

l i g h t i n g d e s i g n l a b

2915 4th Ave South

Seattle WA 98134

t. 206.325.9711

f. 206.329.9532

800.354.3864

www.lightingdesignlab.com

Compliance Rates of Lighting in Commercial Buildings

A Pultorak
M Lane
S Wood
D Butler

July 2011

Prepared for:

David Cohan, Northwest Energy Efficiency Alliance
Under Contract 40284

Rosemarie Bartlett, Pacific Northwest National Laboratory
Under Contract 130806

Lighting Design Lab
Seattle, Washington 98134

Contents

Executive Summary	v
1 Introduction	1
2 Plan Survey Methodology	1
3 Plan Review Analysis.....	2
4 Field Verification Review Analysis.....	4
5 Experiences While Collecting Data.....	5
APPENDIX A.....	7

Executive Summary

The Northwest Energy Efficiency Alliance (NEEA) received American Recovery and Reinvestment Act funding from the U.S. Department of Energy to study commercial lighting compliance at local building jurisdictions around the Northwest.

The fundamental approach used in this study was to review lighting designs which had been submitted to nine local building departments across the Northwest region and assess, first, if sufficient data was included in the submittal to ascertain whether the design met the applicable energy code and, if so, to determine whether or not it actually met the code. Both lighting power densities (LPD) and lighting controls were reviewed. A subset of the buildings which had their plans reviewed was then visited in person to see if the installed lighting matched the lighting plan that was submitted. Ninety-one plans were reviewed (46 office and 45 retail) and 29 buildings received site visits.

Key findings from the plan review included:

- Based on the watts and square footage submitted on the plans, only 69% of office buildings and 60% of retail buildings should have been approved for LPD compliance.
- Average LPDs for all buildings were very close to the code requirements though many individual buildings did not meet them.
- Designers misstated both square footage and wattage in a large percentage of buildings.
- Only 67% of office buildings and 64% of retail complied with the control requirements. It was evident that neither the designers nor the building officials have a clear understanding of the control requirements of the energy code.

The key finding from the field verifications was that no major contradictions were found when comparing the plans to actual field conditions. However, not all information needed to determine compliance was always available on the plans.

1 Introduction

The Northwest Energy Efficiency Alliance (NEEA) received American Recovery and Reinvestment Act funding from the U.S. Department of Energy to study commercial lighting compliance at local building jurisdictions around the Northwest. Lighting power densities have been identified as an area of the code which may have a low compliance rate but little hard data exists to support this assumption. The extreme importance of lighting energy in determining overall commercial building energy consumption justified this study.

NEEA contracted the design and implementation of the project to the Lighting Design Lab (LDL) in Seattle, Washington. The LDL then contracted with lighting designers Stephanie Wood and David Butler to do much of the data collection and analysis.

2 Plan Survey Methodology

The fundamental approach used in this study was to review lighting designs which had been submitted to local building departments and assess, first, if sufficient data was included in the submittal to ascertain whether the design met the applicable energy code and, if so, to determine whether or not it actually met the code. Both lighting power densities and lighting controls were reviewed. A subset of the buildings which had their plans reviewed was then visited in person to see if the installed lighting matched the lighting plan that was submitted.

A preliminary task of the project team was to narrow the scope of the study to ensure that the results would be useful which was done through three steps. First, the building types included in the study were limited to office and retail, both of which use large amounts of lighting energy and represent significant fractions of total commercial floor space. Constraining the number of building types ensured that a relatively large number of each type would be included in the study which assured sufficient variation within each type to see distributions and trends if they existed.

The second step circumscribed the size and vintage of the buildings. Buildings were required to be 5,000 square feet or greater and to have been permitted under the current or preceding energy code. The minimum size ensured that the buildings in the study would represent a significant amount of square footage and the permitting requirement ensured, as much as possible, that the lighting used would be representative of systems still in use in current construction projects.

The final step was to include buildings from around the region to see if, even in these very small sample sizes, any variation by location emerged. Buildings from the following cities were selected for inclusion in the study:

Washington: Everett, Bellevue, Tacoma, Spokane and Seattle
Oregon: Portland, Salem/Eugene
Idaho: Boise
Montana: Missoula

Table 1 shows the targets that were set for both plan review and field verification and how many were actually completed in the study. The “Plans Previewed” column represents all the plans that had to be looked at in order to find those that met the study criteria.

Table 1. Sample Targets and Actuals

City	Target for Plan Review	Plans Previewed	Plans Reviewed	Target for Field Verification	Field Verified
Everett, WA	12	475	11	4	2
Bellevue, WA	12	225	12	4	5
Tacoma, WA	12	85	9	4	2
Spokane, WA	12	350	12	4	2
Seattle, WA	12	375	11	4	4
Portland, OR	12	160	4	4	3
Salem/Eugene,OR	12	75	8	4	5
Boise, ID	12	110	12	4	4
Missoula, MT	12	90	12	4	2
TOTAL	108	1945	91	36	29

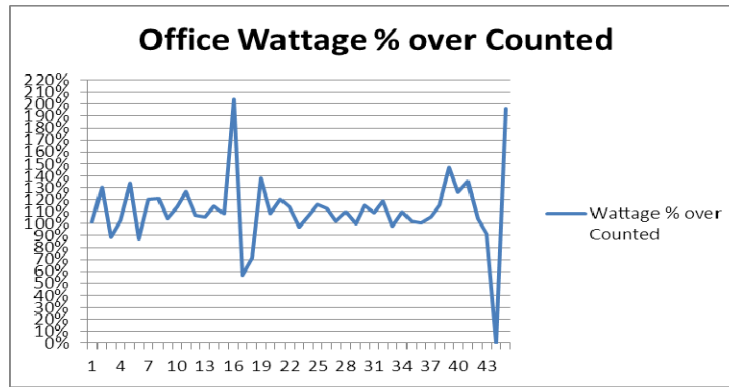
Once the type of buildings and cities were determined, the contracted lighting designers contacted the building department in each city, described what they were looking for and requested plan sets that met the criteria. Using the information on the plans, the lighting designers re-calculated the lighting power density for each building reviewed and compared their results to the lighting power density shown on the plans. They also verified the presence of code-required controls on each plan.

3 Plan Review Analysis

Ninety-one plans were ultimately reviewed, 46 office and 45 retail. Of these, 45 office and 42 retail buildings had sufficient data to be reviewed for both lighting power density (LPD) and control compliance. The spreadsheet accompanying this report contains all data recorded for all buildings.

Office Buildings

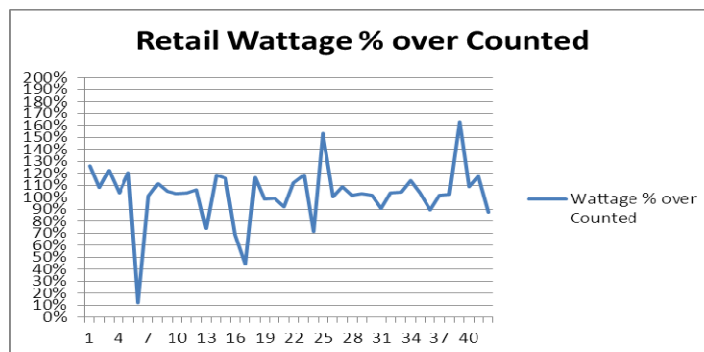
- Based on the watts and square footage submitted on the plans, 69% of the buildings should have been approved for LPD compliance. (100% were actually approved as all the plan sets reviewed were for buildings that had already been built.)
- Further analysis showed that 84% of the buildings actually complied with the LPD portion of the energy code. The discrepancy with the preceding bullet was due to the designer incorrectly stating the square footage of the building or the installed wattage.
- Based on the analysis only 67% of the buildings complied with the control requirements. Interestingly, in two cases buildings failed the LPD requirements while passing the control requirements.
- The average LPD was 0.97 for all of the office buildings. The average for the complying buildings was 0.93 and for the noncomplying the LPD average was 1.07. The average code requirement was 0.99 W/sf.
- In 82% of the buildings the designer overstated the installed wattage on the compliance forms. The higher the wattage the harder it will be for the building to comply with the LPD. On average the designer overestimated the wattage by approximately 10% (see chart below).



- 73% of the buildings overstated the square footage of the buildings. This will be a difficult input for the AHJ to catch that it is incorrect. Overstating the square footage will make it easier to comply.

Retail Buildings

- Based on the watts and square footage submitted on the plans, only 60% of the buildings should have been approved for LPD compliance. (100% were actually approved as all the plan sets reviewed were for buildings that had already been built.)
- Further analysis showed that 57% actually complied with the LPD portion of the energy code. This discrepancy appears to be due to the designer incorrectly stating the square footage of the building or the installed wattage. However, it is unknown from the documentation on the plan if any of the wattage is part of the additional power allowance for retail display lighting so final determination of code compliance is not possible.
- Based on the analysis only 64% complied with the control requirements. Interestingly, in one case a building failed the LPD requirements while passing the control requirements.
- The average LPD was 1.47 for all of the retail buildings. The average for the complying buildings was 1.27 and for the noncomplying the LPD average was 1.71 Code average LPD is 1.5 watts/sf.
- In 82% of the buildings, the designer overstated the installed wattage on the compliance forms. The designers overestimated/underestimated the wattage in a wide pattern (see chart below).



- 26% of the buildings overstated the square footage of the buildings. Overstating the square footage will make it easier to comply.

Conclusions

- The average LPD for all the buildings reviewed is extremely close to code-required levels. (.97 reviewed vs. .99 code for offices; 1.47 reviewed vs. 1.5 code for retail). However, this is not a pattern one would expect for a mandatory code. In theory, the code requirement should be a lower bound and there should be a distribution of efficiencies above the code minimum.

- No evidence indicates a consistent or conscious effort to “cheat” on the code. In fact, 82% of both office and retail plans over-stated the installed wattage which actually makes it harder to comply with the code. This was offset by a large majority of the buildings over-estimating square footage, which makes it easier to comply with the code. The most reasonable conclusion is that a large percentage of designers simply don’t understand basic code-compliance calculations.
 - Efforts to address this lack of understanding are needed. Currently, it would be difficult for a building official to catch overstated square footage. Providing clearer guidelines and a form where square footage calculations are clearly shown might help resolve this. With regard to eliminating stated fixture wattage discrepancies, it might make sense to require designers to use wattage from a code-published table. Currently, designers record maximum lamp/ballast wattage or manufacturers’ listed wattage, but how does the building official know that they are correct without a reference sheet?
- 30% of the office plans and 40% of the retail plans should not have been approved for LPD based on the designer’s stated watts and stated square footage. This strongly indicates that either they are not being reviewed (evidence for this is given in Section 5) or that building officials do not understand the code well enough to properly determine compliance. Either training or resources or both will be needed to address this.
- Additional power allowances for retail accent lighting, as allowed by code, need to be clearly documented separately on the plans/compliance forms. Without this documentation, code compliance cannot be definitively determined.
- Only 67% of office buildings and 64% of retail complied with the control requirements. It was evident that neither the designers nor the building officials have a clear understanding of the control requirements of the energy code. Designers need much better training on control requirement, especially with the new codes that are focusing on more control requirements. Building officials need better training on spotting control discrepancies

4 Field Verification Review Analysis

A total of 29 (18 retail, 11 office) of the 92 reviewed projects were physically walked through and had a field verification report completed that compared submitted plans to actual field conditions for six major categories:

1. Space Layout - verifying general space layout, ceiling heights, wall/window heights.
2. Square Footage – spot checking areas to verify that square footage matches plans.
3. Space Use - reviewing if actual space is being used as indicated on plans.
4. Daylight Zones - verifying daylight zones match indicated zones on plans.
5. Fixture Totals - comparing installed fixture counts to plans.
6. Fixture Types/Locations - verifying installed lighting fixture types and fixture locations match plans.

The following results were obtained for the field verified projects. The spreadsheet accompanying this report contains all data recorded for both the plan review analysis and the field verification of all buildings.

Space Layout:

- 90% had a space layout that matched what was indicated on the plans.
- 7% had a space layout that did not match what was indicated on the plans.
- 3% had a space layout that was not applicable.

Square Footage

- In 100% of the projects, the square footage matched what was on the plans.

Space Use

- 90% had space use that matched what was indicated on the plans.
- 10% had space use that did not match what was indicated on the plans.

Daylight Zones

- 72% had daylight zones that matched what was indicated on the plans.
- 10% had daylight zones that did not match what was indicated on the plans.
- In 18% of the projects, the daylight zone was not applicable.

Fixture Totals

- 72% had counts that matched what was indicated on the plans.
- 28% had counts that did not match what was indicated on the plans.

Fixture Types

- 75% had fixture type/locations that matched what was indicated on the plans.
- 25% had fixture type/locations that did not match what was indicated on the plans.

Conclusions

- No major contradictions were found when comparing the plans to actual field conditions.
- Minor field changes typically changed the as-built conditions from the submitted plan. Examples include:
 - Slight changes in use of space (i.e. copy room becoming a private office)
 - Fixture relocation due to change in use of space
 - Construction issues due to other trades (i.e. plumbing, HVAC, ceiling grid layout)
 - Post-occupancy adjustments (i.e. lighting track moved for display lighting)
 - Partitions moved
 - Slight changes in fixture specifications
- Daylight zone controls were at times difficult to verify due to a lack of end user knowledge.
- Daylight zones could be better indicated on the plans for field verification.
- Controls were not always clearly indicated on plans which made field verification difficult.
- Examiners did not appear to be reviewing controls.
- Plans submissions need to have “use of space” indicated on the plans more clearly.
- Compliance forms inserted onto a drawing were much easier to find/manage/read/interpret than those submitted as a separate document.
- Compliance forms used for tenant improvements could be improved by specifying where to notate the automatic after-hours system if part of a larger building.
- Lighting power density calculations did not always make it clear if ballasts were factored in.

5 Experiences While Collecting Data

One of the U.S. Department of Energy’s goals in funding this project was to better understand barriers to determining code compliance. By far, the most problematic aspect of this project was obtaining plan sets from the local jurisdictions which met the project criteria. It was initially assumed that this would be a

straight-forward task but experience proved otherwise, with one of the lighting designers estimating that 75% of his overall time was spent on obtaining appropriate project records.

Following is a summary of the experiences and lessons learned from dealing directly with the building jurisdictions. Detailed notes are provided in Appendix A.

Project as a Whole

- Obtaining appropriate records took majority of the project time.
- Plans, on average, do a much better job documenting lighting power density compliance than controls compliance. Controls schedules are few, and daylight zones are not generally defined on plans. Lighting power density generally gets strong attention from plans examiners; lighting controls compliance is frequently not checked and records vary widely in documentation.

Jurisdictions

- It normally takes multiple attempts to get through to records departments by phone. Plans are sometimes kept at offsite locations which require a separate request for review. Most important, in many jurisdictions it took weeks to have requests fulfilled.
- In-person visits are much more effective than phone or email correspondence. In some jurisdictions plans examiners do not take calls, they are only available in person.
- Most jurisdictions were not concerned with copyright restrictions on releasing copies of public documents due to the research-oriented nature of the project though this did become a major obstacle in one jurisdiction.
- Jurisdictions, with one exception, offered requested services without charge (except the cost of copies).
- Jurisdictions' administrative procedures are not always logical or consistent. For example, a plans examiner jurisdiction at one Washington jurisdiction stated that they do not require electrical plans nor non-residential energy code forms to be submitted because those are required and reviewed by the Department of Labor & Industries. A phone call to Labor & Industries revealed that they only review electrical plans for medical and school projects.
- The form of the records varies. They may be on paper of different sizes, microfiche or electronic. Scanned plans may not include the electrical plans or compliance forms. One plans examiner said they do not scan the electrical drawings nor code forms due to cost. The electrical plans get destroyed and the code form is returned to the project site. Another said drawings/plans are destroyed due to space issues and a third said they only keep drawings for 180 days after certificate of occupancy.
- Project permit information online is generally not searchable by the criteria (building type, size) used by the project. It may be available only by address or permit date which means researchers had to go through files one-by-one to locate buildings that fit the criteria. Alternatively, they sometimes used outside sources (internet searches, newspapers, etc.) to identify new construction projects and then request the records for them.

APPENDIX A

SNOHOMISH COUNTY

They do not require electrical plans nor NREC forms to be submitted. A plans examiner told me that L&I (Labor & Industries) requires/reviews the plans & forms. I called L&I and they only review electrical plans for medical & school projects.

Responsive to first call; put me in contact with the correct person to assist me & provided me with a list of projects that may fit our criteria. I broke down the list & requested to review projects.

They keep their project manager's 8x11 paper files per project at office. Occasionally, I came across a NREC form within these files. Then would have to request the drawings for projects after reviewing the paper files.

They keep drawings/plans at an offsite location; therefore, separate request for review. They only keep Architectural & Structural plans as a rule. I still found some electrical plans which had not been separated from project plans.

Copies of paper files varied between 8x11 & 11x17; plans were full size sheets sent to a reprographics for printing.

CITY OF EVERETT

They do not require electrical plans nor NREC forms to be submitted.

At first it was difficult to get someone to respond to my request. I went into the location & was given a name to contact; this person arranged to have a list forwarded to me. The list was not long but was a nice start.

They have all their projects on microfiche. They allowed me to pull the film, review & print myself. All on 11x17 & free.

They typically only scan architectural & structural. Some projects included the electrical plans.

Project permit information online is by address only which makes it difficult if you do not know addresses of specific projects. I was able to create my own list & reviewed them as well. Also, since I had access to the film myself, I was able to look for projects per street & date without specific projects in mind.

SEATTLE

They do require/review electrical plans & NREC forms which are reviewed by plans examiner in house. I talked with a plans examiner & he said that they do not scan the electrical drawings nor NREC forms due to cost. The electrical plans get destroyed & the NREC form is returned to the project site.

Not very helpful via telephone; I was transferred & given different phone numbers to call a number of times. Plans examiners do not take phone calls; can only talk to them in person which I eventually did. The first person I was given to talk to was not helpful & was rude. He spoke to me like I did know anything & did not answer my questions. He spoke to me like I was a child - "...you take a document

(then would motion with his fingers the shape of a piece of paper in the air) ...then you take a drawing and count (pretending there was a drawing on the table & he was slowly selecting each fixture on the plan)...". Most everyone else I came in contact with at the department was helpful & respectful.

They could not provide a list based on our criteria. The project permit information online is by address only which makes it difficult if you do not have addresses of specific projects. I did find a map locator online which shows locations of projects based on criteria that you can choose. Then I would select each project to determine if it may or may not fit our criteria. If so, then it was added to list & I would look up each project at the planning department.

Seattle is the only jurisdiction that has scanned information available for review on a computer – only accessed at the planning department. The personnel in this department were very helpful. I could review the information on the computer & print without permission due to copyright. All information printed on 11x17 (sometimes I was charged & sometimes I was not - \$ 0.15 per sheet).

MISSOULA

It took a number of phone calls & messages before I actually spoke with someone. Once I did, they were very helpful. I was put in contact with a gal who walked me through their website & provided the project codes I should use to search for projects that fit our criteria. Their information is arranged my month; therefore, I went to each month for each year, looked for projects that appeared to fit our criteria. I created a list of projects & the gal said she would pull the projects for my review.

They require electrical plans & energy forms & are reviewed in house.

All information is scanned & kept on microfiche - including electrical plans & energy forms. They had the most complete & organized information.

When I arrived, I was given a box of film (of the projects I requested for review) and printed what I wanted on 8x11 sheets.

SPOKANE COUNTY

It only took a few phone calls to find the correct person to talk to. She provided a list of projects based on our criteria. I reviewed the list, broke it down & requested to review the projects.

I reviewed 8x11 paper files (similar to Snohomish County records). After my review of the paper files, I requested to review the plans. They do not keep drawings/plans; they are destroyed due to space issues & they do not scan files.

CITY OF SPOKANE

They do require electrical plans & NREC forms & they review them in house. Although, they only keep drawings for 180 days after certificate of occupancy. They do not scan files.

It took several phone calls to get to the right person to help. The first couple sent me on non-productive paths. After many calls/emails, I was told that there have been personnel cuts due to budget & that it would take 30 days to look into my request to review drawings. After 30 days, they pulled three projects (one of which had only one sheet). I eventually was given the names of two additional people to contact. One being a plans examiner, he said if I came in he would pull projects for me to review in the office.

Due to copyright laws, they could only make copies of plans with the permission of the architect. Therefore, I analyzed the projects in the office. He was very helpful.

Project plans did not always have complete information.

PORTLAND

They require electrical plans & energy forms & review them in house. Although, they do not scan all information.

It took a number of phone calls. They were helpful in offering ideas for searching for projects that fit our criteria. Online permit information is listed by address which makes it difficult if you do not have addresses for specific projects.

I created a list of projects for review & forwarded it via email along with the public request form as directed online. I received an email response right away that my request had been sent to the proper department & that I should hear back within a few days. I did not receive a response so I started to make phone calls. No one could find my request so I resent once again. Once I finally was put in contact with the correct person, I was told it would take two weeks to pull the microfiche for my review & I would have to send a check (\$15 per project to have the film pulled).

I sent the check & arrived on the agreed date which was determined via emails. I arrived on a Monday which is a day that is not open to the public but was told in an email that it would be a good day since I had a number of projects to review. The person who I had been in contact with said that he was not expecting me until the next day & was just pulling the film (two weeks to pull & he was doing it that day). He said I would have to return the next day. Another gal in the office told me to wait & went to get the supervisor who was very helpful. She asked him to pull the projects & let me review them as he pulled the files since it was a long drive to return the next day.

Depth of project information varied. There were some complete plans but more often just architectural & structural. I tagged the film that included information I would like printed. Because of the quantity of information to be printed, they could not do it the same day. He had to print the information, re-scan it & then sent it to me via email. (\$3.50 per 11x17 sheet) Because it was a scan of a scan, the information was not very clear. One project was unreadable.

Due to copyright laws, they are required to receive permission from the architect to print drawings. I was able to sign a form stating that my request for information was for a study / research / teaching etc. thus eliminating the need for permission.

BELLEVUE, WA

Bellevue stores permit records documents as originals (in original physical paper form), by permit number.

Bellevue was able to search their records database by project size, and supplied Excel list of around 250 possible projects, which was eventually refined to 25 records.

Bellevue has an online search facility that allowed access to added detail – was able to whittle down initial list to 25 projects that appeared to meet study parameters – very time consuming, though.

Process at Bellevue:

1. Initial contact by phone, followups by phone, email.
2. Request list of possible projects.
3. Visit Bellevue planning office to review possibilities with staff, add to and subtract from list.
4. Request records for viewing (1 to 2 weeks wait).
5. Return Bellevue planning office (as necessary) to review plans, viability; request copies.
6. Return to Bellevue to p/u copies when ready (normally 1 week or so after request).

Search internet (Google, etc.) for new offices, stores in Bellevue for additional leads. Some available. Not sure why they weren't on initial list from city.

Bellevue staff very helpful and willing.

Allowed free use of private conference room for reviewing plans (in 4 or 8 hour sessions).

Supplied good quality copies of records at reasonable cost.

Ample visitor parking available in city offices parking garage.

Overall, a pleasant but timeconsuming experience.

TACOMA, WA

Tacoma discards records for most projects after 180 days (core and shell and other miscellaneous records excepted).

Some records stored as paper originals and some (fewer) as .tif files but most are destroyed. This made it impossible to access enough records to meet the study target of 6 office and 6 retail projects.

Tacoma database cannot retrieve records by size (square footage), but can by cost. Received list of projects over \$500,000 in cost. Mostly unavailable.

Used outside sources (internet searches new businesses, stores, in Tacoma WA and personal contacts) to identify additional potential projects – some of which resulted in records being obtained. As in Bellevue, no idea why these projects didn't turn up in provided lists from city database.

Eventually obtained 5 office (3 paper, 2 digital) and 4 retail (2 paper, 2 digital) project records for use in study.

Staff friendly and helpful during visits and when answering calls, but not good at returning calls or emails.

Limited space available for review of projects.

“Lot” parking available across street from city offices.

BOISE, ID

Boise stores all records except current projects digitally (as .pdf files)

Boise records department not very responsive by phone or email.

Once visit scheduled, records staff prepared good list of prospects.

During visit staff extremely courteous and helpful.

Had a staff person assigned to search and view records with me sitting in, for entire day.

Viewed plans and forms on screen (50 or more projects) for appropriateness to study.

Came away with pdf's of 20 projects on flash drive – at no charge

EUGENE, OR

At first, it seemed city attorney rules about copyright restrictions and permissions would slow down or block access to files, but staff contact decided to send “originals” for review and return, rather than wait for permission or not to copy.

Contact staff person very helpful and responsive.

Was able to get suitable records located by staff person, without necessitating a visit to Eugene: 8 records in all – 4 office, 4 retail.

More recent records stored as paper originals. Older records as micro fiche digital files.

Micro fiched files do not include compliance forms.

Received 6 records by mail as paper originals (3 office, 3 retail).

Received 2 records by email (1 office, 1 retail) as pdf files.

SALEM, OR

Salem “records office” staff friendly and apparently supportive, but not effective in delivery of records.

At first, Staff indicated could locate and supply copies of appropriate project records – quickly, without copyright issues, and without the need for a visit to their office.

In reality, Salem could not deliver as indicated. They had trouble locating appropriate records. Legal department ruled no records could be released unless “signed permissions” were obtained. Scheduled trip to visit Salem city offices, with no guarantee that plans could be copied.

During visit, staff very friendly and helpful, had difficulty locating viable projects.

Salem staff person discovered (during my visit – and months into the process) problem accessing appropriate records stemmed from fact that records (originals) had been sent to technical services for scanning (months earlier), had been scanned and returned on CD, but had not yet been uploaded to the network and were not currently available as either as originals or as digital files.

Result of visit: Have officially requested copies of 4 records sets: So far – No response and no project records obtained from Salem.