Depth-of-Field for Smarties - Full

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This little e-book is about Depth-of-Field, something everyone who wants to master the art of photography needs to know. I added the 'for Smarties' because Depth-of-Field (from here on, DOF) is more complicated than it appears, and many explanations I have seen are wrong.

Some photographers want shallow DOF in some of their images. Wide open lenses and long focal lengths get that result easily. But for landscapes, I want sharp focus from the nearest objects out to the horizon. Achieving this is source of frustration when it fails … and it usually fails because of the complexities of DOF and 'shallow' explanations. I hope this document solves this issue for you. It can be simple!

Introduction

This e-book briefly covers ISO, shutter speed and then DOF in depth. DOF is related to aperture, one of the three settings for exposure: **ISO**, **shutter speed** and **aperture**, the components of the 'Exposure Triangle'. Obtaining deep DOF for landscapes may require that you adjust Iso and shutter speed to achieve proper exposure for the desired aperture (f/stop). Note that these settings are each related to one of three physical things: the film or photosensor, the shutter and the lens[1].

ISO	The sensitivity of your camera's image capture surface to light. (It is more complicated than this. See below for details.)
Shutter Speed	How long the film or sensor is exposed to light. The camera may have a mechanical shutter or use an electronic shutter. Many digital cameras allow the user to select which to use.
Aperture	This controls the amount of light passing through the lens. The physical mechanism is the diaphragm (iris); the actual opening is the aperture. The aperture is represented numerically as the f/number or f/stop; for example, f/4.

ISO - The sensitivity of your camera's image capture surface to light.

This will be film or photosensor. For film, ISO (the same as the older ASA) is part of your purchase decision. You buy film with the ISO you need for your subject; high ISO for dark venues or moving subjects, low ISO for studio or daytime photography. Film's sensitivity to light is primarily based on the size of the light-sensitive crystals in the emulsion; bigger crystals, gather more light. Big crystals also cause more 'grain' in the final image.

[1] For point-and-shoot cameras, the sensor, shutter and lens are all one unit. DSLRs combine the sensor and shutter in the 'body' but have interchangeable lenses. Large and medium format cameras may have the shutter in the lens, and may have interchangeable backs, with digital or film options.

With digital photography, you use a dial or menu option to change the ISO setting to an appropriate value. Increasing ISO beyond the sensor's base ISO (typically 64, 100 or 200) amplifies the voltage data from the sensor's photosites, so you get a grain effect in digital photography similar to high ISO film.

Shutter speed - How long (or short) the film or sensor is exposed to light.

Shutter speed is not always critical to making images. Some subjects demand long exposures. I like my waterfall images to show enough blur in the moving water to emphasize flow, yet not so slow that I lose texture. I usually start with a shutter speed of ½ second, with the camera on a tripod. Wildlife photographer often want tack sharp animals in their images and so choose a higher ISO for faster shutter speeds.

Aperture - The lens opening controlling the amount of light passing through the lens.

Smaller apertures yield deeper DOF, exactly what I want my landscapes. Of these three items, aperture or f/stop is the most difficult to explain. The difficulty is that changes in DOF are nearly impossible to pre-visualize or even visualize in-camera. The lens stays wide open even when making changes to aperture, so you always see the 'shallow' version. If your camera has a DOF Preview menu option or button, the viewfinder may get too dark to see the effect well. Many would also argue that the LCD on a digital camera does not have enough resolution to accurately determine sharpness throughout in the image and may actually be applying some digital sharpening that can deceive you.

And frankly, the transition from sharp to blurry in your image is gradual. It also depends on the size of your final image. What looks sharp on the LCD may not be sharp on a 16x20 print.

There are two additional impediments to understanding DOF: (1) the numbering system for aperture, the f/number or f/stop, is peculiar, and (2) smaller apertures cause diffraction, a blurring of the image as light passes through a small opening. So you might ask …

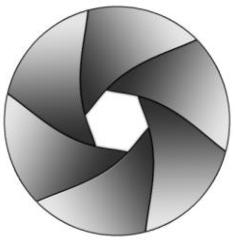
1. What f/number gives me the DOF I want?
2. At what f/number does diffraction become a problem?

The rest of this e-book is devoted to answering these questions.

Optics

You can understand DOF by learning a bit about optics. Modern lenses are complicated, with many lens elements, some glued together forming one or more lens groups. When you focus or zoom, elements or groups will move independently within the lens. Some lenses change their physical length as you do this. But the good news is that even complicated lenses can be understood from the basic optics of a simple lens, and I'll do that here.

Aperture and f/numbers



Every lens or camera has a diaphragm, which is a mechanical device whose opening can be made large or small. The opening is the aperture. Most modern cameras use an iris diaphragm as shown. It is open until an image is being made, so is generally not visible.

If you want to see the diaphragm in action, try this experiment: set your camera to manual with an f/number of f/11 or f/16, and a slow shutter speed, say 1 second. It doesn't matter if the exposure is correct. Look into the front of the lens and depress the shutter button. You should see the diaphragm close for 1 second, then return to wide open.

If your camera has interchangeable lenses, each lens has a diaphragm. The size of the opening is indicated by its f/number. These are the numbers you are likely to see.[2]

Number:	1	1.4	2	2.8	4	5.6	8	11	16	22	32
f/stop:	f/1	f/1.4	f/2	f/2.8	f/4	f/5.6	f/8	f/11	f/16	f/22	f/32

More Light — Less Light

Each number is about 1.4 times the previous number. Why? The diaphragm controls the amount of light entering the camera by controlling the *area* of the circular opening that that light passes through. Remember the formula for the area of a circle? Area = πr^2. To change the area of the circle by a factor of 2, or 1 stop, we change the radius by the square root of 2. In the formula, when the radius of the lens, r, changes by 1.4, the 'r^2' change is then 1.4 x 1.4 = 2.

What do the numbers mean? The f/number or f/stop is a numerical value for the 'relative aperture'. Turns out that not only is the size of the opening important, but so is the focal length of the lens. Literally, f/2 means an aperture opening that is ½ of the focal length of the lens, f/4 is an aperture that is ¼ of the focal length. The letter 'f' in f/4 is the focal length!

The f/number is a fraction! Fractions with a bigger denominator are smaller. Remember, ¼ of a pie is smaller than ½ of a pie!

TIP: *The secret for all lenses: the same f-stop lets in the same amount of light. When you switch lenses, the same f-number is still correct.*

Note that f/numbers may also be called 'stops', 'click stops' or 'f-stops'. Historically, large format camera lenses had a lever or ring that 'clicked' into these positions. It was easy to set the exact

[2] Your camera, or lens aperture ring, may show just the number or may include the 'f/'.

aperture value by feel or sound from behind the camera. Some lenses have click stops at ½ or ⅓ stop intervals.[3]

This is the vocabulary: if we go from f/4 to f/16, we are "stopping down" 4 stops.

f/4 -> f/5.6 -> f/8 -> f/11 -> f/16

1 2 3 4

Just count the number of steps in the list above. 4 steps = 4 stops. Going from f/8 back to f/4 is "opening up" 2 stops.

To make it even more confusing, many digital camera lenses do not have aperture rings anymore; you set the aperture using a dial on the camera while watching a digital display.

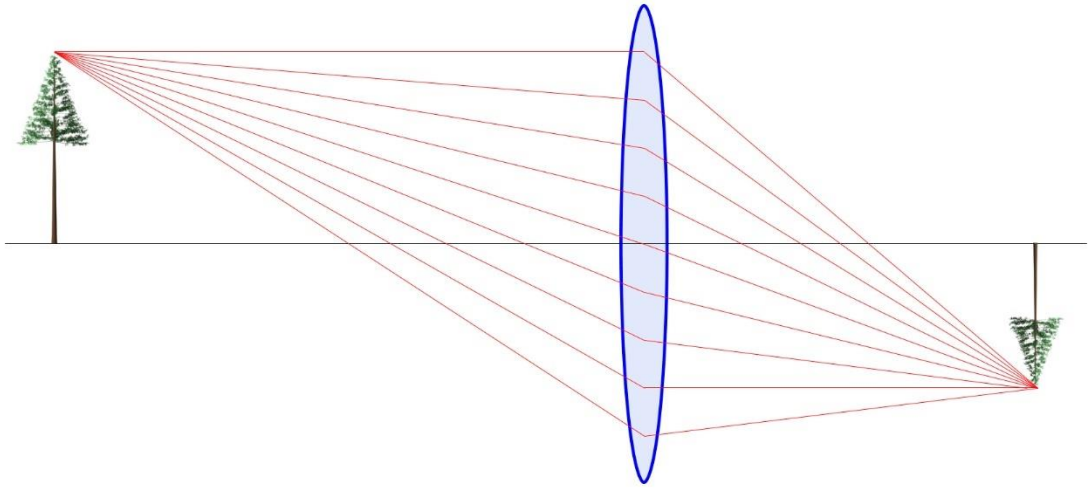
Camera lenses typically have their widest aperture written on the front of lens. This gives the photographer a measure of the lens' light gathering power. A lens that gathers a lot of light is sometimes said to be a 'fast' lens. An f/1.4 lens is faster than an f/4 lens. The lens itself is not faster, but faster shutter speeds can be used when more light enters the camera. For news or event photographers who might work indoors, or in relatively dark places, a fast lens that gathers a lot of light is required.

A zoom lens may show two f/stops, one for each end of the zoom range. My old normal zoom was the "Nikon 18mm-70mm, f/3.5-f/4.5". The widest aperture at the 18mm wide angle setting is f/3.5, and f/4.5 at the 70mm setting. (This could also be written 18mm, f/3.5 – 70mm, f/4.5.)

Simple Lenses

Now we know what the numbers mean, we need to see how they are related to depth-of-field. To do that we need to understand how a lens works.

[3] You will hear the word 'stop' applied to shutter speed as well. If the shutter is changed from 1/125 to 1/500, we might say the shutter was 2 stops faster: 1/125 -> 1/250 -> 1/500. Either way, each 'stop' changes the exposure by factor of two.



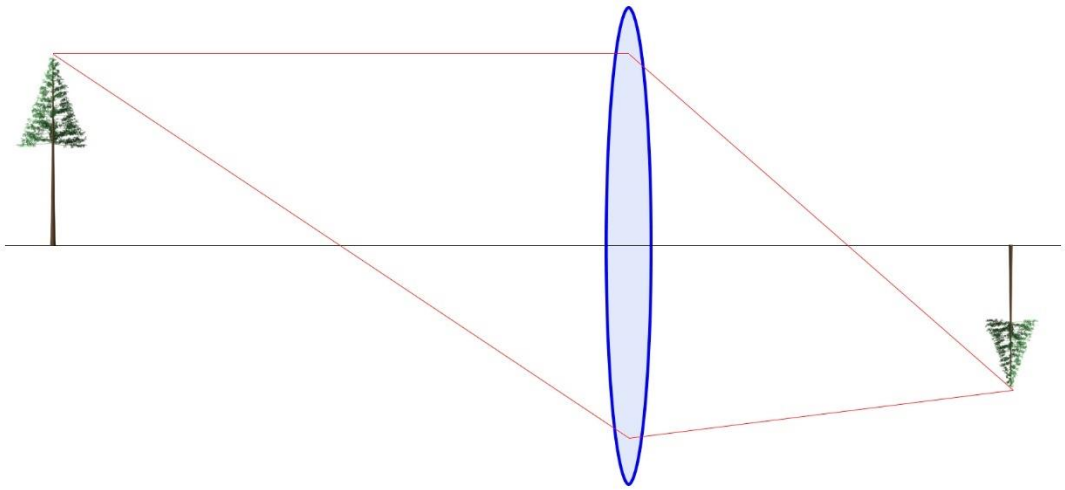
The subject tree on the left. *The tree image focused on the sensor/film on the right.*

On the left, a tree that is part of our landscape has focus. On the right, the image of that tree as it falls on the film or sensor. It is important to understand that light scattering off the very topmost leaf travels in all directions, and those rays that happen to hit the lens are focused to make the topmost leaf of the image. Light rays from the subject use all of the lens.

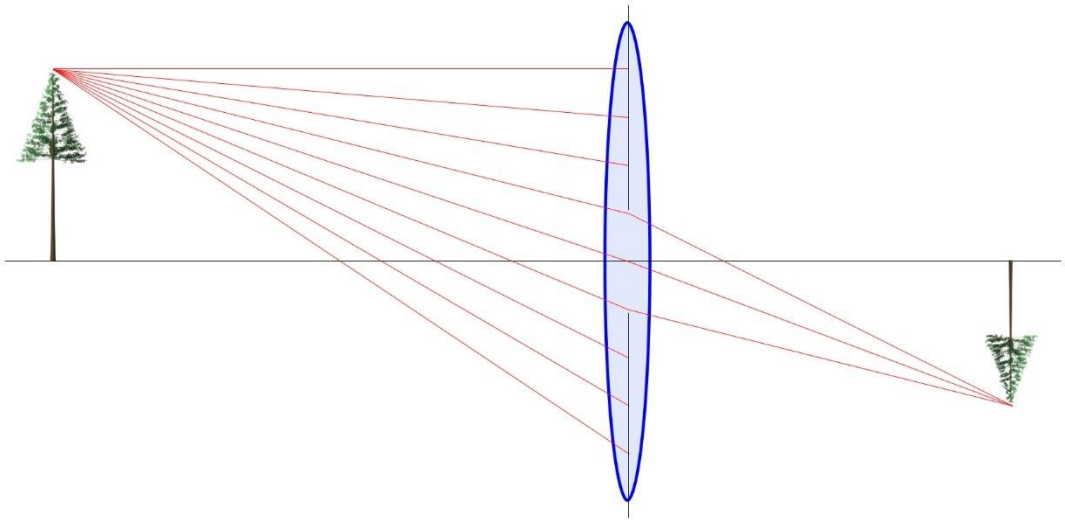
In a perfect lens, the focused light rays from any single point on the subject will converge on a single, perfect point on the film/sensor and form a perfect dot. Objects closer or farther from the tree will *not* form a perfect dot; it will be a blurry dot. This is called the 'blur circle' or the circle of confusion (COC).

We never see the same dot that the sensor sees. We see the dot as part of a final image: pixels on a computer screen or projected image, or on ink drops on a print. On a small print, a dot with a small amount of blur will look fine. When projected, or as part of a large print of the same image, that dot may look blurry.

This is how the f/stop affects the size of those dots, and how this results in changes to the DOF. When the aperture is wide open, say f/2, all parts of the lens are involved in forming the image. If we just consider the outer-most rays, when they converge on the film/sensor, they form a very wide angle. Only objects very close to the tree, front or back, will form sharp dots that look in-focus, all others will be out-of-focus and blurry.



If we use a smaller aperture, say f/11, only the rays that pass through the middle of the lens are focused on the film/sensor. Notice that these rays converge at a very narrow angle. Objects can be much farther way from the tree, near or far, before their dots get blurry.



This is the basis of DOF: Small apertures make smaller out-of-focus dots that look like they are in-focus when displayed. Here's a more formal definition of DOF.

DOF: *The distance about the plane of focus where objects appear acceptably sharp in an image. The smaller the aperture, the deeper the DOF.*

What is an 'acceptably sharp' image?

If you print your image at 8"x10", the whole image may look great – sharp throughout. But will it look that good at 11"x14", or 16"x20"? What if it is projected even larger? Are you starting with a full 35mm image, or a smaller APS-C image that might need more enlargement to reach these sizes?

The perceived DOF depends on both the size of the blur circle and the size of the image.

Although I'm repeating myself, it is difficult, I would say impossible, to accurately check DOF before you make an image. The transition from sharp to unsharp is gradual. You cannot see this with your eyes. In camera, it simply is not at its final size. The 'stop down' DOF preview method used by a DSLR is too dark to determine focus, certainly for me. Reviewing images on your digital camera's rear screen at 100% may help. But you are actually looking at a JPG produced in-camera, with some sharpening applied by your camera. I've found that focus peaking on newer digital cameras can be fooled by bright, contrasty highlights, showing a peaking outline even when out-of-focus.

DOF Tables

Many photographers rely on DOF Tables in difficult scenes which require sharp focus both near and far. These tables require that you know the distance to your main subject, and the focal length of the lens you are using. You then look through the table to find the f/stop value that meets your needs for near and far objects.

I rely on these tables, but not in the way you might suspect. In many cases, using the tables as written is simply wrong. However, they do provide important information that you need! I'll show you this later. A DOF table for a 50mm lens is on the next page.

Printed tables are hard to use. Subject distances are given in integer feet, sometimes at one-foot intervals, sometimes 10' apart. What if your distance is in between? I find it hard to estimate accurate subject distances. What if I estimate incorrectly? Some near and far DOF values are to the nearest tenth of an inch. It's unlikely you will be able to make that accurate a measurement in practice, especially while hiking. This table is for just one focal length lens: 50mm. What about your other lenses, or you zoom lenses? You would need a printed table for each.

This is a DOF table for a 50mm lens on a full frame (FX) camera.

	f/2		f/2.8		f/4		f/5.6		f/8		f/11		f/16		f/22	
Distance (feet)	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far
1	0' 11.9''	1' 0.1''	0' 11.9''	1' 0.1''	0' 11.9''	1' 0.1''	0' 11.8''	1' 0.2''	0' 11.7''	1' 0.3''	0' 11.6''	1' 0.4''	0' 11.4''	1' 0.6''	0' 11.2''	1' 0.9''
2	1' 11.7''	2' 0.3''	1' 11.6''	2' 0.5''	1' 11.4''	2' 0.7''	1' 11.1''	2' 0.9''	1' 10.8''	2' 1.4''	1' 10.3''	2' 2''	1' 9.7''	2' 2.9''	1' 8.8''	2' 4.3''
3	2' 11.3''	3' 0.8''	2' 11''	3' 1.1''	2' 10.6''	3' 1.6''	2' 10''	3' 2.2''	2' 9.2''	3' 3.3''	2' 8.2''	3' 4.8''	2' 6.9''	3' 7.2''	2' 5.2''	3' 11''
4	3' 10.7''	4' 1.4''	3' 10.2''	4' 2''	3' 9.4''	4' 2.9''	3' 8.5''	4' 4.1''	3' 7.2''	4' 6.1''	3' 5.4''	4' 9.1''	3' 3.2''	5' 1.9''	3' 0.4''	5' 10.3''
5	4' 9.9''	5' 2.2''	4' 9.1''	5' 3.2''	4' 8''	5' 4.6''	4' 6.5''	5' 6.7''	4' 4.6''	5' 9.9''	4' 2''	6' 3''	3' 10.8''	6' 11.7''	3' 6.8''	8' 4''
6	5' 9.1''	6' 3.2''	5' 7.9''	6' 4.6''	5' 6.3''	6' 6.7''	5' 4.2''	6' 9.9''	5' 1.5''	7' 2.8''	4' 10''	7' 10.9''	4' 5.7''	9' 1.3''	4' 0.6''	11' 7''
7	6' 8''	7' 4.4''	6' 6.5''	7' 6.4''	6' 4.4''	7' 9.3''	6' 1.6''	8' 1.8''	5' 10''	8' 9''	5' 5.5''	9' 9.1''	5' 0''	11' 8''	4' 5.6''	16' 1''
8	7' 6.8''	8' 5.8''	7' 4.8''	8' 8.5''	7' 2.1''	9' 0.4''	6' 10.6''	9' 6.6''	6' 6.1''	10' 5''	6' 0.5''	11' 10''	5' 5.8''	14' 9''	4' 10.2''	22' 9''
9	8' 5.4''	9' 7.5''	8' 3''	9' 10.9''	7' 11.6''	10' 4''	7' 7.3''	11' 0''	7' 1.8''	12' 2''	6' 7.1''	14' 2''	5' 11.2''	18' 8''	5' 2.4''	33' 6''
10	9' 3.9''	10' 9''	9' 0.9''	11' 2''	8' 8.9''	11' 8''	8' 3.7''	12' 7''	7' 9.2''	14' 1''	7' 1.3''	16' 10''	6' 4.2''	23' 7''	5' 6.2''	54'
12	11' 1''	13' 2''	10' 8''	13' 8''	10' 3''	14' 6''	9' 7.7''	15' 11''	8' 11''	18' 4''	8' 0.7''	23' 6''	7' 1.1''	39' 1''	6' 0.7''	587'
14	12' 9''	15' 7''	12' 3''	16' 4''	11' 8''	17' 7''	10' 11''	19' 7''	9' 11.6''	23' 6''	8' 10.8''	32' 9''	7' 8.8''	74'	6' 6.3''	∞
16	14' 4''	18' 1''	13' 9''	19' 2''	13' 0''	20' 10''	12' 1''	23' 10''	10' 11''	29' 10''	9' 8''	46' 5''	8' 3.6''	218'	6' 11.1''	∞
18	15' 11''	20' 8''	15' 2''	22' 1''	14' 3''	24' 4''	13' 2''	28' 6''	11' 10''	37' 8''	10' 4''	69'	8' 9.7''	∞	7' 3.2''	∞
20	17' 6''	23' 5''	16' 7''	25' 2''	15' 6''	28' 2''	14' 2''	33' 11''	12' 8''	47' 8''	11' 0''	112'	9' 3.1''	∞	7' 6.9''	∞
30	24' 8''	38' 5''	22' 11''	43' 5''	20' 11''	53'	18' 7''	78'	16' 0''	236'	13' 5''	∞	10' 11''	∞	8' 7.8''	∞
40	31' 0''	56'	28' 4''	68'	25' 3''	96'	21' 11''	228'	18' 6''	∞	15' 1''	∞	12' 0''	∞	9' 3.7''	∞
50	36' 8''	79'	33' 0''	103'	28' 11''	185'	24' 7''	∞	20' 4''	∞	16' 4''	∞	12' 9''	∞	9' 9.1''	∞
75	48' 6''	166'	42' 3''	332'	35' 10''	∞	29' 5''	∞	23' 6''	∞	18' 4''	∞	13' 11''	∞	10' 5''	∞
100	58'	371'	49' 2''	∞	40' 8''	∞	32' 7''	∞	25' 6''	∞	19' 6''	∞	14' 7''	∞	10' 10''	∞
∞	137'	∞	97'	∞	69'	∞	48' 6''	∞	34' 4''	∞	24' 4''	∞	17' 3''	∞	12' 3''	∞
Hyperfocal Distance	137'		97'		69'		48' 6''		34' 4''		24' 4''		17' 3''		12' 3''	

This is how you use the table:

1) The left column is subject distance.
2) The top row is a list of f/stops.
3) As you move down the table for farther distances, the distance between the near and far in-focus points increases.
4) Your 'in focus' DOF is about 1/3 in front of the subject distance and 2/3 behind. (This is a very rough guideline!)
5) The next-to-last row is for focus at infinity, effectively the horizon or a very long distance.
6) The last row is the 'Hyperfocal Distance'. This is the closest focus distance which has 'infinity' as the far distance. (Note: the f/22 hyperfocal distance, 12'3", is between the 12' and 14' rows. Values at subject distances between rows are hard to estimate exactly!)

   Note that the Hyperfocal Distance depends only on focal length and f/stop.

Hyperfocal Distance is the closest focus distance at the selected f/stop which includes 'infinity' as the far distance.

Printed DOF tables are not practical! You do NOT need all the data shown in the table above to achieve sharpness in depth. I'm not even going to mention printed DOF tables from here on! DOF apps on your smart phone or tablet will give you all the information you need, and you will not even see the data you do not need!

Below, I will show examples from the two DOF iPhone apps I use: "Simple DoF" and "PhotoPills".

Overcoming Limitations

If you start to compare DOF tables, you will find that they often have somewhat different DOF values. The math formulas used to calculate these tables are based on the "circle of confusion" (COC), or the largest dot that looks 'acceptably sharp' as displayed. Different formulas lead to different values. You will seldom know which formula, and which COC value was used.

A lens has the same blur circle on a full frame FX camera as on a small sensor DX camera. But typically for the small sensor, a smaller COC must be chosen for your DOF tables to account for the greater degree of enlargement for the same size print.

DOF is a property of the blur circle on the film/sensor and the degree of enlargement.

Even on smart phones you will find differences. For example, my DOF phone app lets me choose my specific full-frame Nikon model, the D850. Thankfully, the app also displays the COC it uses (0.030 mm). So do several other DOF apps I have used. This value is based on the so called 'Zeiss' formula for 35mm film and fairly small (about 8"x10") prints. [4]

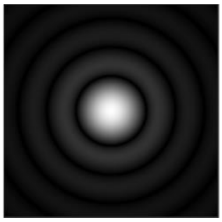
But my app also allows selection of a specific COC, and I use 0.025mm. Because of the smaller COC, this app's suggested aperture is smaller. However, I get reliable sharpness in depth at 16"x20". And that is that the goal! (For my DX camera, the tables use 0.020 mm, but I choose the specific value of 0.016 mm.)

These modern COC choices (0.025 for full frame, 0.016 for APS-C) are used to specifically overcome issues related to the Zeiss formula. If your camera uses a different size sensor, use a COC value about 1/5th smaller.

[4] If you check Wikipedia for Zeiss formula, you'll find the origin of the name is obscure, and unlikely to be related to the Zeiss lens company or its founder.

Diffraction

We need to supplement the discussion of f/stops and DOF with information on how diffraction at small apertures affects image sharpness. After all, we are looking for sharpness in depth and we do not want diffraction to rob our image of that sharpness.



Diffraction is the bending of light waves around the edges of an obstacle or aperture. The image at right is the diffraction pattern of a beam of light passing through a small aperture. Not only does the central spot get fuzzy, there are fainter concentric rings of decreasing brightness around it. (This is called an 'Airy Disk'.) The bright central spot is the blur circle, or circle of confusion (COC).

Diffraction and Lens Design

Photographers looking for the sharpest image will be concerned with diffraction and avoid f/stops that produce it. This will vary between lenses based on their design. As you might imagine, cheap lenses generally do not perform as well as costly lenses. And newer versions of expensive lenses might control diffraction better than older versions.

I used the weasel words 'generally' and 'might' above because price and manufacturer are not the whole story. In modern, complex lenses the manufacturer will include aspheric elements, elements made of exotic glass, and special coatings to improve performance. These minimize internal reflections, chromatic aberrations, and other sharpness-robbing effects. To keep prices down, many parts may made be plastic and costlier lenses may have better weather sealing. Neither may impact image quality.

The best sources of information are web sites that actually test lenses and report their actual performance. Two that come to mind are www.dpreview.com, and www.dxomark.com. If you are looking to purchase a new lens, an on-line review can help make that decision. If you work outdoors, a well weather-proofed lens may hold sway over a slightly sharper one.

There are some tradeoffs made by lens designers. A lens may be sharpest wide open, but only in the center of the lens; the corners will be soft. As the lens is stopped down, the corners will improve, but at some point, diffraction will start to rob the images of sharpness.

You really want to know the sweet spot that maximizes sharpness across the whole image.

If you want to evaluate your own lenses for their sweet spot, check the appendix to this e-book.

Depth of Field in Practice

This is what you need to do when you start to make an image. You've selected your shooting location, set the tripod in position, attached and leveled the camera. You've set the desired f/stop, shutter speed, and ISO for the proper exposure.

To use digital DOF data for deep sharpness, you only need 4 pieces of information:

- From the camera, the *focal length* you are using; compose and check the lens.
- From the camera, the *f/stop* you will use; you may change this after using the DOF app.
- From the app, the *hyperfocal distance*, which only depends on aperture and focal length.
- From the app, the *near in-focus distance*, which depends on where the lens is focused.

The first two items you do for all images, the latter two when you need to assure deep DOF.

Open the DOF tables in your app, set focal length and f/stop. The hyperfocal distance depends only on these two values. You will utilize the hyperfocal distance initially; the near in-focus distance will depend on where the lens is focused.

The last piece of information you need is the distance to the nearest part of your scene that must be sharp. You will choose the appropriate focusing method below to be sure that your near part of the scene is farther away than the near in-focus distance reported by your DOF app. Detailed use of these apps is covered below.

> In practice, it will take less time to use the DOF app and make your settings than it takes to mount your square filters or scout for the best composition.

There are several ways to achieve deep DOF reliably. These are the four approaches I've seen recommended to maximizing DOF:

- Hyperfocal Distance
- Double the Distance
- Focus at Infinity
- Double the Hyperfocal Distance

Hyperfocal Distance

This is the most commonly recommended focus distance for maximum DOF. You get the hyperfocal distance from your DOF app after aperture and lens focal length are set. You will then focus the lens at that distance. The DOF app will also provide the near in-focus distance. You must be sure that this will include the nearest parts of your subject that must be in focus.

I do not this method. The reason this often fails was hinted at above. There is a lot of variation in the printed tables and smart phone apps. And if you have not set the exact hyperfocal focus distance on your lens, your near or far objects may be out-of-focus.

At the hyperfocal distance, your near and far objects are at the edge of the sharpness zone.

Some will suggest using the tables to determine the hyperfocal distance at the selected f/stop, the set the aperture to one stop smaller. That's actually a really good idea; it's the same as using the 'modern' COC values suggested above!

Double the Distance

This method suggests that you determine the distance to the nearest object that must be in focus, then focus your camera at exactly twice that distance. It's very curious that actual apertures are seldom mentioned for this method. *Ross Hoddinott* doesn't mention a value, and *Ian Plant* mentions his favorite apertures (f/8 and f/11), but then suggests aperture bracketing. The extreme wide-angle lenses used for some types of grand landscape photography will have substantial DOF at these f/stops. Still, lack of specifics is curious.

What's clear is that many great photographers have mastered DOF through years of experience. I hope this little guide provides a shortcut to this knowledge. Google these great photographers if you are not familiar with their work!

I find that wide-angle lenses diminish distant mountains too much. I tend to go with moderate focal length to bring the mountains closer. Rather than rely on the DOF of wide-angle lenses, I use one of the techniques below.

Focus at Infinity

This method guarantees good detail in distant objects, mountains, or cityscapes. This method is often all I need. You must use DOF tables to check that near objects are well beyond the near focus distance. On your DOF app, you may not be able to set infinity as a subject distance. But this value remains at a constant value if subject distances get more than a few hundred feet. Again, you must be sure that this will include the nearest parts of your subject that must be in focus.

Double the Hyperfocal Distance

I use this regularly; focus the camera at twice the hyperfocal distance. With this subject distance, the horizon is still in-focus and the near in-focus distance is closer than when focused at infinity. Use your tables or smart-phone app to check the near focus point at the double distance. If your nearest objects fit, and you can accurately find a target at the double hyperfocal distance to focus on, this is the way to go. As usual, you must be sure that this will include the nearest parts of your subject that must be in focus.

But … there is one more issue.

You will often be surprised that when you attempt to focus your lens at the hyperfocal distance, or double that distance, you may not have a way to determine where that actually is! It may also be a problem trying to focus your camera if there is no object to focus on (e.g. over the edge of a hill or cliff.)

Choosing a DOF Method

It's interesting to look at some real-life examples. Here's an example, perhaps a surprising example.

24mm lens - f/11 - COC 0.025mm - Full frame (FX) camera

Let's see how the near focus distance changes for each method:

Focal Method	Focus Distance	Near Focus Distance
Focus at Infinity	infinity	6' 9"
Double Hyperfocal Distance	13' 6"	4' 5.8"
Hyperfocal Distance	6' 9"	3' 4.5"
Double Distance	???	???

- When focused at infinity, the near focus is the hyperfocal distance.
- Using the Double Hyperfocal Distance, the near in-focus point gets about 2' closer.
- The hyperfocal distance only moves the near focus distance about one foot nearer.

The near focus point may be closer than expected, and changes far less than expected!

Your primary concern: which method keeps your nearest important subject in focus.

As you can see, the Near Focus Distance is a key factor in achieving deep DOF in your image.

- Use 'Focus at Infinity' first.
- Use 'Double the Hyperfocal Distance' if you need a closer near in-focus point.
- Use 'Hyperfocal Distance' if necessary.

If my nearest subject gets close to the Hyperfocal Distance, I use a smaller f/stop or move to Focus Stacking.

If your tripod is used at eye level, common for many landscapes, your near focus point for the Double Hyperfocal Distance method is just about the same as your tripod height.

See Appendix 2 for a typical set of DOF bench marks / settings you might print and carry.

Expert Tools

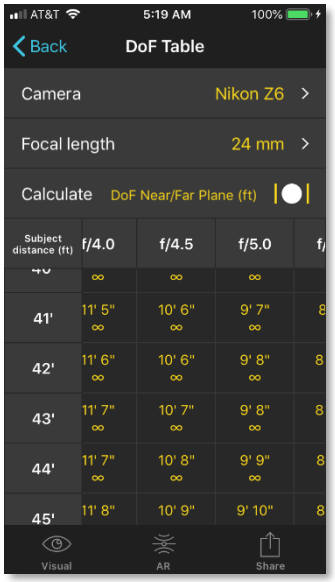
These are the tools I use to get good DOF results.

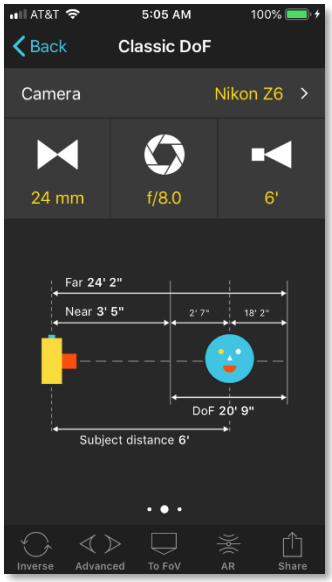
Electronic DOF Tables

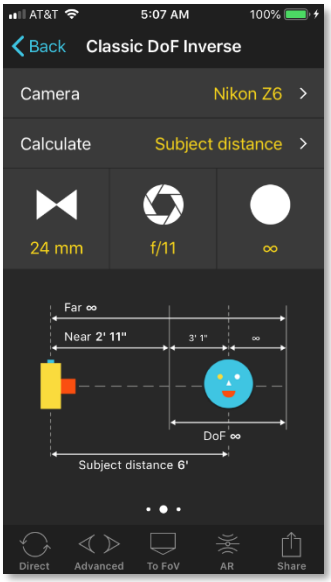
Paper DOF Tables are just too awkward to use. But DOF tables on a smartphone or tablet? Oh Yeah! There are a lot of apps that can provide this functionality, but here are two that I use.[5]

PhotoPills

PhotoPills is a suite of several useful modules and includes several types of DOF support. It offers an interactive version of the traditional table and a DOF graphic display that shows the values for hyperfocal, near and far distances.







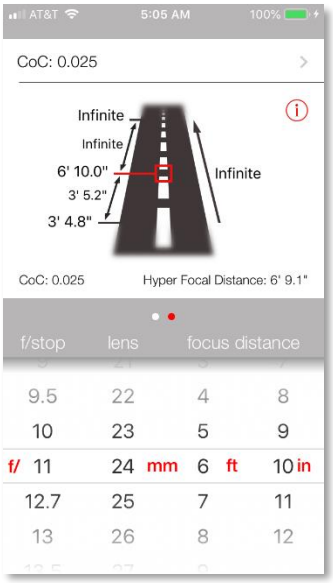
There are also traditional DOF Tables and a Hyperfocal table display options. The list of tables for specific camera models is enormous! For my FX Nikon, the tables use the Zeiss formula value of 0.030. This is not displayed in the screen shots above but is on the list of camera models.

You can set a COC value using PhotoPills' Advanced DOF option!

[5] There are many DOF apps available. I purchased these and use them regularly. I receive no financial benefit by recommending them.

Simple DOF

Simple DOF uses the graphical display exclusively, and is my preferred app. I find the scrollable settings at the bottom of the screen faster than typing individual values for focal length, aperture, and subject distance on a keypad.



Below the display, the four columns for f/stop, lens focal length, and focus distance in feet and inches scroll vertically. You can 'fast spin' these to get to the desired value quickly. Note that near the middle of the display "COC: 0.025" shows that I have selected a specific value. I also could have chosen 'Nikon D850', which would show the numeric value of 0.030 in the middle of the display.

This app also lets you save settings for up to four cameras.

Hardware for accurate Distance Measure

My ability to estimate distances for the DOF tables is miserable!

Then I found a tip from *Steve Perry*: Use a laser distance measuring tool! The one at right measures up to 120'. In bright sun, the laser's red dot can be hard to find even only a few dozen feet away. That said, it works fine for establishing the relatively close hyperfocal and near in-focus distances.

Bosch Compact Laser Distance Measure GLM 35

Press the red button once to turn the laser beam on. The displayed distance changes as the dot moves. When until the laser dot rests on an object at a specific distance, press the red button again and the distance is locked on the display. If you are using one of the methods above, that might be the hyperfocal distance, or double the hyperfocal distance. This is the best feature of this model! Many others erase the distance when the button is released. On your camera, focus on the object you just identified.

The actual measurement is from the bottom of the device to the red dot, so its length is part of the result. (Perfect for measuring the interior width of a window or wall.) To be hyper-accurate, hold the bottom of the device at the film/sensor plane mark on the top of your camera. This mark is usually a circle with a horizontal line through it.

Finally … the detailed steps for proper landscape DOF using tables!

Since we're talking landscapes with sharpness in depth, the three methods above assure that 'infinity' is in focus.

1. Be sure you are using a 'modern' COC for your DOF tables or smartphone app.

   With these settings, focusing at the hyperfocal distance keeps your subject within the traditional bleeding edges of 'acceptable focus'. You only need to do this once.

   - For full-frame (FX) cameras ------ 0.025mm.
   - For APS-C (DX) cameras ---------- 0.016mm.

2. Set up your camera for the landscape image you want to make.

   - Identify your subject.
   - Find your shooting position.
   - Compose your image.

3. Set your exposure … sharpest f/stop, ISO, and proper shutter speed.

   - Get your histogram right!
   - Note the focal length being used by your lens.

     If your zoom lens does not have accurate focal length markings, use the next higher marking.

4. Focus the lens at a distant subject, or the horizon.

   We are starting with the *'Focus at Infinity'* method.
   The distant object may be a canyon wall or rock face if there is nothing farther away in the image.

5. Check your DOF tables or smartphone app.

   - Find the entry for the chosen f/stop and focal length, at the distance in step 4 (infinity or farthest value).
   - Note the hyperfocal distance and near in-focus distance.

6. Find the distance of the nearest object in your frame that must be in-focus.
   (This is where the Bosch device really shines!)

   - If it is substantially farther than the near in-focus distance, you are all set … shoot away!
   - If it is close to but farther than the near in-focus distance, use your table or app to evaluate refocusing using the *'Double the Hyperfocal'* distance method.
   - If the near in-focus is still too close, try the *'Hyperfocal Distance'* method.
   - If it is nearer than the near in-focus distance, consider either …
   - Using a smaller aperture if it falls within the 'good' range of your sharpness tests, or …
   - Using focus stacking.

In a nutshell …

The Near Focus Distance is a key factor in achieving deep DOF in your image.

- Use 'Focus at Infinity' first.
- Use 'Double the Hyperfocal Distance' if you need a closer near in-focus point.
- Use 'Hyperfocal Distance' if necessary.

If my nearest subject gets close to the Hyperfocal Distance, I use a smaller f/stop or move to Focus Stacking.

It is faster in practice than when written. Once you have achieved some fluency with your DOF app, a mere glance will suffice.

In all cases, it is sensible to make a test image and examine on the camera's LCD. Zoom to 100% and scan the near and far points in the image. If you have travelled a long distance, or hiked to the top of mountain, evaluate your images to be sure you have the good stuff before you leave!

Beyond DOF Tables – Focus Stacking

Balancing Diffraction and DOF is the heart of the sharpness dilemma for landscape photography: maximizing depth-of-field without sacrificing sharpness. If you can get the desired DOF at the f/stops you find best for your lenses, you are one lucky photographer. If you are making images with a strong emphasis on near-far relationships, you may *never* have enough DOF at optimal f/stops; this leads to … *focus stacking*.

Focus Stacking

When you need deep DOF, inches from the lens to the horizon, only focus stacking will do. The idea here is to make a 'stack' of images that can be combined into one final image that contains all the sharp in-focus parts of the stack's images. Focus on the nearest object, make your first image, then refocus and shoot at farther distances, until you have the farthest part of the image in focus. The trick is finding a way to be sure that the frames are close enough together such that no part of the subject is missed; this would lead to bands of fuzziness.

Manual Stacking

Many new cameras have built in automated focus stacking. I cover this a bit later below. If your camera does not, here's how to proceed. I did this for a few years, and it works well; gotta practice, though! I've used three approaches:

> Method 1: Guess - You begin by focusing the camera on the nearest part of the subject that will be in focus and take your first image. You will refocus just a bit farther away for the second image … step-by-step … until the stack is complete. *Ian Plant* has a nice video on this technique!

But really, we want to use a more accurate approach. Here are two.

> Method 2: Visual - Begin by focusing the camera on the nearest part of the subject that will be in focus and take your first image. After the first image is made, review the image on the camera's LCD screen. Check that the closest parts of the image are in focus, then use a 100% zoom to check where the zone of sharpness ends. Find a part of the subject that is close to the end of the focus zone, yet still in focus. Refocus your lens on that part of the scene and make your next exposure. Review as above. Continue moving step-by-step until you have frames covering the whole depth of the image.
>
> Method 3: Tables & Bosch Device - Begin by focusing the camera on the nearest part of the subject that will be in focus and take your first image. Use the Bosch Laser Distance Measure (see above) to find the distance from the focal plane to this nearest point. Use DOF tables to determine the far in-focus point. Then use the Bosch device to find a point in the scene at that distance and refocus the camera there for the second image. Continue step-by-step until your DOF Tables indicate an appropriate far point has been reached.

When I saw Method 1 demonstrated, the photographer did *not* use the LCD to check the focus zones. The steps were estimated! With a small aperture, and some experience, this method will

work just fine using small apertures. I had a few banding issues early on, though; too few frames at the closest focus distances.

Method 2 relies on the ability to check focus on the camera's LCD. But the LCD image is a JPG created by the camera and may have sharpening applied that is not there in a raw file. I have not used this method.

Method 3 was my go-to approach. The Bosch device is easy to use too! Note that setting focus to the far in-focus point places that part of the image in the center of DOF for that next frame. There is good DOF overlap from there toward the camera. This assures that everything between the two focus points is sharp.

Automatic Stacking

My current camera, the Nikon D850, and the new Nikon Z series of cameras, all have focus stacking built in. (Nikon calls this 'Focus Shift Shooting'.)

Having this process automated in-camera is a true advancement. Modern digital cameras always know (1) what f/stop is set, (2) what focal length is being used (fixed or zoom) and (3) the distance to the focal plane. All the elements needed for calculating DOF and creating a focus stack are known to the camera. With the D850, Z 6 and Z 7, internal software can now build a stack in mere seconds, truly a minor miracle.

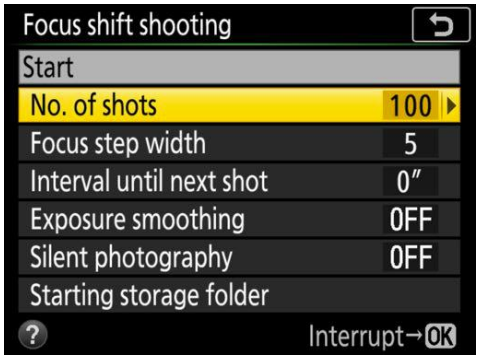
The basic approach is as follows:

1. The camera is focused on the nearest feature that must be in focus.
2. The Focus Shift menu is used to set a few parameters.
3. 'Start' is selected, and the OK button pressed to begin the stacking process.

The camera takes multiple frames, automatically refocusing at increasing distance for each subsequent frame. The stack process stops when the preset number of frames is reached, as set in the menu, or the lens reaches infinity. On the D850 top LCD panel, a 'count down' that starts with the number of shots selected is displayed. You'll hear the shutter close when the stack ends. It seems that the Z 6/7 do not display the count down.

This is an image of the Focus Shift Shooting menu. There are 6 items that the photographer can set.

1) Number of shots
2) Focus step width
3) Interval until next shot
4) Exposure smoothing
5) Silent photography
6) Starting storage folder



General Settings

The bottom four settings are likely to be the same for all situations, so let's cover them first.

Interval until next shot – You can use this setting, 1 or 2 seconds, if you want to allow the camera to be free of shutter and mirror vibrations. If creating stacks for subjects needing electronic flash, use this to allow enough time for the flash unit to recharge. (If you choose 'Silent photography' leave this at 0.)

Exposure smoothing – If you are shooting a deep stack under changing lighting conditions, the D850 will adjust exposure automatically. The camera should be in the Aperture Priority mode. The Z cameras do not have the Exposure Smoothing option.

Silent photography – I suggest that you set this to 'ON'. In silent mode, the D850's mirror is locked up, and the frames captured electronically. No shutter or mirror slap! With none of these vibrations, the shooting interval can be 0. If you are using Silent photography, the individual frames are captured quite quickly. The Z 6/7 have no mirror, but the mechanical shutter can add some vibration, so use this option for these models, too.[6]

Starting storage folder – I do not use this option. It has to be reset for each sequence, so more of a chore than an advantage.

> *Tip*: If you do not use the folder option, make marker frames with your hand or lens cap in front of the lens before and after each stack. Stack sets will be clearly apparent in Bridge or Lightroom.

[6] The EXIF data for Nikon Z cameras has entries for Shutter Count and Mechanical Shutter Count. The latter may be important in estimating wear-and-tear on the camera.

Scene specific settings

As a photographer you will immediately ask yourself several very pertinent questions about aperture settings and the top 2 menu items:

- What f/stop should I use?
- How many shots are really needed?
- What is the appropriate 'Focus step width' value?

Aperture - First, use the f/stop that gives you the sharpest image … your sweet spot! Focus stacking no longer requires small apertures to obtain deep depth-of-field. The stacking process literally builds depth-of-field for you. *You can forget DOF tables!* (Well, not really. Stacks can raise issues with ghosting, so single frame images are sometimes preferred.)

No. of Shots – The camera will stop when the selected number of shots has been reached, or the focal distance has reached infinity. The true number of frames needed will depend on the calculated DOF for the working f/stop. The inherent DOF at f/4 is shallower than at f/11, so more frames would be necessary. Just allow the camera to go to infinity. There really is no simple way to estimate the exact number. (There is a complex way, and we'll deal with it for macro stacks!)

Note that that the camera actually does keep shooting until it is focused at infinity. But at modest f/stops, the farthest parts of the scene will be in focus before the lens is at infinity. In fact, some modern lenses may actually focus beyond infinity. Several images at the end of the stack may be completely out of focus.

Focus step width - Nikon provides no information about the meaning of the value for 'Focus step width'. At f/11, a photographer would expect that the step width could be wider than at f/4. You might also expect that the steps would be wider at greater distances into the scene.

I've done a lot of tests on these values, and for '*normal*' landscape photography, I recommend

- Number of shots = 20
- Focus step width = 4

What is 'normal' landscape photography? Normal is when the nearest subject matter that must be in focus is more than 2-3 feet away. When you get closer, and you are getting near the 'macro' photography range, the number of frames goes up beyond 20.

I've used these setting for focal lengths from 16mm to 70mm, at f/2.8 through f/11. All worked correctly! At the shorter focal lengths, I have found that the stacking process frequently stops at infinity with less than 10 frames. Use of a telephoto lens may require more.

On a recent waterfall shoot, using the 20 shot / 4 step width settings, and my 24mm lens at f/8, my camera created 10 images, but only 3 were needed for a complete stack! Lately, I have been using a focus step width of 6 for normal work. As you gain experience, you can confidently reduce the 20 frame count to a smaller value.

If you are not sure you have a complete stack, review your image stack on the camera's LCD. If no frame has good focus at distance, just run a new stack without refocusing the camera!

> Remember: There may be several frames beyond infinity, so be sure to review the whole stack, not just the last image!

These values are not the most efficient. You may be able to use a step width of 6 for images shot at f/11 and expose fewer frames. For digital photography, the cost of a 'wasted' frame is zero.[7]

I have tested these settings for macro photography down to the 1:2 reproduction ratio. I used the Nikon 105mm f/2.8 lens. Even at f/2.8 the step width value of 4 worked correctly. But the number of frames jumps dramatically. At a reproduction ratio of 1:2, 100 frames may be needed for just five inches of DOF! I have a separate guide for macro work on the web site. Please check it out!

Rendering Image Stacks

I use two programs to render the stacks. Here are the 'in-a-nutshell' versions of how to render the stacks in Photoshop and Helicon Focus.

First, you need to determine which images in the stack are 'keepers' and which can be deleted. To review the stack, use the image browser in Bridge or the library module in Lightroom. If you followed my suggestion by adding a marker frame after each stack you can begin by simply selecting all the images in the set and choose Add to Group in the menu.

The goal is to find the last image in the stack that has sharp focus at distance. So simply start at the last frame in the stack and view at 100%. Move frame-by-frame back toward the beginning of the stack until you find the best last frame. Delete the out-of-focus images. (Of course, you will want to be cautious about this; always double check before deleting frames!)

> Caution: There may be several frames beyond infinity, so be sure to review the whole stack, not just the last image!

Before you render the stack, be sure to make any necessary adjustments to the raw files in Lightroom or Adobe Camera Raw… brightness, contrast, capture sharpening, etc. Both can apply the same adjustments to all the frames in your stack.

Rendering using a Photoshop workflow

In Bridge, navigate to the folder containing your stack. Select the first image in the stack, then Shift+Click the last image. Then use the menu sequence

Tools > Photoshop > Open Files in Photoshop layers …

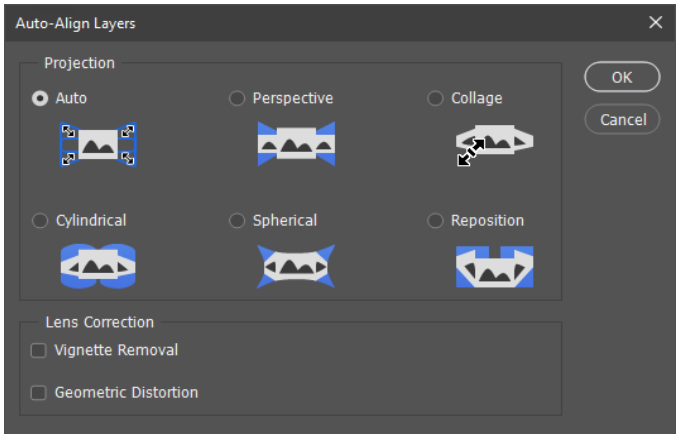
From Lightroom, use the menu sequence

Photo > Edit In > Open as Layers in Photoshop …

[7] If your memory cards are near full, you might think about reviewing your stacks on the LCD and deleting the frames that are beyond infinity as you work.

When Photoshop has finished opening, select all the layers in the Layers Panel, then use the menu sequence

Edit > Auto-Align Layers … Choose the 'Auto' option and Click OK.



Tip: *I have found that Photoshop does an excellent job of auto-aligning stacks. But many lenses change focal length (and thus magnification) slightly as you change focus. This is 'focal length breathing' and is common. During the alignment, Photoshop changes the size of some frames due to the magnification change; some are actually smaller than others!*

To see this effect, turn off the visibility of all the layers except the bottom-most layer. (Just Alt + Click the 'eye' icon for the bottom layer. If you see a white border around the image, use the menu sequence

Image > Trim

then select the 'Transparent pixels' option at the top. Click OK. Turn the visibility of all the layers back on … Alt + Click the bottom eye icon again.

I recently discovered that my telephoto lens 'breathes' in the opposite fashion. So, try Alt+Click the 'eye' icon at the top layer as well!

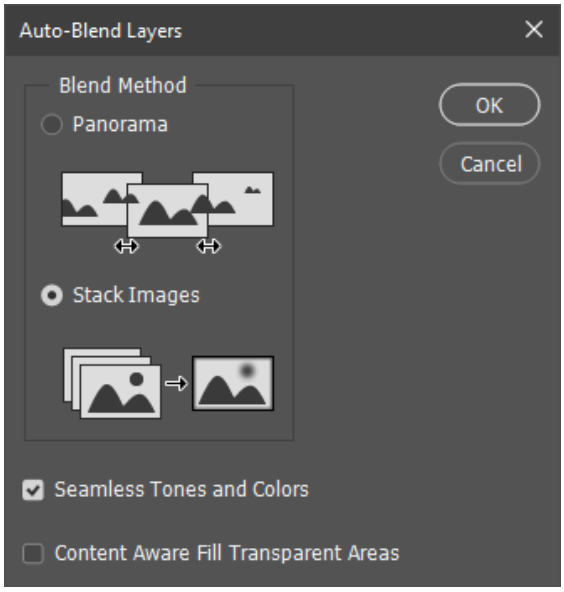
This trims all the layers, even the invisible layers, and the rendered image is sharp across the full width.

Without this step, the edges of the rendered stack will be blurry. This could be later cropped, of course. With this issue in mind, you might want to compose stacks with some 'extra' pixels at the edges.

With all the layers visible and selected, the menu sequence

Edit > Auto Blend Layers …

will render the stack. In the dialog, be sure *Stack Images* is selected, as is *Seamless Tones and Colors*. (The *Content Aware Fill* option can be used to fill in the blank areas due to focal length breathing, but it does not solve the blurry edge problem described above. Not necessary if you trim as mentioned in the tip above.)



When finished, each layer will be masked with black to exclude un-sharp areas. Flatten the image and save as a PSD to the source folder. When you save the image, give it a meaningful name; I like to include the image numbers used, e.g. DSC_2123-2128.PSD.

In my work, I convert this layer to a Smart Object and use a non-destructive workflow.

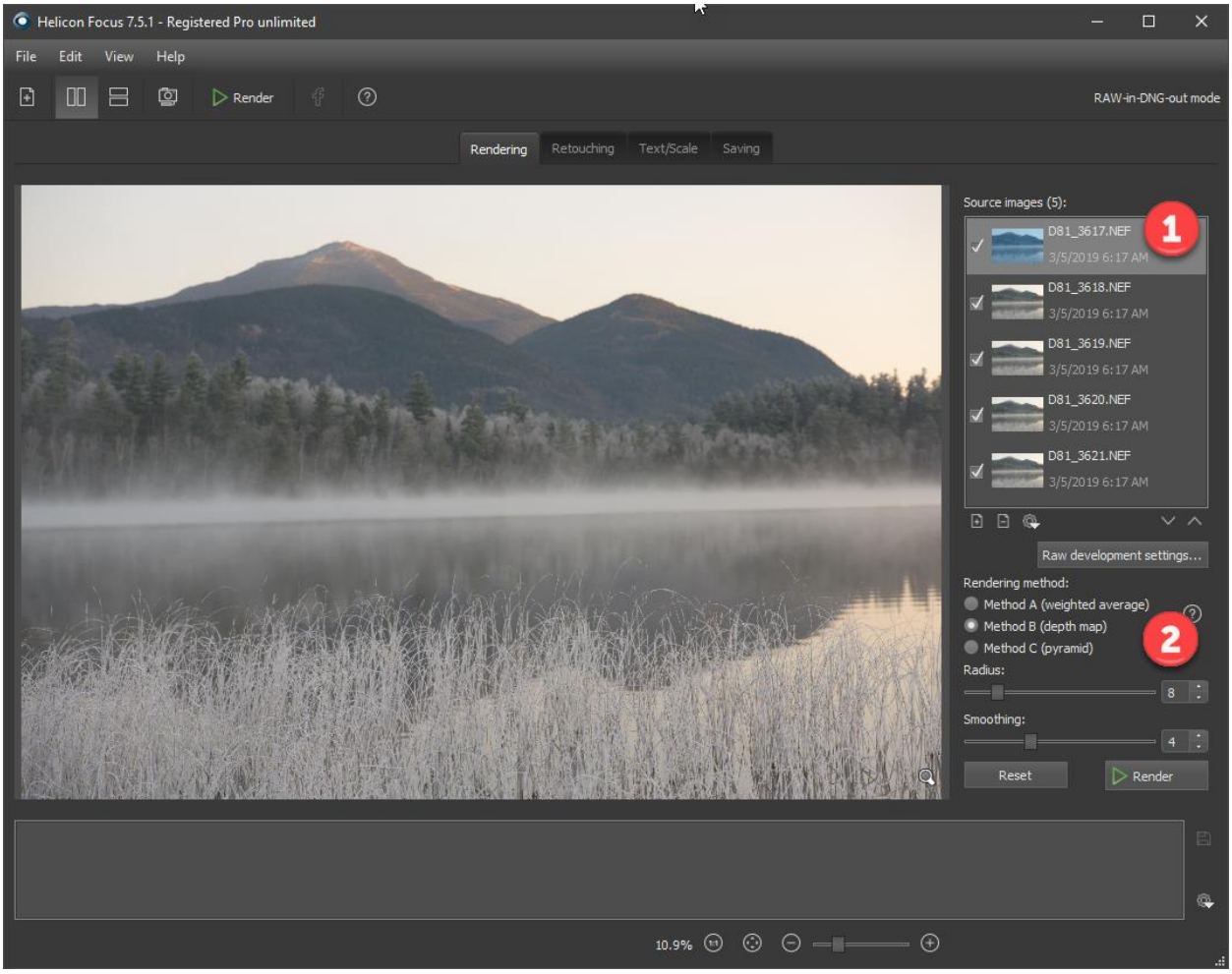
Rendering using a Helicon Focus workflow

Start Helicon Focus and use the *File > Open* menu sequence to navigate to and select the images in the set. Or you can use drag-and-drop to place the images in the Helicon Focus window. A screen capture of the Helicon workspace is on the next page.

Once the files are loaded, choose a rendering method. I have had good success with Method B, using the default settings of Radius 8, Smoothing 4. Click the Render button. Once finished, save to the source folder. Helicon Focus suggests a file name based on the last filename and rendering settings. But I suggest using similar names as above. If you want to try both Photoshop and Helicon Focus on the same stack, be sure to modify the Helicon names so they are different. Helicon can save as JPG or TIF; if starting with RAW file, as a DNG.

In the screen capture, I have loaded five frames of a scene at Connery Pond near Lake Placid, NY. Item 1 is the list of files in the stack. They may be selected individually to preview in the image window. Note that the 'RAW in DNG out mode' reminder just above. Item 2 shows the available rendering options.

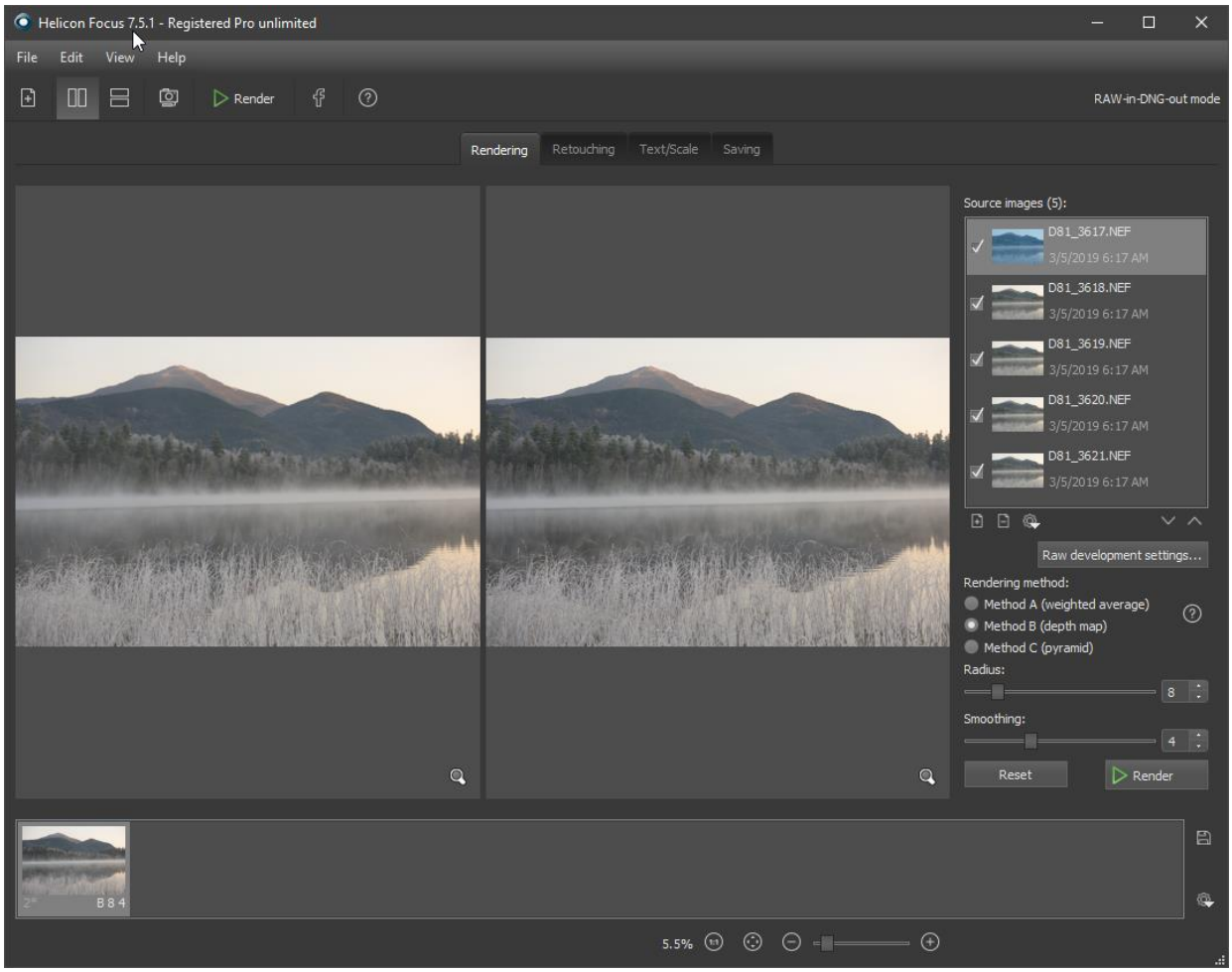
Note: If you are using Helicon Focus with RAW or DNG files, the on-screen appearance will be generated from the RAW image's RGB values. Adjustments made in ACR will *not* be seen. However, when Helicon creates the output DNG file, it will apply your adjustments to the DNG image and should look fine back in ACR, Bridge or Photoshop. (If this is problematic, you could generate 16 bit TIFF files from your adjusted raw images and stack these, In Helicon Focus, the images will look as expected.)



Tip: *Note the files names in the source image stack. The first is D81_3617.NEF. I change the three-character prefix to D81 for my Nikon D810, and D72 for my Nikon D7200. The camera's menu system offers this ability. Using the default file name, which would have been DSC_3617.NEF, can cause a lot of file name conflicts if you have multiple cameras.*

After clicking the render button, a side-by-side view opens, with the rendered image on the right. On the left, the displayed image is the one highlighted in the file list. It is also the one that will be used as the source image during retouching as described below. A thumbnail of the rendered version is in the film strip at the bottom. You can render the stack using several options and settings to compare.

Note: Helicon Focus automatically trims your stack when it detects focus breathing issues!



Close inspection shows a lot of ghosting within the frost-covered reeds. Select the Retouching tab to fix this issue.

If the mouse pointer is hovered over or near the ghosts, Helicon shows you the frame that was used to render that part of the image, and the hint to use the F9 key to load the parent frame into the left panel. Follow that tip and use F9.

If you then simply drag the mouse over the ghosts, it will replace the area under the mouse with pixels from that frame. Note the reed just below the brush. Ghosts gone!

Move the mouse to each area that shows ghosts. Check the F9 tip for each.

Really … pretty magical!

When done, use the Save tab to save your stacked image. I love the ability to save as a DNG as it opens in Adobe Camera Raw for additional editing. This is a really nice feature of Helicon Focus.

Photoshop or Helicon Focus?

No … Photoshop *and* Helicon Focus. You likely will use both. I used the Photoshop workflow for a long time, and it still is my first choice. But I did find a few image stacks that Photoshop just failed to render correctly. When ghosting is a problem, Helicon Focus becomes indispensable.

To conclude

I hope this has provided you with the tools and resources to get the maximum DOF you want. For 'normal landscape photography', the 'Double Hyperfocal Distance' and 'Infinity Focus' methods will work the best. Use Focus Stacking for 'deep' near-far compositions.

For true macro work, the number of frames can be enormous – dozens to hundreds! That requires a lot of testing to get right. Check out my Macro Focus Stacking e-book!

Have a question?

Find errors or things that need correction? Let me know!

By-the-way … here's that image after retouching in Helicon Focus and adjusting to taste in Photoshop:

Robert Stone

www.wetbootphoto.com
bob@wetbootphoto.com

Appendix 1 - Finding the sharpness sweet-spot

Remember… all images are based on the three parts of the exposure triangle. We can select specific ISO values, shutter speeds and f/stops to achieve the results we want. One of the values we should know is the sharpest aperture for each of our lenses.

The two links mentioned in the main article show sharpness values across the whole image as part of their lens tests. If your lens is not listed on these sites, or you want to test them yourself, it is quite easy. Just note that we are only looking at sharpness here; full testing of lenses is exceptionally complex as it might include field curvature, aberration, bokeh, astigmatism, vignetting, misalignment, focus breathing, *et cetera*, all of which may vary according to subject distance.

Start this process using a representative subject distance for your macro work, and the center of the image. Repeat for the corners if you wish.

Find that sweet f/stop! Here's how:

- *Select a target for the test.* Sophisticated focusing targets available on the web, some free, some for purchase. There are high resolution pre-printed targets you can download and/or print at home. (Note that inkjet printers do not produce adeqately sharp targets.) But a fresh newspaper works very well! Tape all four corners of a single page on a wall to keep it flat.
- *Set your camera on a tripod and center it on the target.* Don't get too close! You want to test the lens at a normal working distance. I suggest centering the camera on a part of the page that has text, not pictures. Text makes it easier to determine sharpness.
- *Be sure that the film/sensor plane is parallel to the target.* The image needs to be sharp across the whole frame. This deserves a good deal of care; take your time. Make some test images and check they are in focus across the whole image. If your camera can display grid lines on the LCD, carefully drawing some horizontal and vertical lines on the newspaper can help with the alignment.
- *Place your camera in Aperture Priority, auto-exposure mode.* In this mode, you can make a series of images by simply using a dial or menu to step through all the f/stops your lens has.
- *Minimize factors that might spoil the test.* Try the following:
  - Be sure the tripod and head are locked down tight. Some of your exposures at small f/stops will be measured in seconds. But don't be afraid to increase your ISO to get a faster shutter speed.
  - If your camera offers mirror lock-up, use it.
  - If you have a mirrorless camera, use the 'electronic front shutter' option.
  - Use a cable release, or a 2 second delay, so the action of pressing the shutter button does not add vibration.

- *Take a series of images, one at each f/stop on your lens.* Refocus the lens before each frame! Ideally, you should focus manually, zooming in using the LCD. (Auto-focus has a certain margin of error, and true focus can change with f/stop.) If possible, create RAW images. JPG images always have some degree of sharpening applied by the camera. If you have to shoot JPGs, do not change the sharpening settings.

When you have made all the images for your test, move them to your computer. I like to place them in a folder just for the test images. This makes it easy to delete them all when done. In Lightroom, Bridge or Adobe Camera Raw (ACR), use the 100 % view to evaluate sharpness.[8]

In Bridge, you can select up to 9 images to open in Preview mode. Click on each image to open the magnifier at 100%. This is the cool part: you can have a magnifier in each image! If you click at the same spot in each image, the magnifier will show the same part of the image at 100%. Then hold down the Ctrl key and drag any magnifier to any part of the frame; all the magnifiers will move together. Sweet! You can choose to open fewer than 9 at a time; I tend to prefer groups of four.

If you open more than 9, select all, then use the keyboard combination Ctrl+B to open a preview carousel. Click on the foremost image to open the magnifier. Then use the left and right arrow keys to move among the images. It takes a few seconds for the 100% preview in the magnifier to display properly as you move to a new image, but after visiting all the fames, there is no delay.

To use ACR for this review, select all in Bridge, then right-click one of the frames and choose Open in Camera Raw. The images will open in the film strip on the left. Right-click any frame in the strip and choose Select All (or just use Ctrl+A). Double click the magnifier in the toolbar to set all the images to 100%. Now you can select any image in the strip and use the Hand tool to evaluate any part of the image.

Interpreting the Images

You will certainly find that RAW images are not natively as sharp as you might expect. Because of sensor design, virtually all RAW images require some 'capture sharpening' (and some may be applied by ACR automatically). But you will be able to see which frames are sharpest. You may find that f/4, f/5.6 and f/8 all look really good! That's great; it allows you some flexibility when choosing exposure settings. You may also decide that although f/11 or f/16 are not quite as sharp, the extra DOF may be important. In my own landscapes, it can be very difficult to tell the difference between f/11 and f/16 in a final print. Fairly easy to see on-screen; not easy in the print.

[8] I am only familiar with LR and ACR. I suspect most, if not all, image browsers or editors have a 100% view.

Appendix 2 Bonus material

With the tip to write down useful DOF values for your gear, here are examples for my gear. If you need other focal length, use the values for the next longer focal length value. Create your own table using the 'sweet spot' aperture value for your lenses. Of course, I still recommend a smart phone app…

Sample DOF Data : Full Frame : f/8 : COC 0.025 — Hyperfocal Distance (HFD) in Red

Distance in **Feet** & **Inches**

14 mm	Focus	Near Focus
Infinity	∞	3' 3"
Double HFD	6' 6"	2' 2"
HFD	3' 3"	1' 9"

16 mm	Focus	Near Focus
Infinity	∞	4' 3"
Double HFD	8' 6"	2' 10"
HFD	4' 3"	2' 1.5"

20 mm	Focus	Near Focus
Infinity	∞	6' 7.5"
Double HFD	13' 3"	4' 5"
HFD	6' 7.5"	3' 3.75"

24 mm	Focus	Near Focus
Infinity	∞	9' 6"
Double HFD	19'	6' 4"
HFD	9' 6"	4' 9"

35 mm	Focus	Near Focus
Infinity	∞	20' 2.5"
Double HFD	40' 5"	13' 5"
HFD	20' 2.5"	10' 1"

50 mm	Focus	Near Focus
Infinity	∞	41' 2"
Double HFD	82' 4"	27' 5"
HFD	41' 2"	20' 7"

Distance in **Meters**

14 mm	Focus	Near Focus
Infinity	∞	1
Double HFD	2	0.66
HFD	1	0.5

16 mm	Focus	Near Focus
Infinity	∞	1.3
Double HFD	2.6	0.86
HFD	1.3	0.57

20 mm	Focus	Near Focus
Infinity	∞	2
Double HFD	4	1.3
HFD	2	1

24 mm	Focus	Near Focus
Infinity	∞	2.9
Double HFD	5.8	1.9
HFD	2.9	1.5

35 mm	Focus	Near Focus
Infinity	∞	6.2
Double HFD	12.4	4.1
HFD	6.2	3.1

50 mm	Focus	Near Focus
Infinity	∞	12.6
Double HFD	25	8.3
HFD	12.6	6.2