

Underground Construction Photography: Documenting a Success Story

Susan L. Bednarz
Jacobs Associates, Portland, Oregon

ABSTRACT: Recent advances in digital cameras and image processing allow photographers to produce excellent high-resolution action shots in low light and high contrast conditions commonly encountered underground. Digital photography is often used for construction and inspection documentation for underground structures. Designers, owners, and contractors benefit from quality photographs that document incremental progress and project milestones. Documentation photos serve as a lasting record of as-built conditions, are an important marketing tool, and help the owner build public support for expensive public works projects. When the project is complete, the only mementos that the participants will hold onto are the photographs.

INTRODUCTION

High-quality photographs of underground structures such as tunnels and shafts can be powerful and dramatic, but are not easily captured. The combination of poorly lit structures punctuated by bright, localized construction lights creates extremely high contrast images. In addition, the two most common types of underground spaces—large open chambers and very confined spaces—are both very difficult to photograph. Add to these difficulties the difficulty of capturing construction activities, such as equipment and workers in action, and it is easy to understand why so many underground photographs are unsatisfactory.

Excellent underground photographs can be obtained by using good equipment, techniques, and composition. Even if you do not have top-of-the-line digital SLR equipment, you can take useful images if you understand the limitations of your camera and work to offset those limitations. The benefits of good photographs are substantial for the owner, designer, and contractor. In addition to documenting construction, dramatic photographs are a great way to promote public works projects, market your company, and win future work.

The following discussion describes how construction photography can help the owner, designer, and contractor document underground structures and lists the numerous outlets for these photographs. Also included are techniques for improving underground photography, equipment recommendations, an overview of image processing, and recommendations for labeling and storing images.

GREAT CONSTRUCTION PHOTOGRAPHS SELL PROJECTS AND SERVICES

Owners, designers, and contractors all benefit from high-quality, dynamic construction photographs. Owners use construction photographs to build public

support, designers use them to sell their services, and contractors use them to document previous work experience. Of the three end users, owners have the greatest need for quality construction photographs and the greatest number of uses for these images.

Owners Use Photographs to Build Public Support and Document Facilities

Quality construction photos educate the public and build public partnership for major public works projects. Owners use construction images in the following outlets:

- Public involvement mailings to ratepayers
- Project Web sites
- Annual reports
- Newsletters
- Project progress posters
- Public outreach presentations
- Presentations to stakeholders and third parties
- Project displays at local museums

The City of Portland Bureau of Environmental Services (BES) uses high-quality construction photography to inform ratepayers about the West Side CSO and East Side CSO Projects in Portland, Oregon. BES directs Jacobs Associates, as part of its construction management contract, to obtain project images on a regular basis to be used in each of the seven outlets listed above. The BES project website, www.cleanriverworks.com, features project photography in progress posters and downloadable public outreach publications. The photos are also used to track activities at each of the structures under construction.

BES also uses progress posters are also used to record project milestones. For example, Figure 1 shows a project poster of a TBM hole-through that includes a photograph of project participants posed

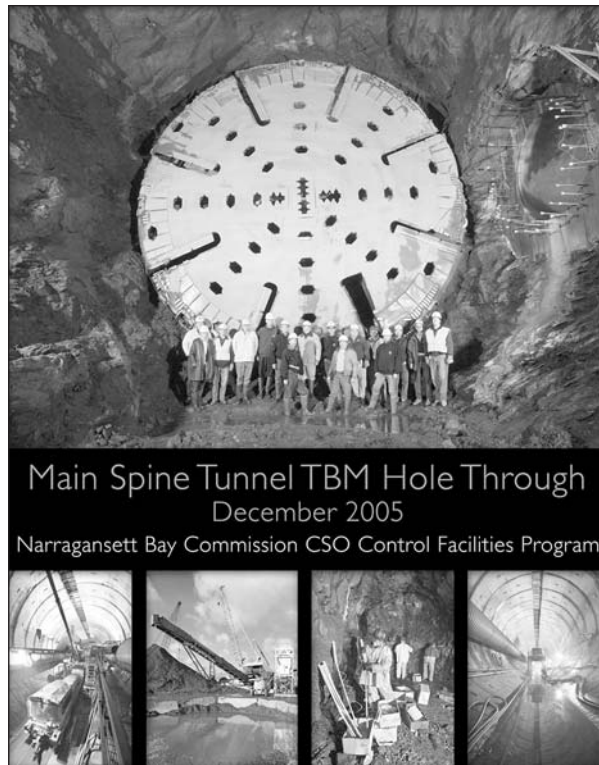


Figure 1. Progress posters document project milestones for owners, designers, and contractors. These posters can be used for office art and make great gifts for project personnel. (Image used with permission of the Narragansett Bay Commission.)

in front of the cutterhead, text to document the event, and additional project images along the bottom of the poster. These posters make great office art and meaningful keepsakes for the participants.

Owners also highlight projects with photographs at industry conferences, such as NAT and RETC, and in trade publications such as underground construction periodicals. Figure 2 shows a dramatic photograph of the Portland, Oregon, West Side CSO Project TBM published in a Tunnel Business Magazine article on slurry tunneling in North America. In addition to the uses discussed above, periodic documentation photography provides a lasting as-built record of construction progress that can be referenced for future facility modifications, repairs, and inspections.

Finally, owners benefit from high-quality underground photography during inspection of existing facilities, as the photographs help identify needed repairs and document conditions for insurance purposes. These images not only show owners where repairs are needed, they also help reduce insurance premiums by clearly showing the non-technical

insurer that an older facility is still in good condition. Figure 3 illustrates the excellent condition of a transition between a lined and unlined section in a tunnel in Connecticut.

Designers Use Photographs to Sell Professional Services

Designers use photographs in a variety of ways to sell their services to potential clients. Dynamic construction photos give the designer a competitive edge when used for:

- Project proposals
- Company Web sites
- Advertisements and articles in trade magazines
- Marketing presentations to clients
- Conference and meeting presentations
- Display art at conference booths
- Marketing brochures
- Company newsletters
- Annual reports
- Books
- Office wall art

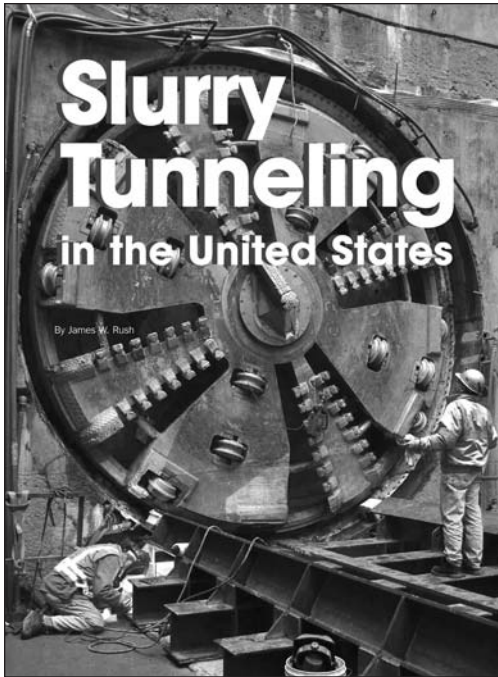


Figure 2. Dramatic project photographs are featured in trade publications such as this photograph of the West Side CSO Tunnel Project TBM that was published in the October 2007 issue of *Tunnel Business Magazine*. (Image used by permission of the City of Portland Bureau of Environmental Services and *Tunnel Business Magazine*.)

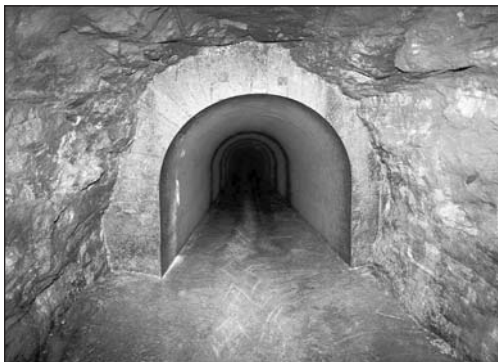


Figure 3. Well-lit inspection photographs provide definitive evidence of tunnel conditions, as shown in this image of a tunnel in Connecticut. (Photo used with permission of the Connecticut Municipal Water District.)

Quality construction photographs in proposals, presentations, websites, and advertisements attract the attention of clients. These images help a company define its image, showcase its work experience, and win new work.

Contractors Use Photographs to Showcase Construction Capabilities

Contractors use photographs to document their capabilities. They may use construction photographs for:

- Project progress documentation
- Company marketing brochures
- Office art
- Marketing and advertisements
- Cover art for bid documents and monthly reports
- Company Web site
- Conference booths
- Presentations to potential clients
- Trade publications

Dramatic images capture owner interest and illustrate successful results. Contractors are ideally positioned to obtain photographic evidence of their expertise by recording project milestones and construction innovations.

UNDERGROUND PHOTOGRAPHY TECHNIQUES

The three things that I hear most when taking construction photographs are:

- My underground photos never come out—everything looks dark and blurry.
- When I take photos of people underground, all I see are the stripes on their reflective vests.
- How did you get so much of the scene in your photo? My camera can't seem to photograph large areas.

Solving these problems requires a combination of equipment and technique. Although pro-quality camera equipment and lighting are a big help, they are not required to take quality underground photographs.

When photographing underground the three most important techniques are:

1. Illuminating your subject using a flash, working with ambient light, or combining both flash and ambient light.
2. Freezing the movement of equipment and workers.
3. Capturing wide-angle images in tight areas.

Use Flash and Ambient Light to Reduce Contrast

Light enters your camera through the lens. The wider the opening or aperture of the lens, the more light reaches your camera sensor. Lens aperture is identified by f-stop, which generally ranges from f1.2 to f22. The lowest number represents the greatest opening size. Fast lenses, which have f-stop values that range from f1.2 to f2.8 are expensive. These lenses, however, allow you to shoot in low light conditions with less chance of motion blur. In addition to cost, the other potential drawback is that a fast lens has very narrow zone of focus—sometimes as little as a few inches in tight areas. While this feature creates wonderful shallow depth-of-field photographs, it is less desirable when recording construction activities or large structures.

Underground light is divided into two types: ambient light (construction lighting) and light from a camera-controlled light source, such as a flash. Ambient light creates dynamic photographs, but may not adequately illuminate your subject. Using a built-in camera flash may light your subject, but the background of the photo will generally be very dark. Worst of all, many cameras with built-in flashes are fooled by the light reflecting off safety vests. These cameras underexpose the rest of the image, resulting in dark photos with prominent reflective stripes. Speedlight flashes that can attach to digital SLR cameras are best, but their high light output can overpower underground photos in some cases. Flash photos commonly contain both over-exposed and under-exposed areas that may not accurately represent underground lighting.

Balancing ambient light with flash illumination produces the best underground photos. Figure 4 shows an image that combines ambient light with flash fill to reduce contrast, light the subjects, and give a more realistic representation of what your eye would see. This technique is accomplished using the following steps:

1. Mount your camera on a tripod to reduce camera shake.
2. Set your camera to take a long exposure using a shutter speed of up to one second.
3. Set your camera to aperture priority mode and use a small aperture (f8 or f11).
4. Use a less powerful flash setting or bounce your external strobe flash off the ceiling of the tunnel or enclosed structure.
5. Make everyone in the picture hold still while you take the photo!

Using a flash to photograph a dusty underground excavation often results in light-colored spots on the image that are caused by the light from the flash reflecting off the dust particles in the air. These dust



Figure 4. Combine ambient tunnel light with camera flash to create balanced underground photographs. In this image of East Bay Municipal District and Jacobs Associates personnel in the new Claremont Bypass Tunnel, the camera flash was bounced off the crown of the tunnel to light the subjects while reducing reflections off of the safety vests. (Photo used with permission of the East Bay Municipal Utility District.)



Figure 5. Use a wide-angle lens to capture dramatic overviews of underground structures, such as this night photograph of the West Side CSO Project Swan Island Pump Station Shaft. (Photo used with permission of the City of Portland Bureau of Environmental Services.)

spots obscure the image and are time-consuming to remove during image processing. One possible solution for this problem is to move your flash off-camera using a remote flash cord or wireless flash trigger so that the direction of the flash varies slightly from the direction of the camera lens.

In addition to using a flash, you can artificially increase the light your camera records by raising the ISO setting, or sensitivity, of your camera. ISO values can range up to 3200 or even higher on several new cameras. High ISO settings help to increase



Figure 6. Use a telephoto lens to create dynamic images by compressing tunnel perspective and construction lighting. (Photo used with permission of the City of Portland Bureau of Environmental Services.)

shutter speed and thereby reduce motion blur, but the trade-off is increased digital noise that degrades your images. Digital noise looks like tiny colored spots that are commonly found in the darkest portions of your photos. Noise reduction software is available, but image quality is always reduced.

Finally, using the proper white balance setting on your camera brings your photographs closer to what your eyes see underground. Different light sources have different colorcasts: sodium and tungsten lights look orange and fluorescent lights have a green colorcast. White balance should be set for underground lighting prior to each photography session. Many digital SLR cameras record images in a format that permits white balance changes during image processing.

Fast Shutter Speeds Freeze Movement

Shutter speed refers to the amount of time that light is allowed to shine off the camera sensor. Fast shutter speeds of 1/125 of a second or greater will generally freeze movement associated with underground construction. Since not all underground shots include movement, slower shutter speeds are acceptable and even recommended for stationary scenes. Slow shutter speeds allow the camera sensor to record the subtle ambient light that illuminates many underground structures. As discussed above, this subtle and commonly very dramatic lighting is generally lost if a flash is used in combination with a fast shutter speed.

Digital cameras do a wonderful job of recording images in low light conditions, as long as the camera is stabilized to prevent camera shake when slow shutter speeds are used. Digital SLR lenses with built-in image stabilization that reduce both motion blur and camera shake are now available.

The downside is that lenses with image stabilization are expensive and heavy and image stabilization is not common on wide-angle lenses. Some models of digital point and shoot cameras have image stabilization built in, which is an advantage for underground photography.

Take Big Pictures in Tight Spaces

A wide-angle lens has short focal length that lets you squeeze more of the scene into your photograph. The focal length of a lens is the distance in millimeters between the rear lens element and the camera sensor. The shorter the distance, the wider the lens, and the more of scene that is included in the photograph. Effective focal length refers to focal length for a full-frame 35 mm sensor. Point and shoot digital cameras and non-pro digital SLR cameras do not have full-frame sensors and thus lens focal lengths must be converted to effective focal length.

Although wide-angle lenses are defined as having an effective focal length of 35mm or less, the best focal length for underground photography in tight spaces is 20mm or less. Most of my underground photographs in tight spaces are taken at an effective focal length of 16mm or less.

Figure 5 shows the dramatic perspective provided by an ultra wide-angle 14mm lens with its 114-degree field of view. This lens allows you to get almost everything that you can see into the photo. Alternatively, Figure 6 shows how a telephoto lens (200 mm) can compress tunnel perspective and construction lighting to create dramatic images that cannot be seen by the human eye.

Overcoming the Challenges of Photographing Existing Facilities

Imagine taking inspection photos as you walk through pitch-black tunnels or shafts with a foot or two of water in the invert and water spraying in from sidewall and crown seeps. This environment is a photographer's nightmare! Since there is no lighting, besides your headlamp, even a pro-quality SLR camera with a top-of-the-line speedlight flash has a hard time focusing. Not only is it technically difficult to photograph the structure, you constantly have to worry about tripping or dropping your camera equipment in the water or having it sprayed from the side or above. All is not lost, however, if you take the following precautions:

- Use a walking stick and a monopod for stability in uneven, slippery, and obscured inverts. The monopod can serve as both a second walking stick and a means to stabilize your camera. Don't keep your camera mounted to the monopod while you are walking.

- Use water-resistant or waterproof equipment or enclose your camera and flash in a waterproof case.
- Use a very powerful speedlight flash to light up large areas. Use an off-camera cord to move the flash off the axis of the lens in foggy underground conditions.
- When the light is insufficient for the camera to focus in a tunnel, focus on your co-workers at a distance in one direction, keep the camera shutter button partially depressed, and then rotate around until you are looking down the other direction before taking the picture. Another option when photographing dark tunnels is to turn off the lens auto focus and manually set your focus to infinity.
- Try to avoid photographing reflective vests close-up, as the rest of your photo will be underexposed.
- Use a 3-foot long black and white scale when photographing tunnel features to provide a size reference.
- Record the location of each photograph by camera photo number and tunnel station. Photograph inspection stationing at each marked interval to provide a back-up means of locating photos.

FLEXIBLE CAMERA SYSTEMS SHINE UNDERGROUND

Underground photography requires adjusting to changes in subject lighting, movement, size, perspective, and atmospheric conditions. The best camera system for photographing underground is flexible, allowing the photographer to capture extreme and variable conditions. Climbing up ladders and through tight openings in the presence of water and dirt requires sturdy equipment that is weather-sealed and shock resistant. Unfortunately, the most flexible and durable underground camera system is also the most expensive. While these professional-quality systems work best, a knowledgeable photographer using a less expensive camera system can still obtain good images in many underground situations by understanding the limitations of his or her equipment.

Single Lens Reflex (SLR) vs. Point and Shoot Cameras

Compact digital cameras that have a non-removable lens are commonly called point and shoot cameras. Depending on the model, these cameras include features such as a built-in flash, zoom lens, image

stabilization, and water-resistant sealing. Point and shoot cameras are generally small and easily fit into a coat pocket. This feature allows you to protect them from impact or from getting sprayed with water. The drawback of point and shoot cameras is that they lack flexibility. You are limited to the focal length range of the attached zoom lens, which generally isn't wide enough or fast enough for underground photography. Another drawback is the limited light output of the built-in flash and your inability to move the flash off the axis of the lens. These limitations often result in underexposed underground photos that include dust reflections.

Digital SLR cameras are flexible, since they allow photographers to select the lens and flash to suit their needs. Lenses best suited for underground photography have focal lengths that range from 14 mm to 200 mm, apertures that range down to an extremely fast f1.2, and image stabilization. High ISO settings are available on digital SLR cameras, as is the ability to trigger a powerful on-camera or off-camera speedlight flash. Digital SLR image quality and size are generally greater than is achievable with point and shoot cameras, due to a larger sensor and superior lens optics. Professional-quality digital SLR cameras have weather-sealed connections between the camera body and the lens and external flash.

The drawback of a digital SLR system is the increased cost, weight, size, and risk of damage due to moisture, dirt, and impact with hard objects. The SLR camera system with several lenses and a separate flash is bulky enough to require a separate bag. This bag may be heavy and cumbersome to carry when walking in and around underground equipment and narrow openings. Non-professional-quality digital SLR cameras are relatively fragile and are easily damaged if dropped, banged, or sprayed with water. Switching lenses underground may allow dust or moisture to get inside the camera and provides an opportunity to drop an expensive lens during the change. Even with these drawbacks, the digital SLR camera system provides the photographer with the best opportunity to capture high-quality, dynamic underground photographs.

Stabilize Your Camera with a Tripod or Monopod

The most important tool for improving your underground photographs is a tripod. Photographs taken using point and shoot and SLR cameras improve dramatically when the camera is stabilized on a tripod. When the camera is stationary, the shutter speed can be lowered, which increases the amount of light reaching the sensor. Ambient underground light is

amplified and blurring of stationary objects due to camera movement is eliminated. With a stationary camera, low f-stops (wide apertures) are not necessary and built-in camera flashes can provide fill flash without the need to light the entire structure.

The disadvantage of using a tripod is the increased size and weight of the equipment that must be carried. Although lightweight, compact tripods are available, they may not be feasible when photographing in tight underground spaces. If a tripod is not practical, consider using a monopod to partially stabilize the camera. A monopod looks like a one-legged tripod that directly attaches to your camera. By holding the supported camera as still as possible, camera shake can be minimized even at relatively low shutter speeds of $1/30$ to $1/60$ of a second. Unfortunately, tripods and monopods provide only a limited advantage when photographing moving equipment and/or personnel underground.

IMAGE PROCESSING WORKS MIRACLES ON UNDERGROUND PHOTOGRAPHS

Digital image processing works miracles on underground photographs by correcting color, contrast, and perspective to make them resemble what the eye sees. Adobe Photoshop image-processing software offers underground photographers the unparalleled ability to correct for image distortion. Unfortunately, Photoshop is an expensive program that is difficult and time-consuming to master. Although a detailed discussion of techniques for using Photoshop to improve underground photographs is beyond the scope of this paper, some of its key features are worth noting here. Photoshop can:

- Reduce contrast by making dark areas look lighter and light areas look darker.
- Straighten diverging or converging walls, beams, or openings.
- Remove colorcasts caused by construction lighting.
- Remove distractions such as invert trash or stray reflections caused by underground lighting.
- Reduce digital sensor noise that is created by high ISO settings.

Many owners, designers, and contractors employ graphic artists that are familiar with correcting and optimizing photographs using Photoshop. These graphic artists can help the photographer improve the quality of his or her underground photographs.

Although Photoshop is the premier image enhancement software, other software products are available that help reduce contrast and improve color saturation. Digital noise reduction software that is superior to that included in Photoshop is also available at a modest cost.

LABEL AND ORGANIZE YOUR PHOTOGRAPHS TO IMPROVE USAGE

Taking great underground photographs is pointless if you cannot find them at a later date. Image labeling must be descriptive and image storage must be organized and accessible. Photographs should be named by location and activity (e.g., 'Pump Station Shaft slab pour'). They should be stored in digital folders that are labeled by date, project, and location. The best photographs should also be organized in separate digital folders by project and construction method for use in presentations and publications. Owners, designers, and contractors should create a shared drive on their computer network that is dedicated to construction photographs. This approach allows easy access by both the technical and marketing staff. If creating a shared computer drive is not possible, images from each photography session should be saved on a separate CD or DVD and cataloged in a storage area.

Images should be stored as both a high-resolution TIFF file for publication and a low-resolution JPEG file for presentations. The TIFF file should have a resolution of 300 dpi (dots per inch) to satisfy publishing requirements. The JPG file size should be no larger than 300 KB for presentations. For Web sites, JPG image resolution should be 72 dpi with an image size no greater than 800 pixels in either dimension.

One great way to find project photographs quickly is to print contact sheets containing up to nine small, labeled images on a single sheet. These sheets can be organized by project and date, which facilitates finding them on a shared drive or on a CD. Photos of a specific structure or construction method can be easily identified by flipping through a three-ring binder of contact sheets created for a specific project.

CONCLUSION

Once construction is done, the only mementos that the participants save are the photographs. The project is buried and no one reads the reports. You may not want to believe these statements, but they are actually quite accurate. Photographs are a lasting legacy of the project. They inspire your clients and sell your projects and services. Although high-quality digital SLR camera systems capture the best underground photographs, especially in adverse conditions, tripod-stabilized point and shoot cameras can record acceptable and sometimes spectacular images. Balancing flash with ambient light; selecting the appropriate focal length, shutter speed, aperture, and ISO setting; and stabilizing the camera all contribute to capturing well-exposed and dramatic underground photographs.