paper profile on matte paper or vice versa will almost invariably produce bad results.

The second important setting is the color management parameters. If you've used Photoshop to control your color transforms, it's critical that you don't also let the printer driver control them too; otherwise you get a second conversion on top of the one that Photoshop has already done. On Epson printers, the option that disables driver-level color management is No Color Adjustment. Other vendors may use different terminology, but the principle remains the same.

The dialog boxes and the locations of the printer driver settings vary between Mac OS and Windows. The specific settings are consistent across platforms. You need to set the media type and print parameters, and then turn off the driver's color management parameters.
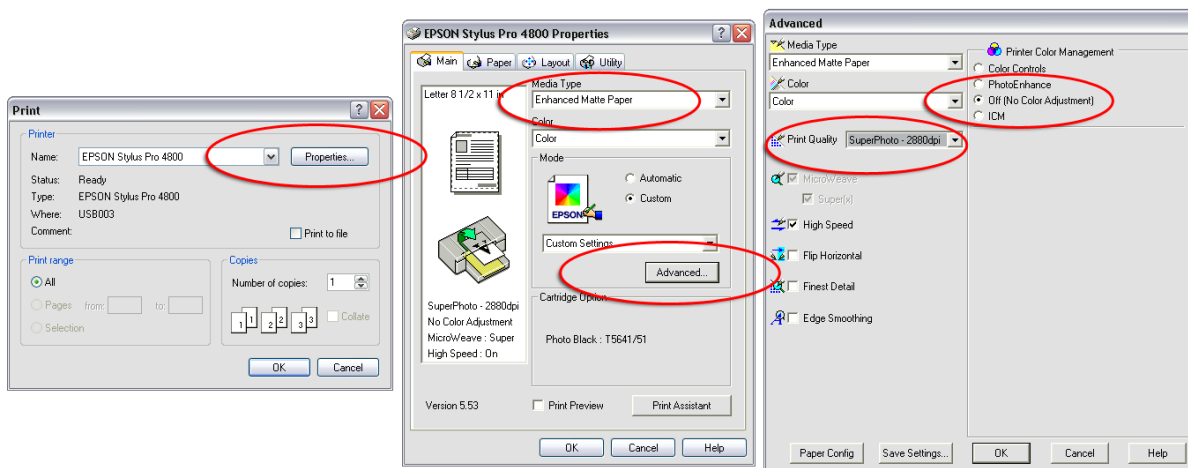
In Windows, click Properties, and then click Advanced. Set the media type and resolution, and select No Color Adjustment for the Windows printer driver.
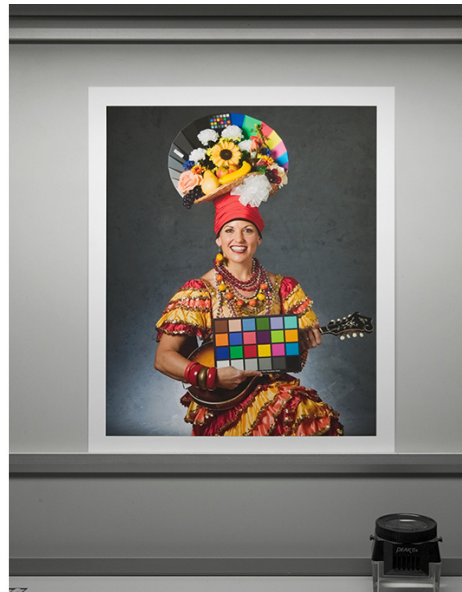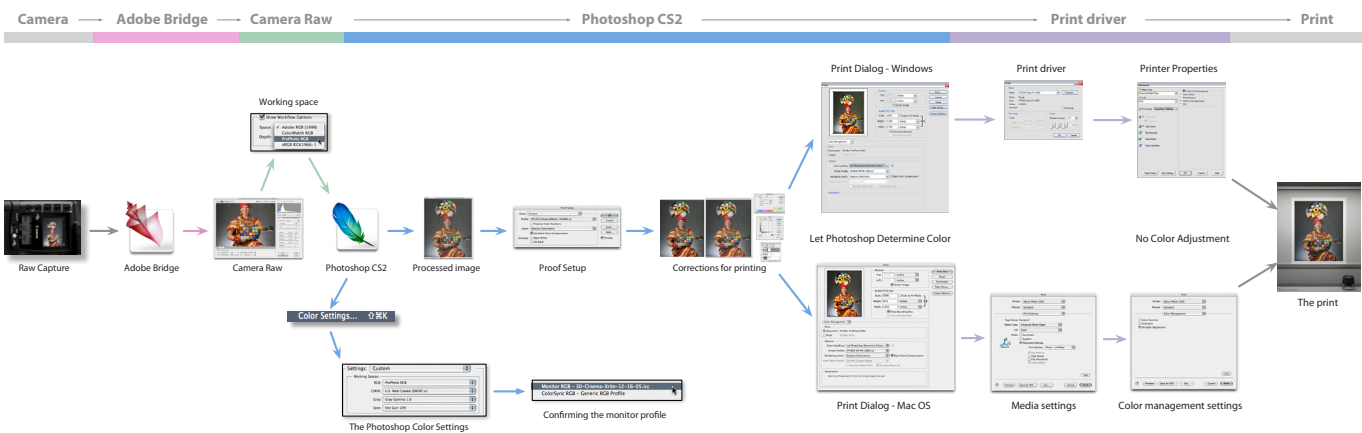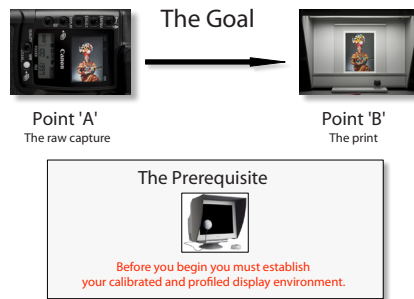
The image on the left is a color-managed screenshot of the actual soft-proofed page. The image on the right is a digital capture of the image printed and displayed on a GTI Daylight light box. Considering all of the iterations and media involved (screenshots and a copy shot of the print), it's a close match.

Now your end print should match the Photoshop soft proof accurately. The potential for error is anywhere, but there are two common errors resulting from improper settings. If your image is overly dark with a greenish cast, it's likely that both the Photoshop color management and your printer driver's color management settings are turned off, which result in no color management being applied. If the print is too light with a magenta or red cast, it's likely that the Photoshop and the printer driver's color management are both turned on. This double color management is very common.

The workflow in a nutshell

The color managed raw workflow

The Goal

Point 'A'
The raw capture

Point 'B'
The print

The Prerequisite

Before you begin you must establish
your calibrated and profiled display environment.

On one hand, using color management in Photoshop and Camera Raw is relatively easy if you precisely follow the correct steps in the correct order. On the other hand, it's quite complicated and has the potential for mistakes at almost every turn. The process will get better. Talented people are working to improve and streamline the process. Until that time though, you have to learn the steps and exert control over the process. The good news is that this process works. You can process an image from camera to print in an accurate, consistent, and predictable manner and achieve a high degree of quality from digital images if you use color management correctly.

Jeff Schewe

Jeff, a summa cum laude graduate of Rochester Institute of Technology, has been an advertising photographer in Chicago for over 25 years. He has been doing digital imaging for over 14 years and is widely known and respected in the digital imaging community as a leading pioneer in the field. Jeff is a feature consultant and alpha tester for Adobe Photoshop.

Bruce Fraser

Bruce emigrated from Edinburgh, Scotland where he escaped the dreary Scottish climes only to discover San Francisco's equally challenging weather. Rumor has it this was the inspiration of Bruce's lifelong fascination with all things relating to color. Bruce has made a study of human vision and how it relates to reproducible color in photography and photomechanical reproduction.