Appendix B:

Scanning and Printing
Scanners and printers play an important role in the quality of the image you create with Color It!. This section provides background information to help you improve the quality of your Color It! images.

Basic Terminology
Resolution: The resolution of an image is correlated to the number of pixels in the image. As the number of pixels used to create an image increases, more detail becomes apparent. When images are scanned at higher resolutions, the computer image is closer to the appearance of the original image.
DPI (dots per inch):   The dpi of a scanner or printer refers to the number of dots scanned or printed in a square inch. While scanners and printers are available in a number of common dpi, 300 dpi will be used for the examples in this section. A dpi of 300 means that each square inch of an image is broken into 300 rows and 300 columns, creating a total of 90,000 cells. While scanners and printers both use 300 dpi as a reference in image production, there are significant differences between an image scanned at 300 dpi and an image printed at 300 dpi. The reason for this is that a scanner records the information in each of the 90,000 possible cells as gradients from black to white (gray levels). A printer, however, reproduces each of the 90,000 cells as either black or white.
Gray Levels: The differences in the appearance between scanned and printed images can be varied by changing the scanner setting. The scanner setting limits the number of gray levels used to define an image. In black/white mode a scanner stores 2 gray levels (black and white). In 4-bit mode, a scanner stores 16 gray levels, and 8-bit mode stores 256 gray levels.
Halftones and Dithering: Because a scanner can store information in up to 256 different levels of gray and a printer can reproduce that information in only two levels of gray (black and white), halftones are used to improve the printed appearance of images created with many different levels of gray. Traditional halftones are created by photographing an image through a special screen made up of tiny holes. Laser printers produce halftones using a process called dithering.
Dithering creates a halftone by grouping two or more dots together to form a halftone cell. The manner in which these dots are distributed is called an array (4x4 and 8x8 are common arrays). The percentage of black dots in any given cell determines the percentage of gray represented by that cell. By placing halftones cells at even intervals, the printer creates an illusion of shades of gray.
LPI (Lines Per Inch):   Lpi refers to the number of halftone cells per inch, which is directly related to the quality of the halftone produced.
Newspapers generally use 65 or 85 line screens while magazines, which

produce more realistic looking photographs, use 133 or 150 line screens. The halftone screens used for computer images are a function of the array for each halftone cell. Increasing the size of an array enlarges a halftone cell and increase the number of gray levels in an image, providing better shading. Resolution, however, is reduced.

Scanning Fundamentals
Scanners and video digitizers convert images to numbers that the computer uses to recreate the image. The numbers that define the image for the computer are organized into cells called pixels. Each pixel contains information on the brightness, darkness or color.
There is a difference between images captured with a scanner and those captured with a video digitizer. A scanner captures the image in segments that are then combined to recreate the image. A video digitizer captures the entire image as a whole.
Memory Requirements of Scans
While increased resolution may improve the clarity of an output image, it also increases the size of the image data file.   For example, scanning a 4x5 image at 100 dpi generates data for 200,000 pixels ([4x100] x [5x100]). Scanning that same image at 300 dpi generates data for 1,800,000 pixels ([4x300] x [5x300]).
Although it's better to scan gray scale images at lower resolutions to keep the data file to a manageable size, once an image is scanned, lost image details can never be recovered. Factors to consider before choosing a scanning resolution are:
•
The detail in the image.
•
The resolution of the printer you are using.
•
The final size of the image once it's printed.
•
The distance the viewer will be from the image (lower resolutions can be used for images viewed from a greater distance)
Storage requirements are not simply a calculation of the number of pixels. The pixel depth, in bits per pixel, is also important. Pixel depth stores data on the tone (or color) of each pixel. The number of bits per pixel tells you the maximum number of shades of gray or color. For example, if you scan a photograph at 4 bits per pixel, the image is displayed as 16 shades of gray. If the original photo had more levels of gray, then the extra information would be lost in the scanning process. The following table shows the relationship between the number of shades of gray or color and the bits per pixel.

Bits per pixel
Number of Colors

1 (line art)
2

4
16

8
256

16
65,536

24
16,777,216
The larger the number of colors or grays in the scanned image, the closer you can reproduce the quality of the original. It also quickly increases the size of the file.

To calculate the final file size of a 4 x 5 image at a given bit depth, you must multiply the number of pixels by the number of bits. While this number is useful, it is often converted to more common units of kilobytes (k) or megabytes (mb). (Please see the following table for the conversions).

Common Conversions used in scanning

1 megabyte (mb)
1,000 K, 1,000,000 bytes,

8,000,000 bits

1 kilobyte (k)
1,000 bytes, 8,000 bits

1 byte
8 bits
The memory needed to store a 24-bit, 4 x 5 photo scanned at 300 dpi would be 5.4 megabytes. An 8-bit version of the same image would only need 675k. From the above calculations, it becomes obvious that as the scanning resolutions and bits per pixel increase, the computer storage increases rapidly. Files may become so large that just a few images may fill the entire hard drive. Another problem with these images is that they contain so many pixels, that doing an image enhancement filter may take minutes instead of seconds to complete.

Scanners
The current generation of scanners scan at rates between 50 and 1,200dpi

for color or gray scale images as well as text. With the wide range of possible scan input, how do you calculate the best scan resolution?

A few helpful hints for scanning images.

Contrary to popular belief, higher scanning resolutions are not always better. If you are scanning color photographs, a high resolution may have little or no effect on the final printed image.

The scanning rate for a color image should not exceed twice the output screen frequency. If you use a 150 line halftone screen, it's pointless to scan the photo at more than 300 dpi. The printer will not use the extra information. For most printers, you may only want to scan the image at the next higher setting than the screen frequency you are using. For example, on a Personal LaserWriter™ where you use a 65 line screen you need only scan at 75 dpi. A spatial resolution greater than 150 dpi does you no good. The extra information will not be used by the printer. When using a high resolution imagesetter (>1,200 dpi), you should use a spatial resolution of 200-300 dpi (grayscale images). If the image is not very detailed, you will also be able to scan at a lower resolution and get acceptable results.

The number of gray levels or colors that the image is scanned at affects the output. You should generally scan the image at the highest possible bit depth. The more shades of gray or color you have, the closer the image matches the original. Higher bit depths give you more precise control over filtering and image manipulations. This rule also holds true for laser printers not capable of printing 256 levels of gray. The following table gives scanning recommendations.

Image type
Bit depth

line art, text
1

B&W photos, halftones
8

color photos
16 , 24

Remember, the printer cannot produce more gray levels or colors than are in the original scanned image (if you scan at 64 gray levels, you can't print 256 gray levels).

Scanning categories

Placing a document in the scanner, setting a resolution, and scanning an image is easy. The challenge lies in producing top-quality scanned images that resemble the original as closely as possible and line art that is crisp and clean.

Images usually falls into one of three categories:

1.) Line art, including text and technical illustrations

2.) Gray scale/Color, such as black-and-white or color photographs
3.) Halftone images, which may appear in magazines or
the newspaper

Scanning Line Art
Line art is the easiest type of image to scan because it contains limited gray levels. Though line art usually brings to mind images of schematic drawings, line art originals may also include solid shapes (such as a company logo), patterned backgrounds or text. When scanning these images it is important to make sure the original is as "clean" as possible. Flaws are faithfully reproduced during the scanning process.
Scans of images with flaws or originals printed on colored paper can improved by adjusting the scanning threshold. The threshold is the level at which the scanning software determines whether a pixel is black or white. Setting the threshold level lower results in a darker image because more pixels are recognized as black. A higher threshold results in a lighter image. For line art, you get the best results if you scan the image at the same resolution as your printer. On a 300 dpi LaserWriter™, for instance, try to scan the image at 300 dpi.

Scanning Gray Scale/Color Images
Gray scale/color images are more difficult to scan. Most gray scale/color originals are photographs. Photographs with a good balance of grays/colors scan better than other photographs.
If the photograph you are scanning is imperfect, it is still possible to get good results. The Brightness and Contrast controls can be adjusted to compensate for such flaws in the original image as folds in the paper, streaks, tinted backgrounds or other background noise. The Brightness control makes your image lighter or darker. Setting the brightness too high washes out some detail in your image while setting it too low darkens features so much they may be unrecognizable.
For example, if you have an original picture of a group of people at a company picnic that is underexposed, increasing the brightness can make the scanned image lighter. This will wash out some of the detail in the photo, which can be corrected by increasing the contrast to sharpen the difference between dark and light elements in the photo.
Experiment with different settings to achieve the best possible scan.

Scanning Halftones
Most halftones are pictures that have been printed in a newspaper or magazine. Halftones present a problem when scanning because the halftone is a screened image. Scanning a halftone is, essentially, screening a screened image (i.e. using dots to create a representation of an image that is itself a dot representation of an original photograph). Since traditional halftones place the dots at some angular rotation, scanning the image (which creates a pixel map that is also a screen-like pattern) can create what is

called a "moire" effect. (The interference pattern created at the intersections of the two screens.)

While it is best to to avoid scanning halftones whenever possible, the quality of scanned halftones can be improved by using the following suggestions.

- Scan at a lower resolution than normal. The scanner may read a halftone dot pattern better at a lower resolution than it can at a higher resolution.

- Scan the original at an angle. Place the original on the scanning surface at different angles to reduce the moire effect.

- Use color halftones. If you have to must use a halftone, remember that color halftones scan better than black/white halftones. This is because color halftones have a more complex pattern of dots that causes less interference with the scanner pattern.

If none of these suggestions improve the moire pattern in the image you are trying to scan, try scanning the image at a much higher resolution and using the Resample feature in Color It!. This will average the values of a square group of pixels, which often reduces the moire effect.

Maximizing Halftone Resolution Output At 100%

The following formula calculates the maximum halftone resolution possible based on the maximum resolution (DPI) of your printer and the number of gray levels desired.

For example, if you have a 400-dpi printer and you want 64 levels of gray in your printed image, the maximum halftone resolution you can achieve is 50 lpi (400 divided by the square root of 64(8) equals 50). Here, you should scan at a resolution of 50 dpi or slightly higher.

Unless you use a high resolution output device such as a photo-typesetter, printing a halftone results in a trade-off between resolution and the number of gray levels.

Maximizing Halftone Resolution Enlarged Or Reduced For Output

If a halftone is printed in a size other than the original halftone, the effect on the resolution of the halftone must be considered when adjusting between resolution and gray levels. For example, if your printer's resolution is 300 dpi, a halftone with a resolution of 75 lpi produces 16 gray levels (300 divided by 75 equals 4—and 4 squared is 16).

Calibrating Your Printer

Calibration of printers can play a significant role in output image. It is possible to significantly improve your output results by calibrating the printer for both Error Diffusion output and normal PostScript™ output (Error Diffusion images are generally much blacker than normal PostScript™ images). The are a number of ways to calibrate a printer. When choosing a calibration method, remember that screen resolution affects the calibration curve.

The following methods may be used to calibrate a printer:

1)
Gamma Adjustments: Create a new image with a gray scale gradient from black to white. Print this gradient out. The image should show a smooth transition from black to white. In many cases, this will not be the case. To correct for these effects, open the Levels dialog, adjust the Gamma, and then print the image a second time. If the image does not look right, undo the filter and repeat this procedure until your printout has the proper appearance. You must always undo your filter between each step since filters can be additively applied. If you did not do this, after a few attempts your calibration curve will be meaningless. When the printout looks right, save the curve.
2)
Grayscale Image Adjustments: Do the above operation with a grayscale image. You will get best results if you first filter the file to get a good image on the screen.

Calibrating Scanners
Calibrating a scanner can also greatly improve the appearance of an image. By creating a custom calibration gray map for a scanner, you can automate process that requires 4 or more steps.
The following example will describe how to calibrate a scanner using a step wedge.
Calibration can be done manually, but for better results buy a 12-step calibrated grayscale step wedge. Step wedges have gray levels ranging from pure black to pure white. For best results scan the wedge at around 72 dpi. A 12 step wedge has the following densities:

Step
Value
Scanner Value

12
0

11
23

10
46

9
70

8
93

7
116

6
139

5
162

4
185

3
209

2
232

1
255

(Y value)
(X value)

1.
Scan the wedge.
2.
Use the Dropper tool and the Colors palette to click inside each step and read an average gray level (place the results in the Scanner Value column).

3.

Once you have filled in the table, open the Image Maps palette.

4.

Using the Line tool draw straight lines from x=0, y=0 to the x,y value for step 12.

5.

Next draw a line from this point to the x,y of step 11. Repeat this for all steps. As you draw these connecting lines, you are creating a calibration curve for the scanner. When you have completed this curve save it as a calibration map.

6.

To check your results, scan the wedge again, apply your new map, and check the values of the gray levels. The values from the scanner should now correspond closely to those of the step wedge. If they do, you have a correct map. Now whenever you scan a grayscale image, apply this map before you try any other filter.