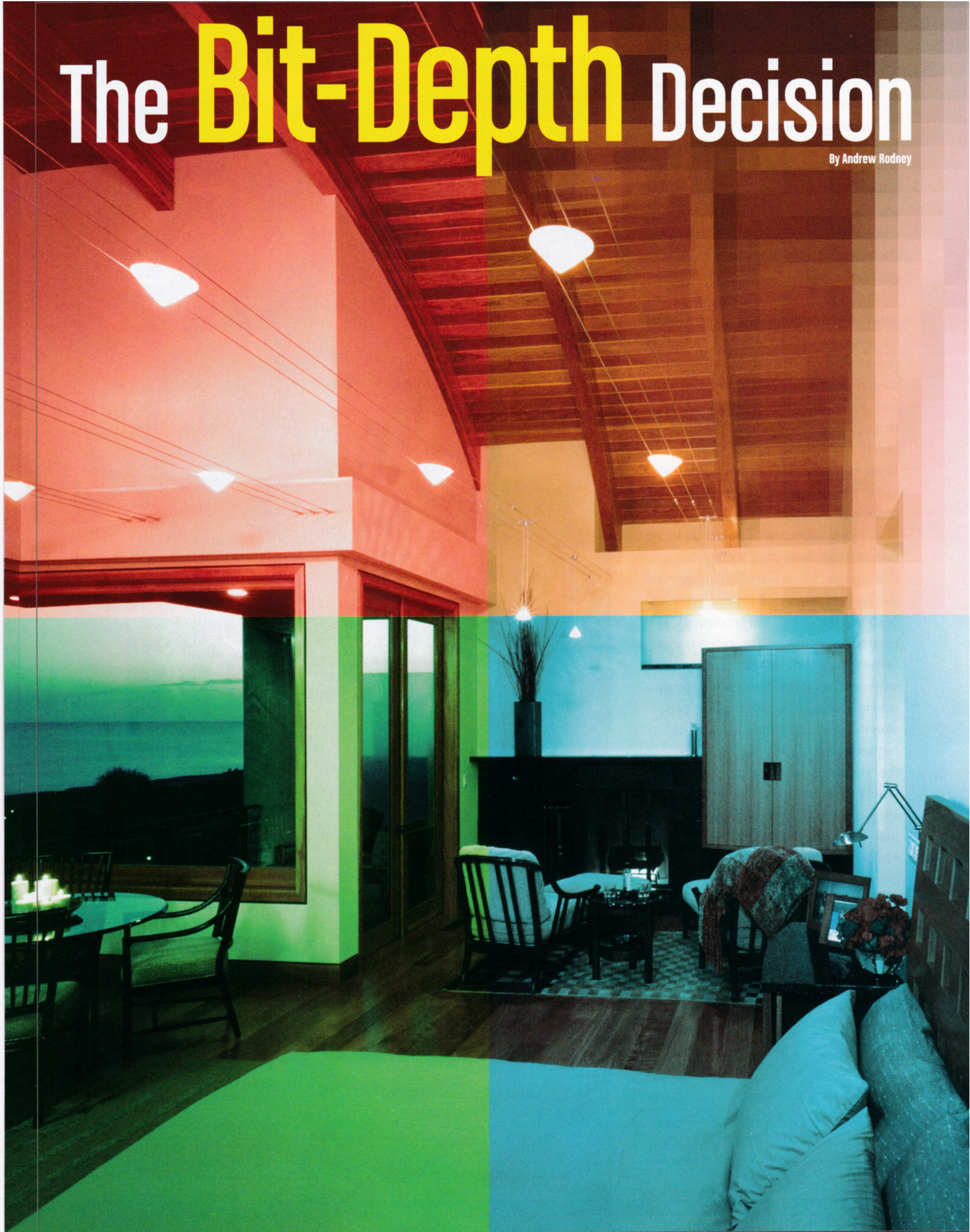
The Bit-Depth Decision

By Andrew Rodney



8-bit versus 16-bit workflow is among the least understood aspects of photography for most professionals. This primer will get you up to speed quickly.

Within the field of photography and digital imaging, a number of debates are argued by users and experts: Nikon versus Canon, Mac versus Windows, zoom versus prime lens, RAW versus JPEG—the list goes on and on. Add to that 8-bit versus 16-bit. What's the difference? Is the controversy useful or viable? After reading our primer, you'll have a better idea about where to stand on the issue.

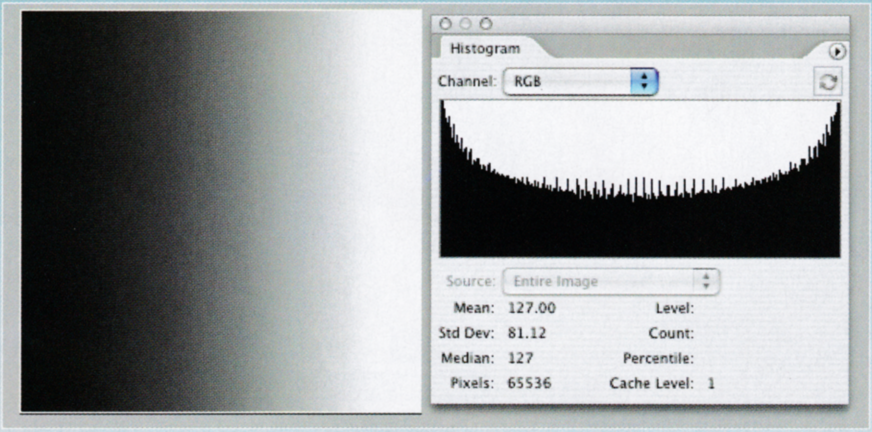


Figure 1 >> **This document is 256 x 256 pixels, with a black to white gradient. The Histogram plots each tone from black to white running left to right. Note its smoothness.**

What Is Bit-Depth?

Digital images are a massive assemblage of numbers. A pixel is merely a solid color or tone defined by numeric values. The earliest computer systems were able to assign a value of 1 or 0 to any single pixel. It was either black or white—a 1-bit file—and was unable to produce a suitable image. What about a 2-bit system? The numeric value can be 00, 01, 10 or 11. This encoding of a pixel could produce four possible pixel densities or shades: white, light gray, dark gray or black—not a very useful system if your goal is to reproduce a full-tone image.

Today, the most common encoding systems use an 8-bit scheme, which allows the definition of 256 shades from black to white ($2^8 = 256$). Research has shown that the minimum number of shades needed to produce a continuous-tone image is in the neighborhood of 250 values. If you have three color channels such as Red, Green and Blue, and each channel uses 256 tones from black to white, you can now create what's known as a 24-bit color image. A three-channel 8-bit file has the potential to describe 16.7 million colors (256 x 256 x 256).

Do we need any more? Yes, and here's why. Anytime you apply an edit to a pixel, you're altering the numbers. The scale of the numbers isn't infinite, and as you move the numbers around, the result is data loss due to rounding errors or what's often called "quantization errors."

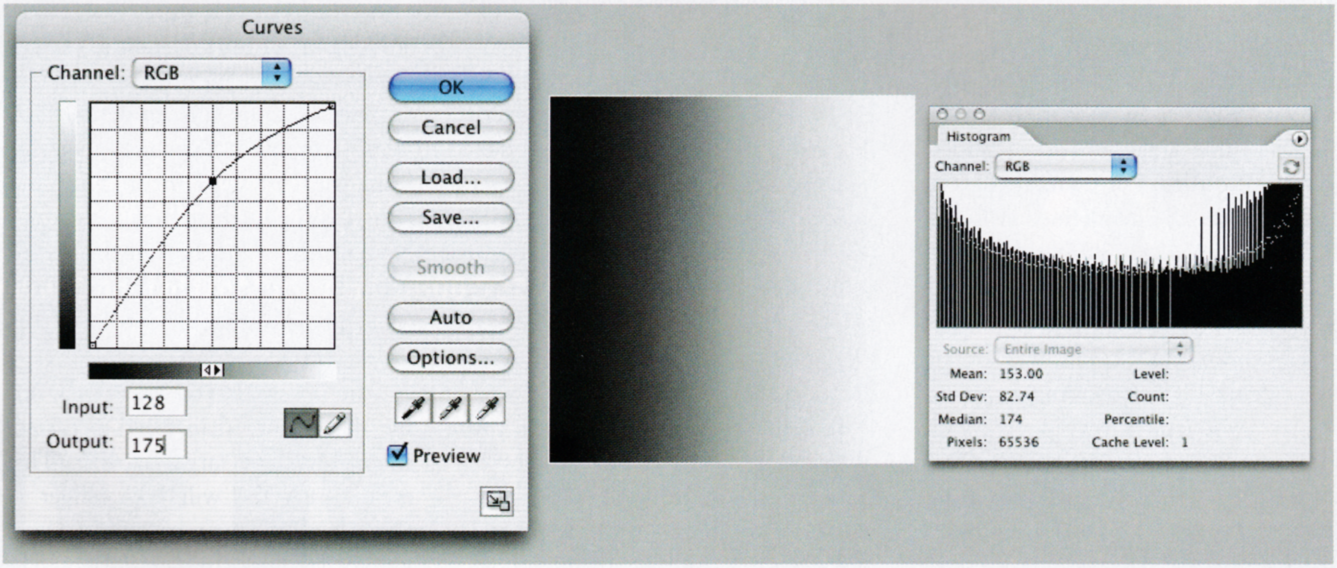


Figure 2 >> **By pulling the curve seen here on Input Level 128 and moving it to Level 175, the result is a gradual lighting of the image over this tone curve. The largest pixel change is here at Level 128. Notice the resulting Histogram. Many original pixel levels to the left side are missing, indicated by the white spikes. On the opposite end, many pixels that originally had a defined and differing pixel value are now sharing the same values.**

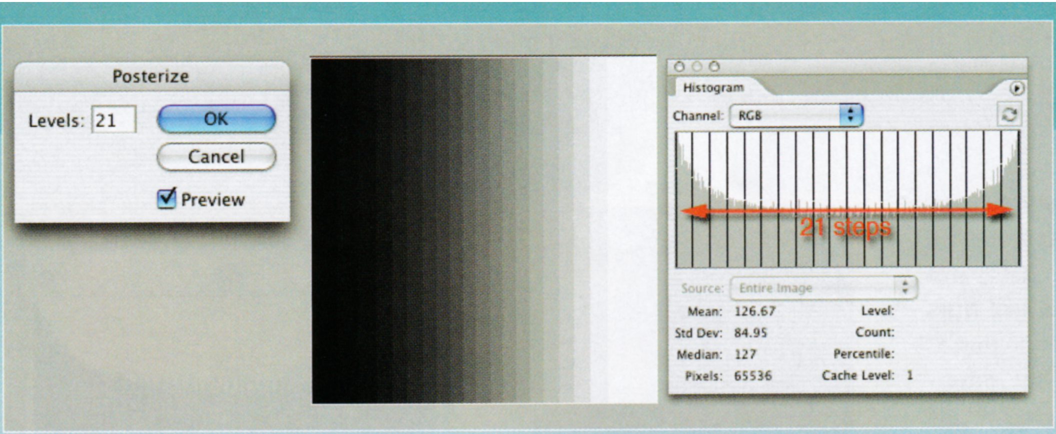


Figure 3>> The Posterize command reduces the entire 256 tones to 21. While the dialog is open, the Histogram shows a "before and after," so to speak. Notice that the "after" is represented by 21 black lines. Hit OK, and that's what the resulting Histogram will show, and those are the tones you'll end up with. Every tone in between those lines is discarded.

Suppose you build a smooth linear gradient in Photoshop from black to white in 8-bit and use one pixel for each value (Figure 1). You'd have 256 tones. Level 0 is used to represent pure black, Level 1 represents the value nearest to that black but just a bit lighter, and so on, going all the way to a pure white at Level 255. The Photoshop Histogram plots these values using a single black line to represent each of the 256 values running left (Level 0) to right (Level 255).

Now you apply a simple edit in Photoshop, say you pull a curve to lighten the image (Figure 2). You change many of the numeric values and their relationship to each other. Multiple and differing levels are now represented by a single value while individual values may be discarded. For example, Levels 1, 2 and 3 are all now defined as Level 1. Levels 128, 129, 130 and 131 may now be represented by a single value, perhaps Level 131.

Depending on the edit, levels may be stretched, again resulting in fewer tones. If you pull a very steep curve in Photoshop, you can see how the image appears to posterize, also known as banding or more accurately, aliasing. In fact, the Posterize command in Photoshop is an excellent tool to see how reducing tones affects smooth gradations and detail. Set the Posterize dialog to 21 on your black to white gradient, and you'll see how the 256 steps are now reduced to 21 steps (Figure 3). The smooth, continuous-tone gradient you built is no longer smooth. If you do make such an 8-bit test file, examine the Histogram before and after editing the image. Notice the white spikes in the histogram after the edit. This represents the tones that were discarded!

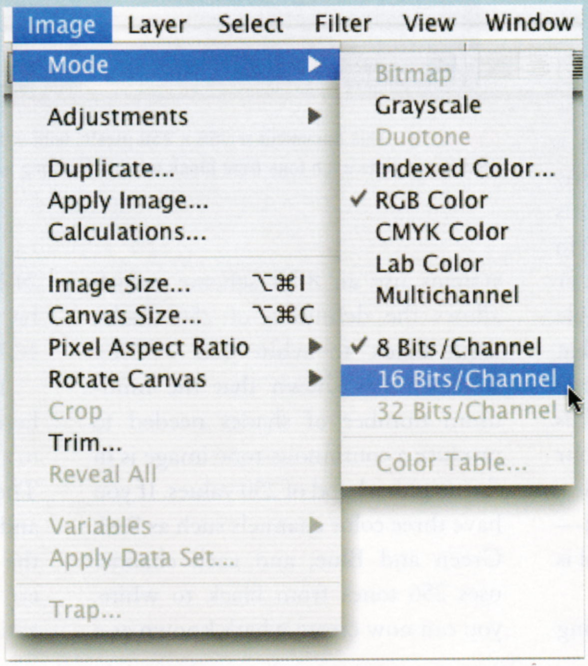


Figure 4>> The bit-depth options available in Photoshop.

In order to improve an image, you often need to change the values of your pixels. The result of editing pixels is data loss, but it isn't something to lose sleep over because on the whole, you're improving the overall look of the image. Ideally, you want to send the best and most pristine 8-bits of data to your printer. Since very few output devices can use more data, the goal is to edit your images without undo degradation. Here's where working with more than 8-bits of color comes into play.

Higher Bit-Depth

Most modern capture devices, such as digital cameras and scanners, collect more than 8-bits per color channel. The manufacturers of these devices do this for a reason. The vast majority of digital cameras can produce 12-bits per channel, while some can capture 14-bits, and a rare few can capture 16-bits per channel.

What's important here is that these devices provide a finer degree of numeric values between pure white and pure black per color channel. A 12-bit file can define 4,096 steps from black to white, a far cry from the 256 steps in an 8-bit file. When you edit these documents, you have plenty of head room due to the extra data provided, so ultimately you can send the best 8-bits per color of data to your printers.

The downside you ask? Well, any file that's more than 8-bits per color channel will be larger in size. That means each file will take longer to process and take up more space on your hard drive. A 50 MB 8-bit file would be 100 MB, or twice the size in 16-bit. Also, prior to Photoshop CS, you had far fewer useful image-editing functions that would operate on documents

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with a bit depth greater than 8-bit. Today, nearly all the necessary image-editing controls in Photoshop work equally on 8-bit or 16-bit documents. Not all third-party plug-in filters can operate in higher bit-depths, which may be an issue in your workflow.

Note that Photoshop lumps all documents larger than 8-bits per color into a single category it calls 16-bit (Figure 4). Your digital camera may produce a 12-bit file, and if you opened this into Photoshop, it would tell you it's 16-bit for the sake of simplicity. For this reason, I prefer to use the term "high bit" to differentiate between an 8-bit file and a file that's higher in bit-depth, which may or may not be a true 16-bit file. The important consideration is that you have more than 8-bits of data with which to edit your documents so you have more editing headroom today and in the future. If you must know, Photoshop is really operating on 15-bits of data, but we don't need to go there.

Is High-Bit Worth It?

So what about the bit-depth debate, you ask? There are those who would say that there's no need to work with more than 8-bits per color since all output devices will only accept this amount of data. First, this isn't necessarily true. While you probably won't encounter too many output devices that can accept this additional data, they do exist. In fact, if you were to use the ColorByte ImagePrint RIP driving many of the Epson printers, you can send and use the full 16-bit data path.

Will you see the difference? It depends on the image. In fact, many of the naysayers suggest high-bit workflows are a waste of time because, they say, the benefit of this additional data is never seen on the final output. This depends upon the final output source, though. Examine a halftone dot from any four-color reproduction device and compare that to the dither of a really good inkjet printer. Under a loupe, you can see how the halftone dot can obscure detail that the inkjet could easily resolve. Take an image that has very fine gradations of saturated color, such as a blue sky, and you may see banding from a better output device. Much of that banding could and often is the result of editing the file in 8-bits to the degree that, much like the black and white gradient discussed, the fine tones are discarded.

That's one of the problems with an 8-bit workflow. You never know for sure where any image may be reproduced nor do you know for sure how the file may be edited. Note that when printing your high-bit images out of Photoshop, there's no reason to convert the file to 8-bit because using the Print with Preview command will do this for you on the fly.

On the other hand, say you're shooting 500 widgets on a white seamless that will be printed on a 133-linescreen press for a parts catalog. The final size of all images is 2x2. Is it prudent to work in a high-bit workflow where each image is twice the normal file size and you'll never output the documents again? Probably not, but it's your call.

What if the image you captured is so stunning that you plan to include it in your portfolio or sell it as a large fine-art print? Discarding the additional data your camera was able to record would be ill advised. You don't know where you'll reproduce that image in the future nor on what output device. If you examine the recent history of desktop printers, in just a few years we've seen an amazing increase in image quality, color gamut and fine reproduction detail (dithering). Imagine the quality of digital printers we'll have at our disposal in just five years. Does it pay to discard data that may be useful in the foreseeable future?

Bit-Depth And Gamut

Another area where you want to implement a high-bit workflow is when you use very wide-gamut working spaces. For example, many photographers are moving from Adobe RGB (1998) to wider-gamut spaces like ProPhoto RGB. This is because as cap-

ture devices and printers improve, so does their ability to capture and reproduce wider-gamut colors. The new Epson K3 inkset is capable of exceeding the Adobe RGB (1998) color gamut.

If you utilize a wider-gamut working space, you want to use more bits and here's why: The wider the gamut of a color space, the farther apart each bit is from its neighbor. Imagine you have a file in sRGB, where the 16.7 million possible colors are represented as dots painted on a balloon. As the gamut of the working space increases, consider what happens as the balloon is inflated. The space between each dot also increases. When you attempt to define 16.7 million possible colors in a small color space like sRGB, the bits are close to each other. But as you work with progressively wider-gamut color spaces, the bits are spread farther apart, just as the dots move away from each other as the balloon is inflated.

Editing the file in an 8-bit wide-gamut space increases the likelihood of banding. If you instead work with a high-bit file, you have more data between the original bits, so as you edit the file, the total data loss isn't as great. Bottom line: if you're working with a color space as large or larger than Adobe RGB (1998), seriously consider working in high bit. The same pundits who suggest we don't need to work in high bit often tell us that we don't need to work with a color space larger than sRGB, despite the fact that our capture devices and most of our output devices exceed this color gamut.

Again, do you want to capture and reproduce all the colors at your disposal or do you feel comfortable throwing away data? It's your data, so it's your call, but I don't see the logic of painting yourself in a corner with your data. Being informed about the issues surrounding a high-bit workflow makes it easier to make these kinds of decisions, just like evaluating how best to handle that 500-widget photo shoot or whether or not to shoot RAW or JPEG for any particular assignment.

Bit-Depth And File Formats

Speaking of JPEG, be aware that this file format doesn't support high-bit data, only 8-bit. So if you're concerned about getting high-bit data out of your D-SLR, you have to shoot RAW. Many users recognize that Photoshop can convert an 8-bit file to 16-bit and wonder if that provides any advantages. Unfortunately, no.

If you started with a high-bit file and converted to 8-bit, the additional data is thrown away; you can't get it back. The reason Photoshop allows such conversions are situations where you might build a composite and paste an 8-bit image into a 16-bit image. This can't be accomplished unless all the documents have the same bit-depth (and for that matter, the same color space). So while you can convert from a lower bit-depth to a higher bit-depth, unless you're doing this kind of composite work, there's no real benefit in doing so. Much like starting with a high-resolution file, if you interpolate it down and then interpolate it up to the original size, you don't have the same original data.

Go With What Will Work For You

Ultimately, how you wish to process your data from capture to output is up to you. While there are those who say they've never seen any advantage to working in high bit, the math is undeniable. Altering pixel values results in data loss, but there's no way to predict if and when that may manifest degradation upon output. A high-bit workflow ensures this is unlikely to ever happen today or in the future. Note that for some users, even a 16-bit workflow doesn't provide enough bits. And note that in Photoshop CS2, you have the option to work with 32-bit documents. For most readers, this isn't a necessary option and is really for those working in HDR (High Dynamic Range) capture, a new and emerging technology. The point is that when this kind of capture is available in more digital cameras, be prepared to work with ultra-high-bit data documents. DPP